EARL D. ANDERSON, Project Engineer, Maintenance and Operations

Facsimile Telegraph Network for Weather Maps

Detailed charts continuously updated and speedily transmitted bring world-wide weather data to U. S. Air Force bases in the United States. Special facsimile circuits and equipment as well as technical training for Air Force personnel have been provided by Western Union.

AN EXTENSIVE new facsimile telegraph weather map network has been provided by Western Union for the U. S. Air Force Strategic Air Command. This system for rapid transmission of weather charts links some 60 stations of the USAF Air Weather Service at Air Force bases throughout the United States and makes possible a continuous flow of up-to-the-minute weather maps to air operation centers of the Strategic Air Command.

Known as the Strategic Facsimile Network, the nationwide telegraph system is leased from Western Union by the Airways and Air Communications Service (AACS) and is operated by Air Force personnel. Both AACS and Air Weather Service are technical services of MATS, the Military Air Transport Service.

Center of the network is the Global Weather Central at Offutt Air Force Base, Omaha, Neb. Other transmitting stations are at the National Weather Analysis Center, Suitland, Md., and at strategically located weather centers at Barksdale AFB, Shreveport, La.; March AFB, Riverside, Calif.; and Westover AFB, Chicopee Falls, Mass. As indicated in Figure 1, each transmitting station serves chart recorders in a wide area with international, national, and local weather information including high altitude data.

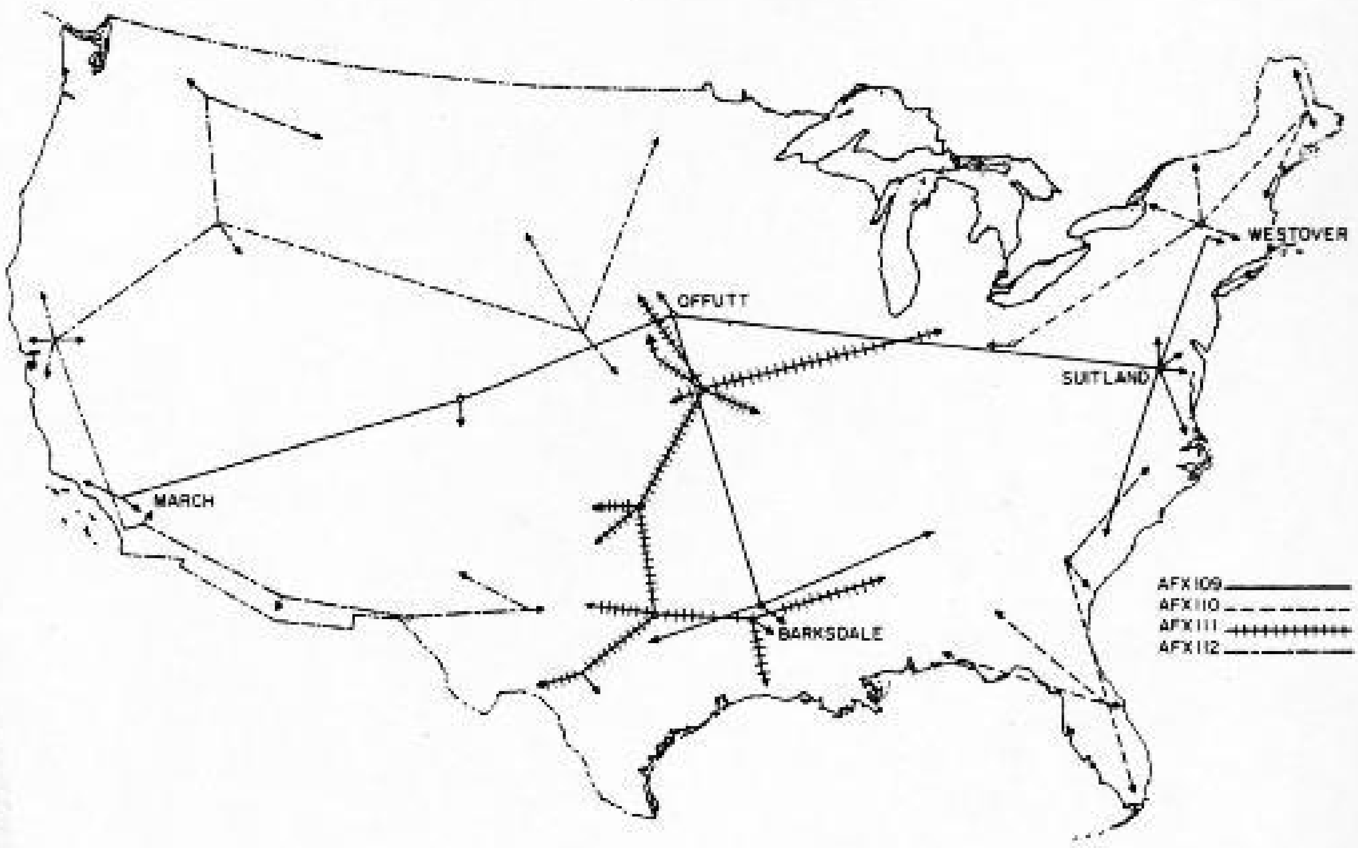
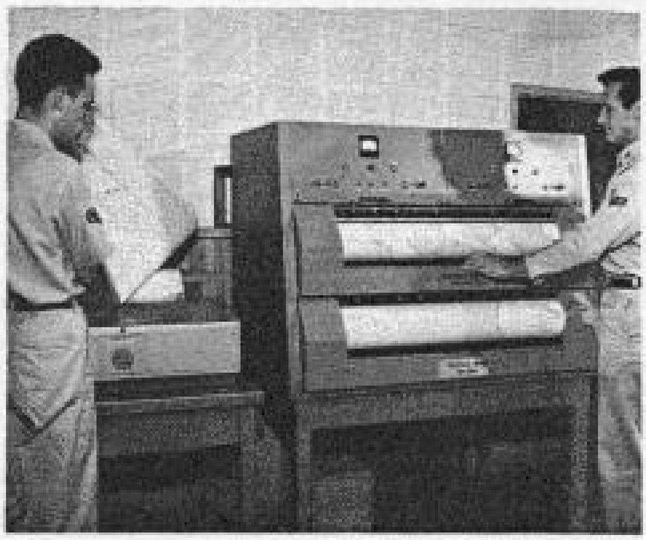


Figure 1. Strategic Weather Facsimile Network for the AACS

Photo R-11,630

Figure 2. Typical transmitting installation—Suitland AFB



USAF Official Photo

Figure 3. Typical transmitting installation — March AFB

Control of the main transcontinental circuit, designated AFX109, rests at Offutt AFB where a manual switch allows transmission by Suitland, Barksdale, March, Westover or Offutt. Switches at these centers except Suitland provide for transmission over territorial networks, designated AFX110 out of Westover, AFX111 out of Barksdale, and AFX112 out of March AFB, or for transmission and simultaneous recording from the transcontinental circuit. Typical installations are shown in Figures 2 and 3.

Important considerations which required attention both prior to and after installation of the network included the following:

1. Completely new equipment scattered throughout the country required training of maintenance personnel.
2. Delay and amplitude corrected facilities, their installation and maintenance.
3. Special test equipment to allow the testing of recorders at all receiving-only drops.
4. Adequate communication facilities between all points for the coordination of testing prior to the installation and for maintaining circuit continuity.
5. Equipment design: does it allow for easy maintenance and what will be required in connection with trouble shooting?

Training Program

First and greatest problem to be solved was the training of maintenance personnel on this new equipment. Two instructors, one from the Chattanooga Training Center and one from the Field, three engineers from General Headquarters Plant Department, and one from Research and Engineering, attended a two weeks' school at the Westrex Corporation (formerly Times Facsimile) plant in New York. A training school was then established at the Chattanooga Training Center.

Installation of the network was scheduled in four phases, each phase separated by one month. Phase one was the installation of AFX109 on February 15, followed by 110 on March 15, 111 on April 15, and 112 on May 15. This schedule allowed maintenance personnel to be trained on the same basis. Three classes were scheduled: a Basic Electronics Class, Recorder Class and a Transmitter Class. Each of these was scheduled for one week and ran sequentially thus allowing a maintainer to attend the classes considered necessary for his job. In addition to training the regular and alternate maintainers, an engineer or supervisor and their alternates from each Area involved were also trained. Except for holiday periods, these classes ran continuously from December 1 through May 15. Over 200 engineers, supervisors and maintainers were trained during this period. Thus with the start of installation in February, the current trainees were returning to their job locations and installing the equipment with their training still fresh.

The second problem was the delay and amplitude equalizing equipment. The Plans and Methods section devised their own training and installation program preceding the equipment installation by one month wherever possible. The problem remaining was how to maintain these facilities, especially since many of them did not go through Western Union offices.

Circuit Check-up

The Air Force allowed one half hour each day beginning at 12 noon to be used for a circuit lineup period. At noon every day WQ (Washington, D. C.) places a 2400-cps tone at zero dbm on the network. This is read by all wire chiefs, who have access to the facilities. The tone is checked for proper level. At 12:15 WQ places a 600-ohm termination on the network and all wire chiefs check for noise. Any deviations from standard levels are immediately reported and action taken to have the fault corrected. At 12:25 the network is restored to normal and traffic is resumed at 12:30.

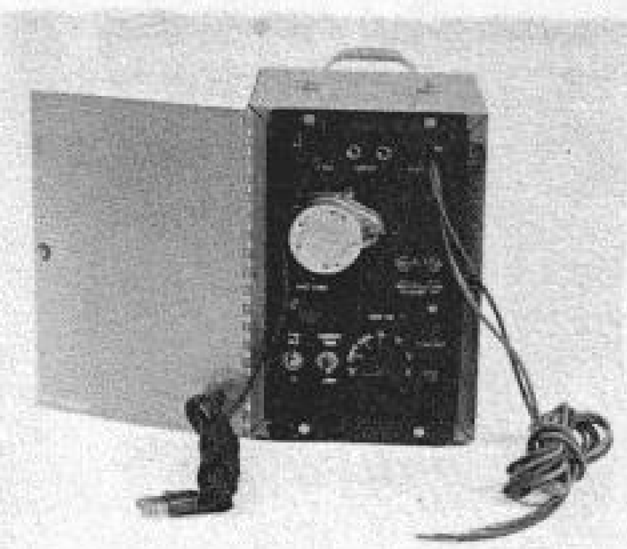


Photo R-11,627

Figure 4. Generator Test Set GT-1

With the exception of the five transmitting stations all others have only recorders and a means had to be provided to test a recorder in the event of a failure. The manufacturer developed a small portable transistorized test generator for this purpose which is known as a Generator Test Set GT-1 (Figure 4). When properly connected to the recorder, it allows the maintainer to check the operating sequence and make adjustments. In addition, it produces a bar pattern which can be copied and used to check the copy for jitter and grouping. The supplier also developed two gauges to be used for the styluses and belts. The first is a stylus sight gauge (Figure 5) which is used to check the tungsten stylus in its holder for alignment. By inserting the stylus into the sight gauge it can be checked for alignment and straightened if necessary. The second gauge is a belt alignment jig (Figure 5)

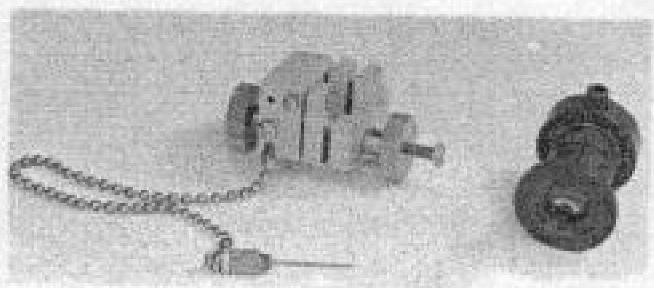


Photo R-11,676

Figure 5. Stylus sight gauge and belt alignment jig

which allows the belt to be clamped in it, and the stylus mounting assembly and holder may be properly positioned. By use of these gauges, running tests and possible refinements, virtually all jitter and grouping may be eliminated from the copy. The run mechanism has a dynamically balanced flywheel which removes nearly all the jitter due to gear mesh in the system.

It was realized initially that, since many locations were some distance from central points, a communication facility of some type would be necessary to allow initial lineup testing and clearing of facility troubles. As a result TC-20 (Figure 6) was set up for this purpose. Since the facsimile system was undirectional it could not be depended upon for communications. This teleprinter "talk" circuit considerably reduced initial testing and lineup time and has been continually helpful in the daily lineup for level comparisons and failures.

Maintenance Aids

The picture would not be complete without discussing some of the maintenance features which have been included in the design. Looking first at the RJ-3 recorder (Figure 7), it will be noted that it requires only the loosening of two large knurled screws to open the cover and expose the complete unit. Taking the electronic section first, all tubes are held in

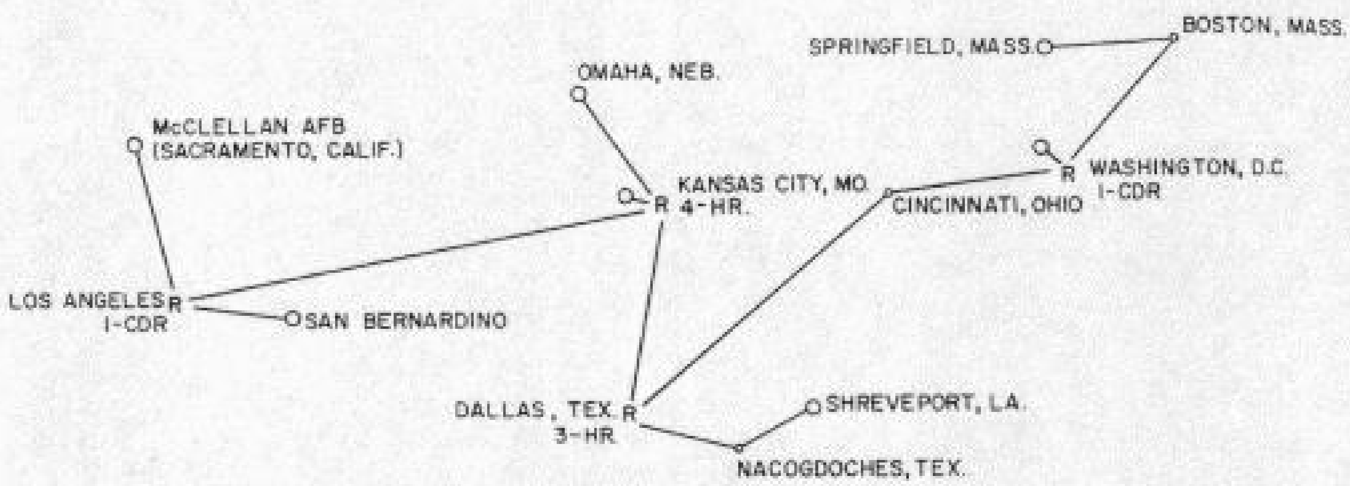


Figure 6. Teleprinter Talk Channel TC-20

place by clamps. All electrolytic condensers are of the plug-in type and are also clamped. All relays, also of plug-in design, are covered to protect against dust and held in by clamps. The dust cover may be removed readily by removing two screws for inspection of the contacts. The bottom of the electronic chassis may be exposed by removing the front two cover plates each of which is fastened with four screw turnout locks. With the exception of one or two small components all are board mounted. Each component has its own designation stenciled on the board directly under it and the designation is the same as the number on the wiring or schematic drawings. All tubes and relay sockets also are clearly stenciled on the chassis for ready identification. All voltage and resistance measurements at all tube and relay socket pins are furnished in the specification. In addition photographs of typical copy with common faults, and their correction, and a complete trouble shooting guide are included.

The mechanical mechanism also is readily removable. A single locking Cannon connector carries all the electrical circuits required. It is necessary only to unlock this, loosen the band screw which separates the exhaust blower unit, and remove the four mounting screws leaving the unit free to be taken out of the housing. In addition, an adapter cord is provided so that the mech unit may be run on the bench away from the housing. A small vacuum cleaner attachment is furnished which when attached very simply to the exhaust blower system allows for the removal of loose soot accumulations. The activated charcoal and glass wool filter in the canister may be replaced on the job by the maintainer.

Transmitter Design

The transmitter (Figures 2 and 8) was designed on a comparable basis, and certainly maintenance was kept in mind. The

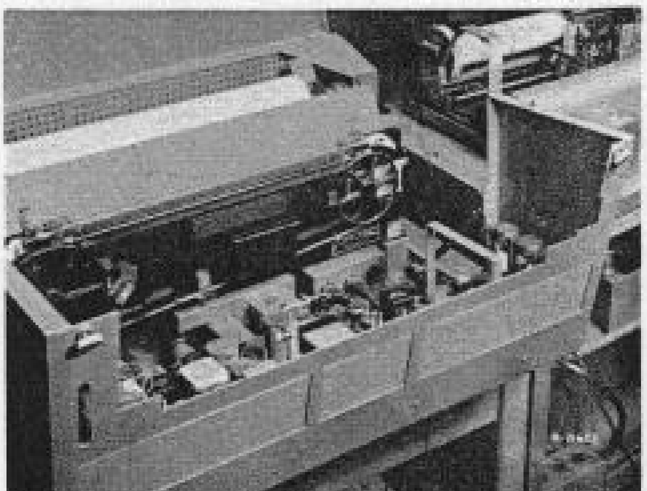


Photo R-11,621

Figure 7. Recorder RJ-3

electronic chassis is separated from the mechanical unit in the housing and is readily accessible. The top cover of the housing is lifted up, the two large knurled screws are loosened by hand, and the chassis may be swung up to permit access to the bottom. Again all components are clearly stenciled and board mounted. All relays are of the plug-in type with the exception of one delay relay in the auto loading circuit. All standard relays are of

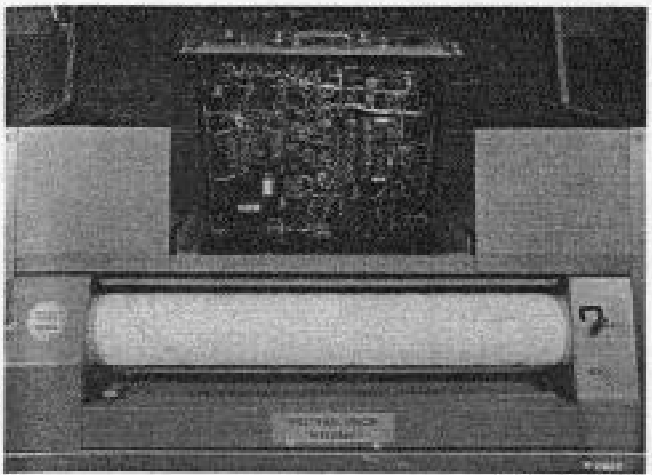


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Figure 8. Transmitter CL-3 — single unit

the plug-in type and all are interchangeable. The delay tube, which is plug-in, and the delay relay are not interchangeable but are readily accessible.

All electrolytic condensers are of the plug-in type and all tubes, electrolytic condensers and relays are held in position by clamps. All relays are enclosed in plastic dust covers which may be removed for close inspection of the contacts. Again, as in the case of the recorder, all voltage and resistance measurements at all relay and tube sockets are given in the specifications. In addition, various waveforms with peak-to-peak readings are given at all critical points. The transmitting points were furnished Hickock 685 LP oscilloscopes with calibration circuits so these tests could be made. In addition, vacuum tube voltmeters were furnished for those voltage readings in sensitive circuits. The electronic unit is connected to the mechanical chassis by two cables both equipped with screw type Cannon connectors.

The mechanical units may be slid out of the housing. The bottom unit is on slides which hold it in an extended position. The top unit may be worked on by swinging open the top cover and swinging up the electronic chassis or sliding it out and resting it on top of the bottom unit. The exciter lamp is readily accessible by removing one knurled screw; however, it is a soldered connection. The one adjustment is to focus the periscope lens system which is done by placing a scope in the proper test point and turning the lens in or out until maximum signal is observed on the scope. The only other adjustment to be made on the carriage assembly is on the half nut which engages the lead screw.

Each recorder location has a working recorder on the circuit plus a working spare recorder which may be connected to the circuit by a Type 6017-E key. In addition, a maintenance spare is used to back these two working units. The transmitters at all locations are of the dual type shown in Figure 2. At Suitland and Offutt Air Force Bases, there are additional dual units which also may be placed on the circuit by means of a Type 6017-E. key. At March, Barksdale and Westover Air Force Bases there are dual transmitter units in service and single transmitters for maintenance spares.

Equipment Description

Equipment used on this network was developed and manufactured for Western Union by the Westrex Corporation in New

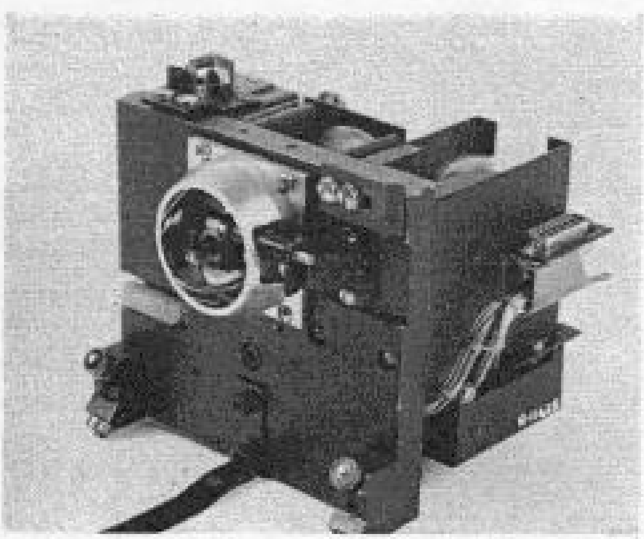

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Figure 9. Transmitter carriage assembly

York City. The transmitter was so designed as to be compatible with most facsimile equipment used in this type service. It is a drum type unit and will handle copy up to 18 by 36 inches. A mylar wrapper and automatic clamping arrangement are used to hold the copy on the drum. The drum speed is 120 rpm utilizing a carrier frequency of 2400 cps. The carriage is positioned electrically by a small reversible motor and belt connected to the scanning head.

The dual type working transmitters are front panel of the electronic chassis, the switch has been fixed at the 120-rpm setting on the units used on this network. Listed below are the speed settings and associated carrier frequencies:

60 rpm	1800 cps
90 rpm	2400 cps
120 rpm	2400 cps

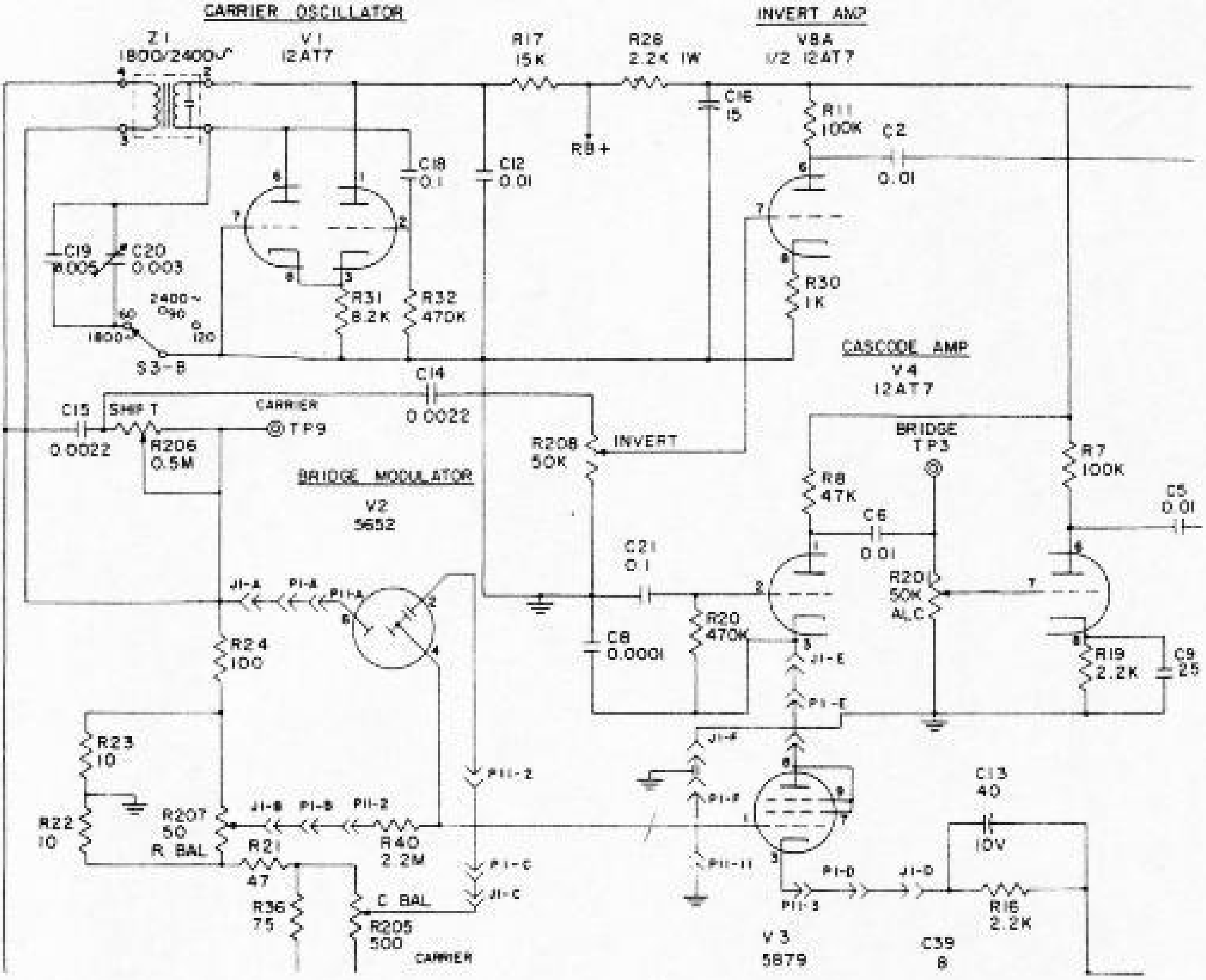

Figure 10. Portion of transmitter schematic showing phototube bridge modulator and cascode amplifier

electrically interconnected so that both drums may be loaded and both transmitters started. However, one transmitter will send its copy to the line, shut off, and the second transmitter will automatically wait ten seconds and then begin its transmission. This allows the recorders to complete their stop cycle and ready themselves for the next transmission. A switch on the front panel allows the operator to move the scanning head either left or right. Although this speed and carrier may be changed by a switch mounted on the

Scanning

The copy scanning head, Figure 9, consists of an exciter lamp, an elipsoidal mirror which focuses the light on the copy, a periscope-mounted lens arrangement, phototube, half-nut assembly, and the first tube in the cascode amplifier section. In the center of this elipsoidal mirror is the periscope arrangement which carries the reflected light to a two-plate phototube. With this arrangement there is no angle of incidence or reflection to contend with from the mylar wrapper.

The phototube is an RCA Type 5652 which was developed by the supplier and is used in a bridge circuit to form a phototube balanced modulator. Refer to Figure 10, a schematic of the transmitter. The carrier oscillator, oscillating at 2400 cps, is connected to one plate. When light shines on the two plates, the resistance between them is lowered and the tube conducts. The signal is then passed to a cascode amplifier which is a low-noise type amplifier. Since more light is reflected from white, the maximum signal is white, minimum, black.

After being amplified in the cascode amplifier the signal is passed to a gain-controlled 6386 tube. Since the signal (see Figure 11) at this point is white maximum, the ALC circuit attempts to maintain this voltage and not the lower black voltage. As a result, some automatic contrast is obtained. That is, it attempts to maintain the voltage ratio between black and white signal. The signal is now taken from the plate of the second half of the 6386 tube and impressed on a 100K resistor. At this same point, the carrier frequency of 2400 cps is arriving but it has been passed through a phase shifting control and an amplification stage such that its amplitude is equal to the white signal, but 180 degrees out of phase, and cancellation occurs. Thus, at this point inversion takes place and black copy now produces maximum signal. This is now passed through the vestigial filter which removes the upper sideband leaving the lower sideband which is amplified and passed to the line.

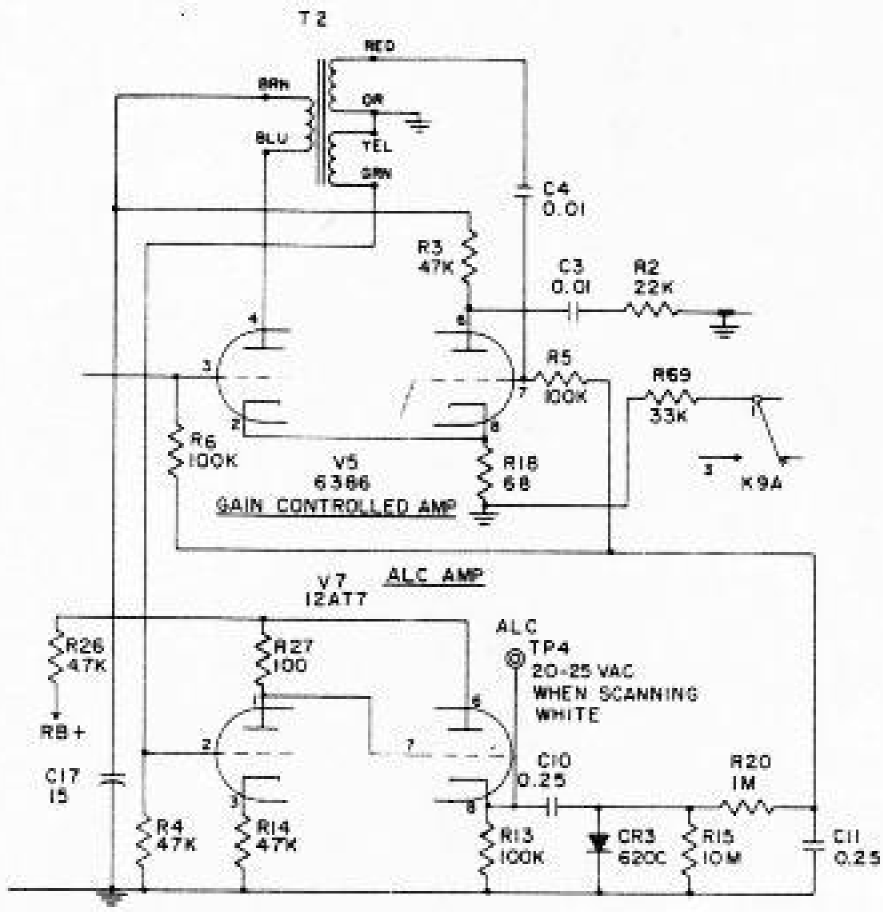

Figure 11. Portion of transmitter schematic showing ALC amplifier

Contained also in this unit is a 450 and 300 cps oscillator and a transformer. (Refer to Figure 12.) The latter allows either 300 cps, 450 cps or 60 cps to be coupled to the 100K resistor instead of copy signal. A diode arrangement causes these signals to modulate the 2400 cps coming from the carrier oscillator. The application of these tones and the copy signal along with phasing pulses is controlled by six cams driven by a small motor and this forms the program timer, Figure 13. The sequence is as listed below:

450 cps (stop tone)	5 seconds
300 cps (start tone)	5 seconds
2400 with phasing pulse	15 seconds
60 cps (start tone)	2 seconds
Fax copy	30 minutes
450 cps (stop tone)	5 seconds

The phasing pulse is obtained from a disk mounted on the end of the shaft. Figure 14 shows the disk, contacts, and the signal produced. The first open is the phasing pulse, the close is the keying pulse, and the last open is the blanking pulse.

1800 cps. The fork oscillator consists of a two-stage triode amplifier, and a peak limiting 606C diode which removes amplitude variations. The fork accuracy is approximately three parts in ten million. This very stable 1800-cps tone is fed to a frequency doubler whose output delivers 3600 cps which is then fed to a frequency divider controlled by the front panel switch as described previously. The divider produces three frequencies for the three drum speeds as listed below:

60 rpm	600 cps
90 rpm	900 cps
120 rpm	1200 cps

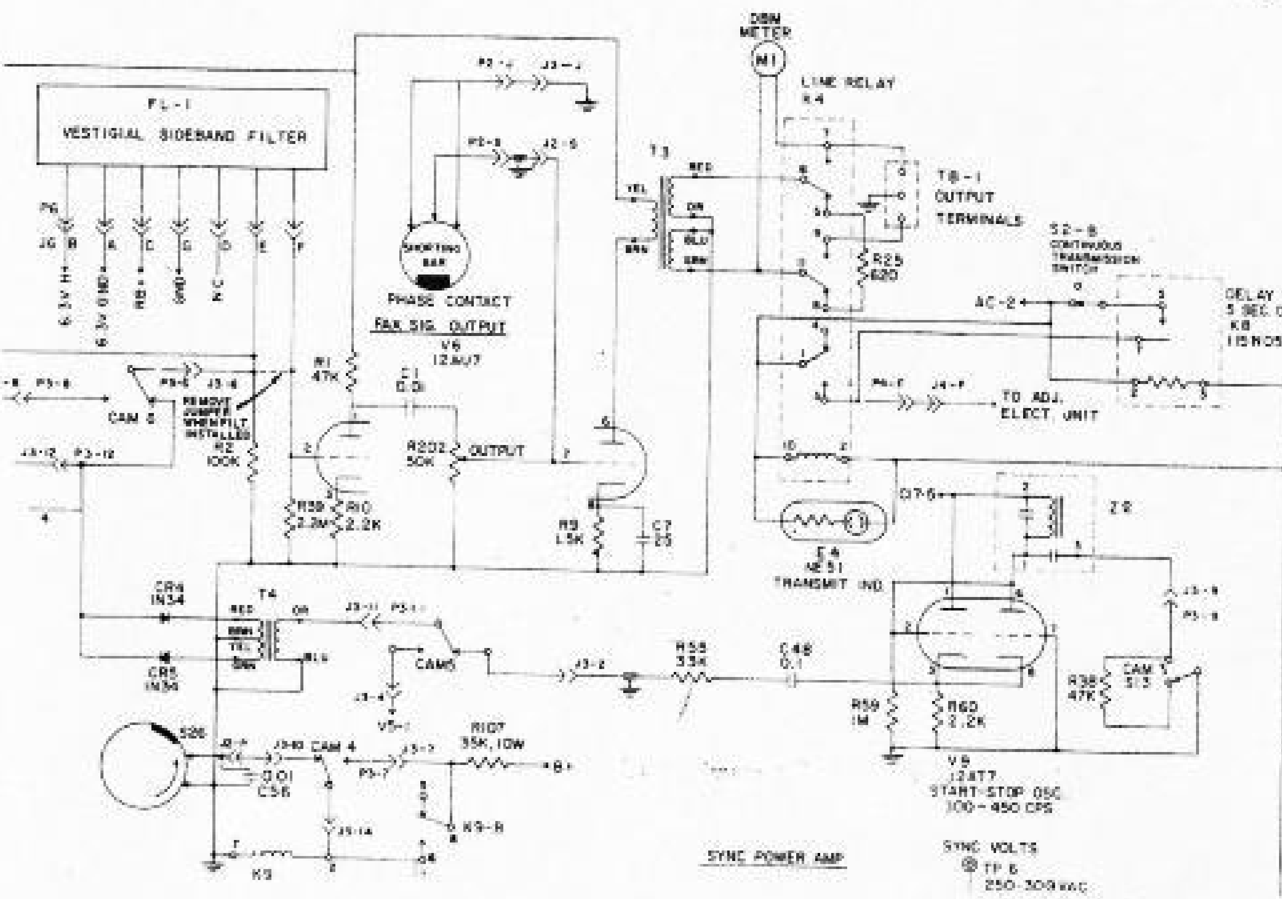

Figure 12. Portion of transmitter schematic showing control tone oscillator

The only signal required by the RJ-3 Recorders used on this network is the phasing pulse and copy signal. The other signal tones were specified so that other American and foreign recorders could be used on this network. How these are used at the recorder will be described later.

Synchronization

The synchronous drive system consists of a tuned fork operating in a thermostatically controlled oven oscillating at

This signal is then amplified and passed through a push-pull stage to the synchronous motor winding, Figure 15. The direct current for the plate supply of the push-pull stage is fed through the motor winding and acts to polarize the magnetic field. There is only one pulse per cycle delivered to the motor. However, there are two phases because of the push-pull stage. One-half of the winding is connected to one portion of the push-pull stage and the other to the second part.

The rotor of this synchronous motor is built up of laminations and is approximately 2-1/8 inches in diameter and 3/8 inch thick. Its periphery has 60 teeth cut in it and the spacing between these and the stator is 0.0015 inch. There is no winding in this rotor. The phase one and two stator coils are so located that when the rotor teeth match up with phase one stator teeth, the phase two stator teeth are halfway between the rotor teeth. Since the phase two stator teeth receive pulses which are 180 degrees out of phase with phase one stator teeth, the rotor receives two magnetic pulses per cycle but advances only one tooth. The motor speed is directly proportional to the applied frequency.

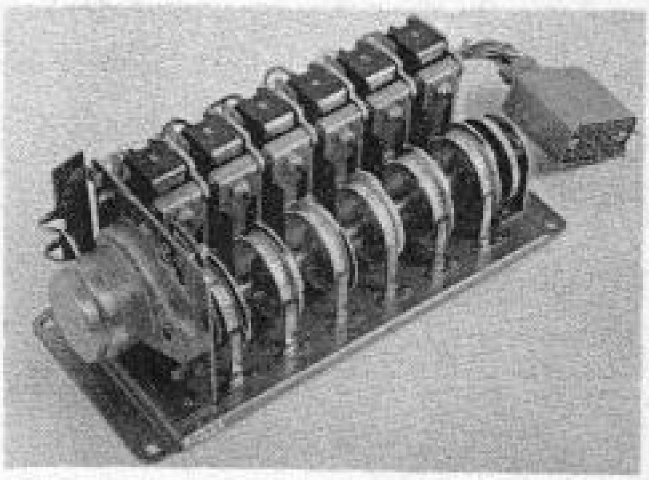

Photo R-11,624

Figure 13. Program timer

The synchronous motor is mechanically coupled to an arm on the drum shaft via reduction gearing. The drum is rotated by a run motor which is belt coupled to the drum shaft and rotates it at a speed slightly higher than synchronous. The arm coupled to the synchronous motor bears against a stop on the drum holding the drum at synchronous speed.

Recording

The recorder uses "Timefax," a dry recording paper 19-1/8 inches wide and in 350-foot rolls. A density control, for the operator's use, operates over a 5-db range and is mounted on a panel in the front of the recorder. The recorder uses two 6BA6 tubes RC coupled and a 12AT7 in an ALC loop as its initial amplification stages. The ALC loop develops appoximately 30 db range. The output of signal to the stylus is via a conventional 6V6 push-pull stage.

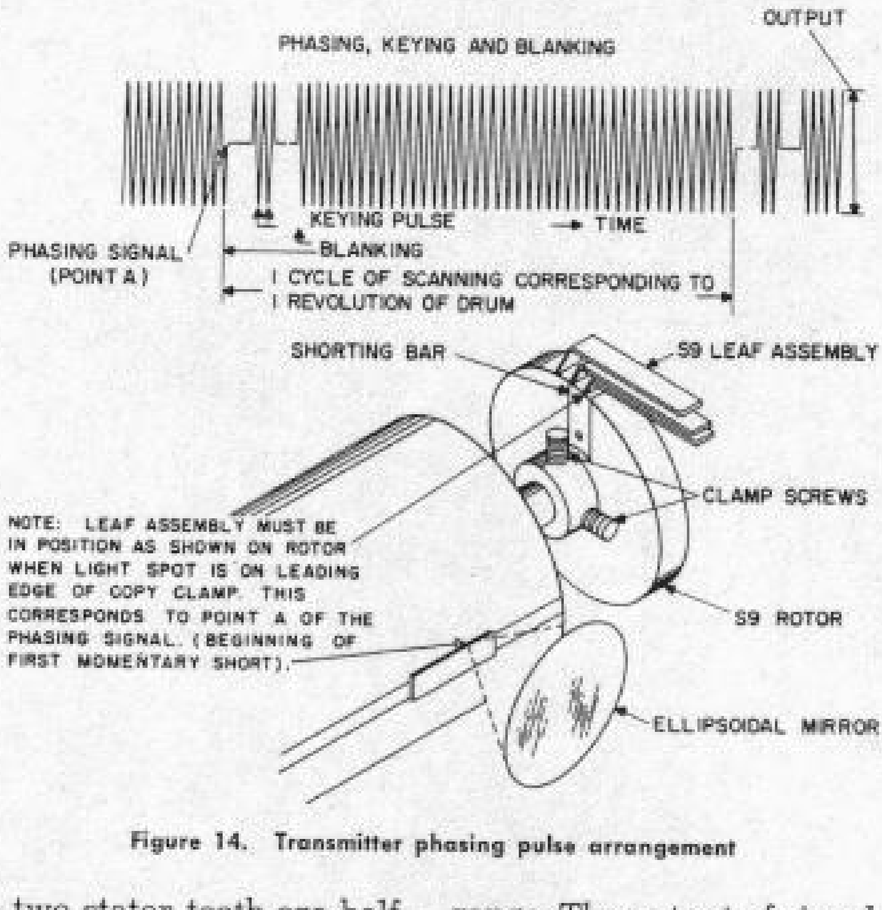

Figure 14. Transmitter phasing pulse arrangement

The recorder requires only the presence of 2400 cps which is the carrier used in this system to begin its recording cycle. A take-off is taken just prior to the 6V6 output stage. The carrier signal passes through a diode limiter which maintains a constant amplitude of both peaks to a tuned circuit which rejects all signals other than the 2400 cps. The signal is then amplified and passed by a biased 620C silicon diode which removes the positive portion of the signal. This develops a negative bias on the grid of the next stage, overcoming the positive bias, cutting the tube off, and causing the relays in its plate circuit to release. This conditions the recorder for starting. The grid of this stage also has a large condenser attached so that when a modulated white signal is received the condenser will store enough negative potential to keep the tube cut off and the recorder running. The recorder will continue to run on signal and will stop when signal is removed.

When the CXR detector relay releases, contacts on it open removing current to the phase actuator and stopping the synchronous drive mechanism. The phasing pulse as previously described is the 2400-cps tone interrupted once every revolution of the drum. A tap is taken at the screen grids of the 6V6 push-pull output stage passing the phasing signal through a filtering network which removes the carrier frequency to a 2D21 thyratron tube. The pulse causes the grid to have a higher potential than the cathode and the tube conducts. The pulse is used to operate a phase actuator which positions the synchronous drive system.

At this point the recorder has been conditioned for starting and phased; however, the stylus belt is not yet rotating. When the CXR detector relay operated, it closed a set of contacts which conditioned the start tube (refer to Figure 8). As soon as copy signal appears the average voltage of the black and white signals drops. The grid becomes sufficiently negative to cut the tube off releasing Relay K2 in its plate circuit and the stylus belt rotates.

Synchronism is obtained much the same as in the transmitter, previously described. The fork is not in an oven; however, its accuracy is approximately three parts per million. The gears must be changed in the recorder to accomplish speed change. In addition to this a strap on the tuned circuit of the carrier detector must be changed to accept the new carrier frequency.

These then are some of the features of the transmitter and recorder, which are different from facsimile units previously used by this company.

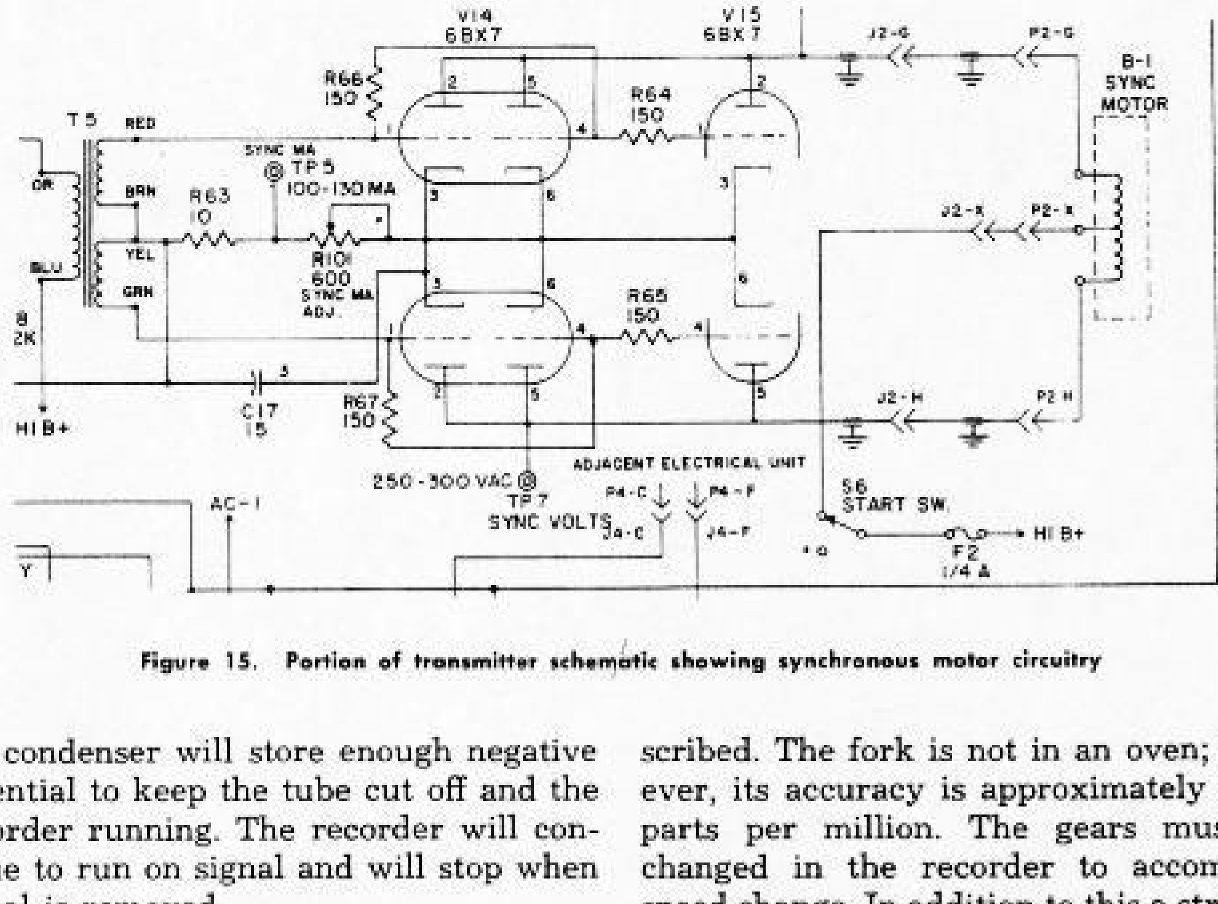

Figure 15. Portion of transmitter schematic showing synchronous motor circuitry

Operation

The new system was developed to fulfill Strategic Air Command requirements for hemispheric weather support capability at every weather detachment that supports SAC operations. At Offutt AFB Weather Central, the largest of its kind in the world, weather data are gathered, analysed and plotted. Forecasts are made and then constantly re-evaluated and revised through current weather reports received from stations all over the world. Not only detachments of the Air Weather Service, but also U.S. Military bases throughout the world submit reports. Weather data flow in from land stations, airborne aircraft, ships at sea, and weather balloons.

The national weather analysis center at Suitland provides a daily report on winds and temperatures, and vorticity (or twisting) wind effects at high altitude, as well as prognoses of Northern Hemisphere weather.

The weather reports of foreign countries broadcast under the conventions of the World Meteorological Organization (WMO) are also used. Weather reconnaissance aircraft fly missions for the Air Weather Service and every SAC and MATS plane submits a complete weather report on the conditions in flight that it encounters. Every corner of the world must be weather reported in order to insure proper weather support of SAC's global mission.

Refueling missions at high altitudes and ballistic missile tests also require accurate weather information from all parts of the country. They need to know not only the usual information found along regular air routes, but also wind directions and speed, temperatures, vertical wind flow and cloud formations, at much higher altitudes than is usually required for commercial flying.

Over 500,000 word groups of weather information flow into the global center at Offutt AFB each day. As many as two million separate weather elements are considered and plotted on maps by personnel skilled in international weather codes.

In order to provide the world-wide weather capacity without the cost of a global weather central at every SAC base, the 3rd Weather Wing at Offutt must produce weather service product that each SAC weather station needs, and distribute this product while it is still timely. Since the weather is constantly changing, the importance of timeliness in weather reports cannot be overemphasized.

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The author wishes to acknowledge the valuable assistance with photo material and schematics furnished by the Westrex Corporation (formerly Times Facsimile).

EARL D. ANDERSON graduated from the University of Connecticut in 1952 with a Bachelor of Science degree in Electrical Engineering. He joined Western Union shortly thereafter and was assigned to the Maintenance section of the Plant Department. He has assisted with facsimile concentrator and private wire installations for the past five years. Included in this were the special Ticketfax installations for the Pennsylvania Railroad at Pittsburg, Philadelphia and New York.

M. G. MUSCARI, Area Material Control Supervisor, New York Area

New York Repair Shop

Material Control Centers have been established in Western Union warehouses to process equipment for installation programs. Where special arrangements are required, as in private wire services, efficient repair shop facilities at warehouse locations can be particularly advantageous.

THE New York Repair Shop is a large-scale enterprise within the scope of the company's operations. As is the case in many phases of Western Union activities, it is constantly growing to meet the demands of increasing responsibilities. The expansion of Private Wire Service operations, for example, necessitated numerous modifications in shop procedures.

In the past, manufacturing constituted about 50 percent of the shop's activity. However, as the numerous plant units required substantial modifications and major repairs, the nature of the work changed. It is fortunate that the location and facilities of the New York Repair Shop were ideally suited to accommodate the change.

The shop's 40,000 square feet of space allocated in the Jersey City (N. J.) warehouse, just across the Hudson River from New York City, its force of 122 employees, and its variety of machines offered a most desirable focal point for manufacture and repair. Here, a complete PWS installation may be processed, pretested and shipped to its destination. Here, equipment requiring major repairs or modifications may be processed and restored to a functional condition. Here, also, model work for the Research and Engineering Department may be produced in order to ascertain the cost and practicability of a unit and to put into effect those drawings which ultimately will be used in the manufacture of the unit.

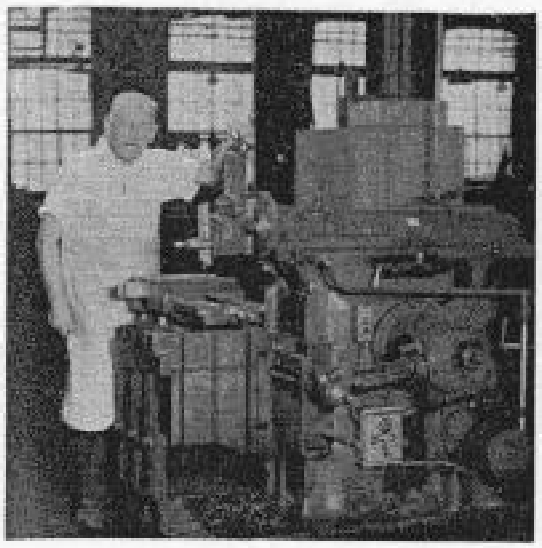
To coordinate the various projects with the operations of the shop and to forecast realistic delivery of equipment, the Industrial Engineering Department fostered a Production Schedule System, a Labor Backlog Report, and a Management Control Report. These determine the labor to be expended and the progress on each order.

Forecasting enables PWS personnel to make firm commitments to customers who expect that such promises be kept. This action promotes good will and enhances the value of the company's service. It is important to remember, however, that the PWS customer is not the only party to be taken into consideration. Government agencies and warehousing people all want dates on which they can rely.

Unlike other company repair shops, the New York Repair Shop engages in many diversified activities. One of these is work other than that on apparatus. This comprehends a considerable volume of orders issued to replenish the warehouse stock of piece parts required for maintenance. In this category falls the packaging of ink and type wheels and the manufacture of typewheels, contact assemblies, cams, and a variety of other equipment. Adding to this the repair of any item from a broom to a complicated switching center control cabinet, the assortment obtained runs the gamut of manufacture and repair.

Inspection

Just as times change and nothing remains constant, so do shop concepts become molded to the times. In the spirit of progress, preinspection was initiated. This concept is reasonable and logical in that equipment and apparatus returned to the warehouse should be inspected to determine their degrees of serviceability. The advantage can be seen readily when one considers that some apparatus may be



Heavy duty shop machines will finish castings

Assembly tables accommodate a variety of work

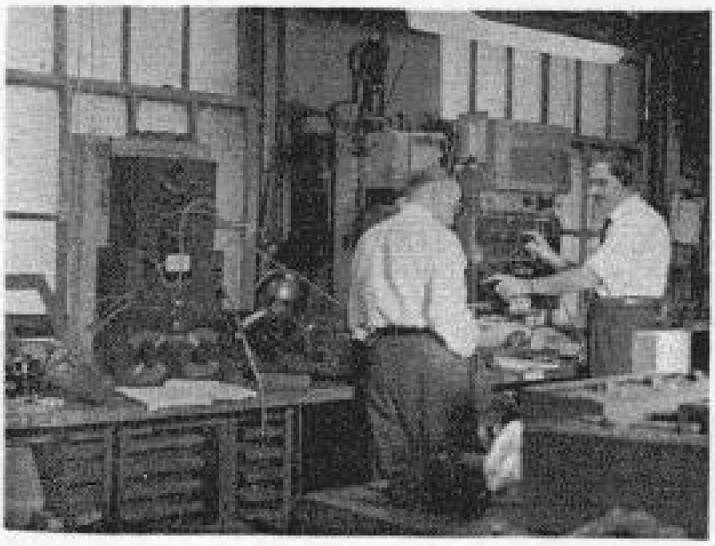
returned after a few months of use. Through working tests, preinspection determines and classifies the units as "A" stock, "R" stock, or "J" stock.

Classifying a unit as "A" stock means that the appearance and operating condition of the unit are good, that no repairs are necessary, and that the unit can be returned to service. The "R" classification denotes that the unit requires repair before it can be placed in "A" stock. The amount of repair necessary on the "R" stock is determined. If it is found, upon inspection, that the cost of repair is excessive, a "J" classification is made. This simply means that in the opinion of the inspector it is desirable to junk this piece of apparatus. However, at the discretion of the inventory control personnel, the unit is either written off, or returned with a notation to repair it at the estimated cost as the item is no longer obtainable. Since this procedure has been in effect, the efficiency and the resulting economies have been gratifying.

Testing

Another essential function of the shop is the operation of its Quiet Room. Here, transceivers, amplifiers, modulators and tuners are tested and adjusted. Relays and relay banks of all types are checked for operating efficiency. The electronic components of large cabinets are tested and subjected to voltage breakdown tests. All this is done to minimize the probability of field forces encountering trouble after the installation of the equipment.

It is contemplated in the near future



Tests and adjustments are made in the Quiet Room

PWS equipment is assembled to order

to expand the testing procedure to include working tests wherever possible. The ultimate aim is to produce a better piece of apparatus on which field personnel can depend. In fact, since April 1959 test equipment has been developed to check various types of duplex, single-line, polar press and other repeaters under operating conditions. Teleprinters and distributors are tested with a stroboscope; the required margins are obtained and checked with bias and distortion meters. Printer units, reperforators and teleprinters are checked with a biased signal distributor. Numbering machines, rotary switches and facsimile equipment are also placed under simulated operating conditions. As new equipment is received, test facilities will be expanded to meet the operating requirements of maintenance and operations personnel.

Extremely important is the program of training that was inaugurated. The objective in mind, of course, was that with the ever-expanding plant and variety of equipment, the shop personnel must be trained to test and repair all types of equipment and to produce materials of good quality.

The volume of repair and manufacturing at this shop is indeed on a large scale. During 1959, 2,816 shop orders were received. This large number becomes even more imposing when it is considered that a single shop order often covers several hundred major units of equipment, such as teleprinters, fax units, relay banks, and so forth.

This brief discussion of the many functions of the New York Repair Shop and the extensive work volume it handles is indicative of the progress being made in many Western Union operations.

M. G. Muscari entered the Western Union Plant Department as a ticker inspector in New York City in 1928. Thereafter he held various supervisory positions including those of Chief Dispatcher and Maintenance Supervisor — City, and in July 1959 he was appointed New York Area Material Control Supervisor. Mr. Muscari graduated in 1934 from St. John's University, Brooklyn, in Accounting and Business Administration.

JOHN R. HYNEMAN, Manager — Patents

Telegraph Measuring Instruments and Test Sets

Continuing development of specialized instruments for telegraph circuit and equipment testing has coincided naturally with changes and improvements in the telegraph art. From time to time, of course, individual test instruments have been described separately and in detail but a general review and summary not only discloses comparative data in a convenient reference arrangement but also aids visualization of this area of telegraph activity with a perspective otherwise lacking.

THE FIRST telegraph electrical measuring instrument must have been a lineman's thumb and forefinger feeling for an unknown voltage. Understandably this ubiquitous instrument was convenient and portable, and while the accuracy was subject to some doubt its sensitivity could be momentarily improved by moistening the fingers from any convenient source.

Continuing from this strictly subjective instrument, this article will attempt to review, first briefly in perspective, the growth of telegraph measuring instruments and then to describe, also briefly, some of the excellent instruments which have now been developed by Western Union engineers to perform various specific functions designed to bring out optimum performance in circuits and equipment. The title, of course, comprehends a wide range of instruments and procedures but it will be necessary here to confine ourselves to the more important instruments useful in the field of signal transmission, direct current telegraphy, carrier telegraphy, facsimile and microwave radio. These measuring instruments guide us in locating faults and in adjusting apparatus for optimum performance throughout the life of the equipment, beginning with the inspector's acceptance test.

Many devices are but a convenient assembly of indicating instruments with cooperating ancillary components, the whole designed to lend convenience in straightforward testing. In other instances, the property to be measured may be elusive and difficult to isolate. Here it is necessary to find a technique for measuring the wanted property and then to embody it into a convenient operating assembly. The first notable telegraph measuring instrument was, of course, the switchboard voltmilliammeter, still a stand-by at all large d-c switchboards. This convenient and versatile instrument plus the Switchboard Bridge Testing Set comprised the testboard man's measuring kit and with it he located troubles and maintained his circuits in operation. Portable voltammeters generally sufficed for installation and maintenance men. Also, the differential milliammeter, an integral part of most duplex sets, was widely used for a variety of purposes other than refining duplex balances.

TELEGRAPH TRANSMISSION MEASUREMENT

Transmission Testing Machine

Such was the prevailing situation in the early 1920's when ever-increasing telegraph speeds and accuracy requirements brought about by the universal changeover to printing telegraphy directed more extensive studies of telegraph transmission. To meet this need, a unique and highly versatile instrument was produced in the Western Union laboratories. This was the transmission testing machine[1] pictured in Figure 1. It comprised essentially a conventional 4-channel multiplex distributor but with its shaft mounted vertically and bearing also an arm carrying a stylus for marking on continuously moving chemical tape. Another essential component was a 10-point switch which permitted the establishment of a variety of code permutations for transmission from the distributor segments.

Any one of the ten pulses of the repeated transmitted permutation pattern, after traversing a circuit or device under

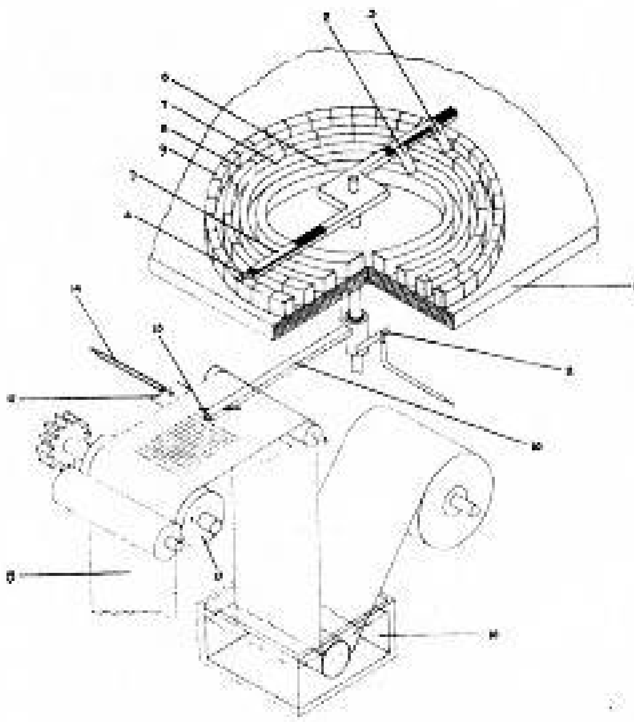


Figure 1. Telegraph transmission testing machine

test and returning to a receiving relay mounted on the machine, could be selected for repetitive delineation on the tape in successive parallel marks. By comparing the length, and the position of the leading and trailing edges, of this selected pulse with their counterparts in a perfect or undistorted signal, the machine could provide a wealth of information as to the transmission characteristics of circuits and apparatus as expressed in measurements of marking or spacing bias, fortuitous distortion as occasioned by random interference, periodic distortion as occasioned by power line interference, and positive and negative characteristic distortion brought about by the reactive characteristics of the circuit or device under test.

The machine was most conveniently used when both ends of the circuit were at hand but means were provided for synchronization with a distant similar transmitting machine or with a multiplex distributor. However, for most purposes approximate synchronization by manual control of the fork speed sufficed. This machine was mounted on a 3-level caster-equipped table and weighed 415 pounds. It was essentially a laboratory instrument, and information gathered by the several machines used universally in the Western Union laboratories, and to a limited extent in the field, took most of the early mystery out of d-c telegraph transmission.

Portable Bias and Distortion Measuring Instrument

The multichannel synchronous multiplex, with its speeds ranging from 30 to 80 cycles per second, has now largely been superseded by the start-stop teleprinter operating at word speeds of 65, 75 and now, in some cases, 100 per minute, to produce line frequencies of 22.7, 28.5 and 37.15 cycles per second, respectively. At the same time, the transmission facility has shifted from predominantly open wire circuits to predominantly telegraph carrier channels.

By far the most common adverse influence on teleprinter signals is the occurrence of marking and spacing bias, with fortuitous distortion occasioned by random interference next in order. Consequently, there had long been a need for a portable, relatively inexpensive instrument which would be simple to operate and would preferably measure transmission performance or signal quality in terms of meter readings. The universal shift to teleprinter operation finally made such an instrument a necessity and this need was met by the Bias and Distortion Meter 6838-A[2] introduced in 1954 and shown in Figures 2 and 3. The random nature of start-stop signalling, together with the nonuniform pulse lengths of the code units, barred the use of any over-all averaging process in the measurement method. The method adopted is based upon measurement of spacing pulses only in order to exclude the long marking stop pulse, but compares the average length of single unit spacing intervals with a standard signal length for that speed as provided by a time constant circuit.

For measuring bias in single current

start-stop signals on standard 70-mil loops, the instrument is designed to provide in its receiving relay two types of response. In the first, a 35-mil bias current is applied to the biasing coil to cause relay operation at the half amplitude point. The pulse length thus produced is then compared with the aforesaid standard length. In the case of uniform signals relatively free from distortion, this measurement provides a satisfactory measure of true bias. However, if the waveshape is badly distorted, relay operation at the half current points will not necessarily yield a true measure of signal pulse length. To overcome this, an initial bias of 50 mils becomes operable at the inception of a transition from marking to spacing, but this bias promptly shifts to 20 mils for the transition from spacing back to marking so that the relay transitions are caused to occur when the operating current has varied only 20 mils from steady state, either marking or spacing, and thus before the customary signal distortions have become prominent. By this expedient, the measurement of bias becomes substantially independent of waveshape. The percent bias is indicated on a meter and any difference between readings for the two types of bias measurement is a measure of the waveshape distortion.

Photo R-9728

Figure 2. Bias and Distortion Meter 6838-A — Front view of field instrument

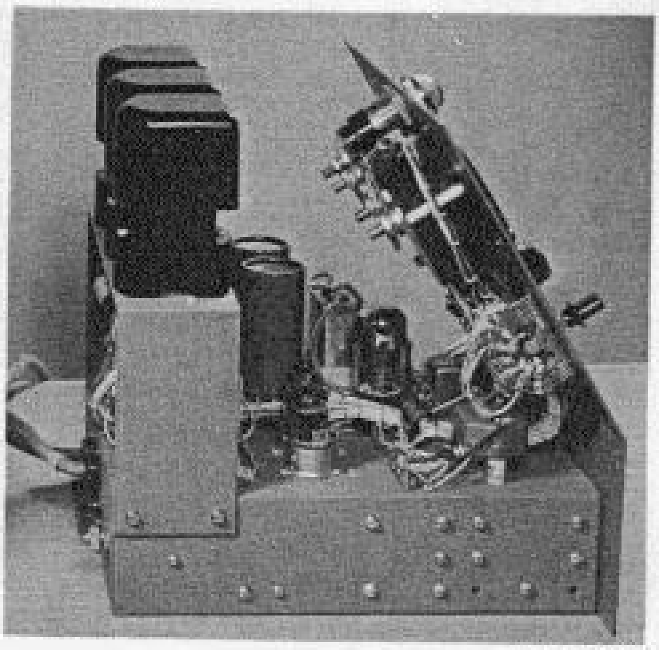


Photo R-9728

Figure 3. Bias and Distortion Meter 6838-A — Interior view of cabinet

By a slight change of procedure the same measurements for polar signals and for synchronously transmitted signals may be made. The instrument will also provide a comparison of the shortest spacing interval against the average spacing signal length, but independently of any bias present, as an indication of fortuitous distortion.

This instrument has become extremely popular and as many as a dozen of them may now be found in large testing and regulating offices not only for routine circuit line-up and maintenance purposes but for examining the signals produced by keyboard transmitters, distributors and regenerative repeaters. By transmitting a suitable variety of characters so as to provide a lone spacing pulse for each transmitting segment or cam, if an excessive bias or distortion reading is noted it is an indication of faulty performance in that part of the item under test.

Telegraph Signal Analyzer

Most of the functions of the Transmission Testing Machine were achievable for start-stop equipment and circuits by means of the Telegraph Signal Analyzer,[3] introduced in 1947, a portable and relatively inexpensive instrument designed for recording, by a stylus on a "Teledeltos"* disc chart, each of the seven units of the start-stop code. As indicated in Figure 4, the instrument comprised a motor-driven vertical shaft bearing at its top a disc for supporting the "Teledeltos" chart for marking by a stylus as the stylus progressed from the center to the periphery of the chart. A selector magnet assembly was included with its contacts arranged normally to short-circuit the stylus marking potential except during transit time of the magnet armature when a short mark would appear on the chart. As the stylus progressed outward from the center of the chart, a record for 190 consecutive characters was produced. A typical chart showing a recording of perfect signals is shown in Figure 5. Such faults as marking or spacing bias, fortuitous and characteristic distortion, and various equipment defects produced identifiable departures in pattern from the ideal chart. These machines have been used in considerable number by Western Union and by various railroad communications departments of the USA and Canada.

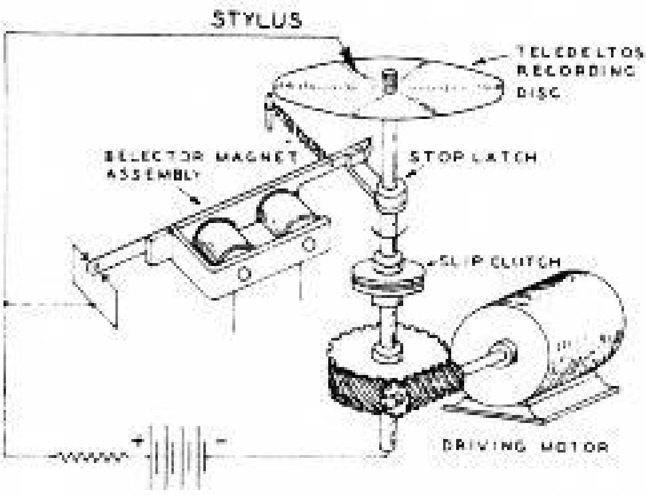


Figure 4. Telegraph signal analyzer — simplified sketch of mechanism

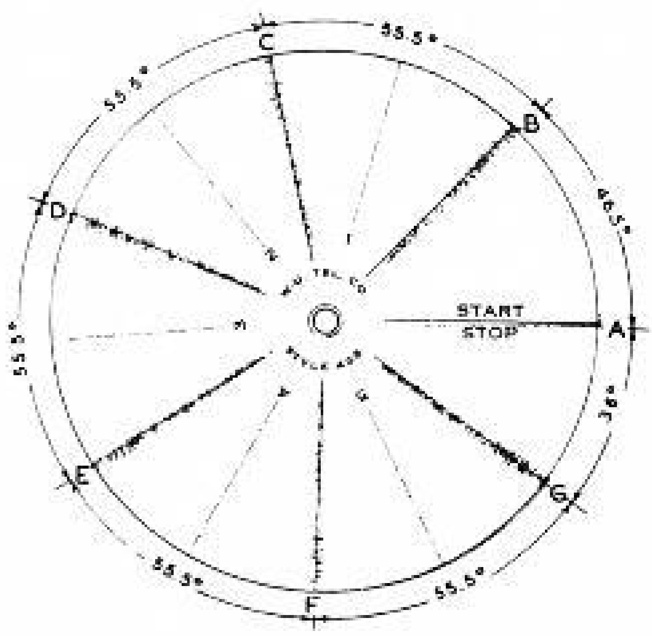


Figure 5. Telegraph signal analyzer — chart with perfect signals

* Registered Trademark, W. U. Tel. Co.

Telegraph Bias and Distortion Test Set

The items of field telegraph test equipment mentioned thus far were designed for the purpose of observing received signals as a measure of the transmission quality of a communications facility, or of the integrity of the signals produced by a telegraph transmitting device. Also needed was a device for use in telegraph offices and maintenance shops which would provide signals typical of those received from lines under regular operating conditions. Recently, Bias and Distortion Test Set 7399-A[4] shown in Figure 6 was introduced for this purpose.

This test set is a rather complex electromechanical device, designed to transmit start-stop signals as derived from perforated tape or a continuous "R" and "Y" without the use of tape. The code transmitted is the 7.42-unit telegraph code and the transmission speeds are 368, 460 or 600 characters per minute, corresponding to word speeds of 61-1/3, 76-2/3 or 100 words per minute, respectively. The instrument will accept tape from the different types of perforators and reperforators commonly found in the telegraph plant.

The 7399-A set is essentially a signal generator adapted to transmit pulse signals bearing either a specified amount of marking or spacing bias, or "end distortion," which is a simulation of characteristic distortion.

As will be noted in the figure, the instrument comprises a horizontally mounted faceplate bearing two sets of brushes which engage two pairs of solid and segmented rings, respectively. One of the segmented rings is fixed, while the other

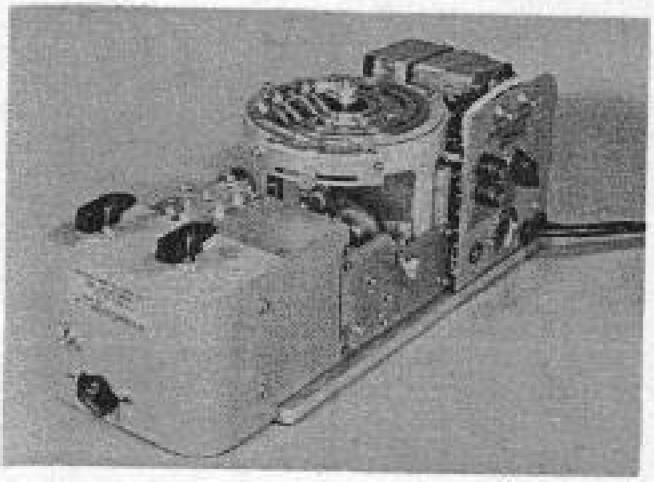


Photo R-11,454

Figure 6. Bias and Distortion Test Set 7399-A

is adjustable, and by rotating the latter with respect to the fixed ring the length of individual signals may be varied as much as 50 percent. The instrument is useful for testing and calibrating the bias and distortion meters previously referred to, and also provides a greater degree of realism in the test signals for adjusting the selector mechanisms of teleprinters and printer-perforators. With a source of calibrated distorted signals available it is possible, after the printing range of a printer has been determined and the operating point set at the center of the scale, to transmit distorted signals into the printer while making final adjustment of the printer selector mechanism.

This instrument has proved valuable as a convenient telegraph signal generator for a variety of purposes, and for achieving optimum adjustment of printing telegraph equipment; further, by its use the condition of subscribers' teleprinters may be checked from the main office thus to reduce the incidence of emergency maintenance calls.

Relay Test Sets

It is only natural that much thought should be expended on methods for testing the ubiquitous telegraph relay and the embodiment of such tests into test sets suitable for general field use. Of the most popular types, the line of succession includes Relay Test Sets 1-A, 42-B and 5605-A.

Relay Test Set 1-A, still widely used, was designed to provide, in addition to tests for gross mechanical and electrical defects, tests for coil balance and efficiency and for armature centering, all of these tests being applicable only to polar relays. Efficiency is a measure of the total on-contact time of the relay armature as related to total time; that is, on-contact time plus transit time, which in a properly adjusted relay is in the neighborhood of 83 percent. It is measured ordinarily first by centering the relay to produce a zero reading on a meter differentially connected to the contacts, and then obtaining a second reading when the meter is connected to the two relay contacts joined together. This latter reading is an indication of the instrument efficiency. The centering and efficiency tests are relied upon to reveal lack of freedom of moving parts, dirty or cracked bearings, defective contacts or incorrect air-gap adjustment.

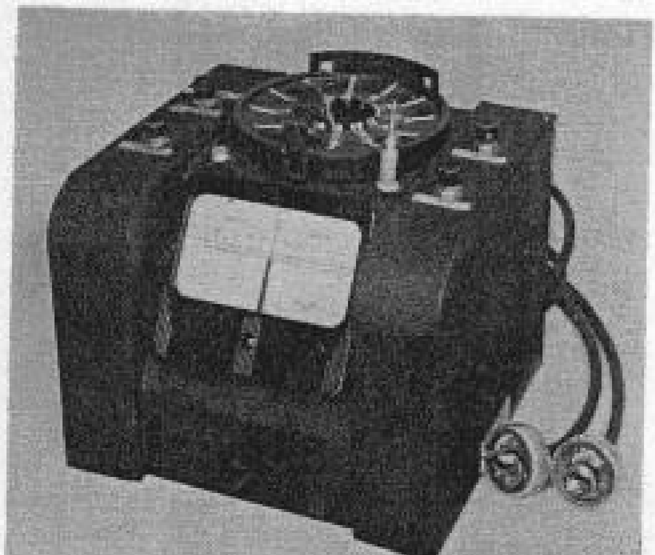


Photo R-5580

Figure 7. Relay Test Set 42-B

Relay Test Set 42-B, shown in Figure 7, extended the previously mentioned test to nonpolar type relays as well and is current standard equipment. Portable Test Set 5605-A combines the testing facilities of Relay Test Sets 1-A and 42-B and certain other common testing equipments into a single portable test set. The device embodies its own power supply and, in addition to the standard relay tests previously mentioned, is useful for a variety of functions including teleprinter leg circuit monitoring, jack and cord testing, breakover measurement, and as a plain milliammeter of from 0 to 175 milliamperes' capacity. This instrument is now widely used.

Breakover and Interference Susceptibility Measurement

Long-distance telegraph transmission nowadays is accomplished almost exclusively by means of carrier telegraph channels operating over highly stable landline or microwave radio facilities. Most of the circuits comprise only a single section and only a few sections are involved at most. Transmission impairment is small and what there is is attributable almost entirely to the terminal equipment; in other words, the impairment is directly proportional to the number of circuit sections connected in tandem rather than to circuit length. This fortunate state of affairs should not allow one to forget the former circumstances when long circuits were composed of a multiplicity of repeatered sections, each presenting a significant signal loss, and indeed this situation is again growing, particularly in patrons' service. Under these circumstances it was necessary to engineer the make-up of long circuits with considerable care, and practices were developed for measuring, evaluating and expressing transmission characteristics with commendable accuracy. These practices involved generally two types of measurement, namely, "breakover level" and "interference susceptibility".

Breakover was a measure of peak interference level and it was represented by the bias current applied to the main line receiving relay of a duplex set connected to a line under usual operating conditions, which would just prevent the relay armature from leaving its contact in response to interference peaks. Such measurements were readily made manually using standard duplex terminal sets. Automatic breakover measuring sets were also developed for this purpose.[5]

Interference susceptibility, as used here, was a figure directly related to the slope of a telegraph signal. Obviously, if perfect telegraph dots were received, the instantaneous rise and fall would provide maximum freedom from interference, or zero susceptibility. However, when signals having a slow rise and fall are received, there is an appreciable period of time during which the state of the receiving relay armature is indecisive and the presence of interference may readily cause either premature or delayed operation with consequent variation in recorded signal length. This range of signal length variation was measured as a time loss and was expressed in milliseconds. To measure the susceptibility of a line, high-speed a-c signals were sent over the line and into a duplex set as a gradually increasing bias was applied to the receiving relay, while the marking and spacing contacts of the relay were differentially connected to a highly damped zero-center meter.[6] It is obvious that if the signals had a sharp rise and fall, the bias current would have no effect until it exceeded the signal current. However, if the reactance characteristics of the line induced a slope in the transition portion of the signal, then the meter reading would depart proportionately from zero as the bias current was increased. The circuit was then said to be subject to the time loss indicated by the meter when the bias current was made equal to the measured breakover for the line. For convenience, an equivalent Susceptibility Test Set was usually substituted for the receiving relay of the duplex set.

From the measurements briefly described in the foregoing, circuit sections were classified as to equivalent "electrical length" of standard circuit and this formed the basis for a reliable but simplified circuit layout procedure.

Printing Range Measurement

Printing range need be mentioned only briefly here. It is familiar to all telegraph operating people as the maximum number of "points" subtended on an arbitrary scale as marked by the limits of rotation of a receiving distributor faceplate or equivalent mechanism before errored signals are printed. Customarily these boundary positions are noted and the faceplate is then located at the center, for best receiving conditions. The number of "points" range represents the operating margin for any given line-receiving set combination.

The following table represents the maximum theoretical range for standard telegraph equipment, and typical ranges encountered in practice:

	Maximum Theoretical Range	Average Short-Circuit Range	Acceptable Minimum Range
4-Channel Multiplex	10	8	4
3-Channel Multiplex	13.3	11.5	6
2-Channel Multiplex	20	18	9
Teleprinter	100	75	60

Range measurement on multiplex sets and teleprinters in telegraph offices is accomplished by manual manipulation of the distributor range scales. However, devices have been developed for automatic continuous range measurement.[7]

Data Transmission Testing Set

The transmission testing machine described earlier in this article was useful only at speeds below about 100 cycles. In its usual form it was not portable and evaluation of the chemical tapes was a laborious procedure. Data transmission circuits and equipment of more recent development require a device possessing the same functions but applicable to much higher speeds of transmission. A completely transistorized Data Transmission Testing Set designed for this purpose provides direct meter indications of the quantities of bias and both fortuitous and characteristic distortion.[8]

A block diagram of the device is shown in Figure 8. As indicated, an oscillator of adjustable frequency generates signals which, after shaping, drive a small beam distributor tube and this is followed by a signal pattern switch for setting up the desired test signal permutation to be transmitted. The same oscillator also drives a second distributor tube which provides gate and reference pulses in

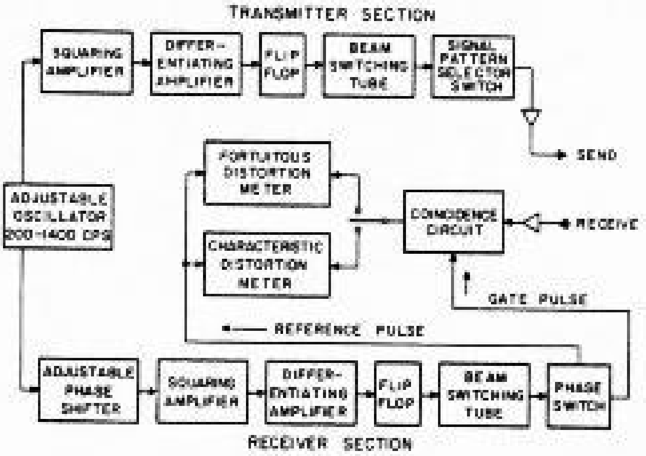


Figure 8. Data transmission testing set — block diagram

synchronism with the sent pulses for use in the receiving portion of the instrument. The receiving drive chain, however, here includes a phase-shifting network and a phase switch to provide any necessary orientation with respect to a delayed received signal. In a coincidence circuit the gate pulses select either a leading or a trailing edge of the signal and this signal then passes alternatively to circuits for measurement of either fortuitous distortion or bias, or characteristic distortion.

The set will perform measurements at rates ranging from 180 to 1400 bauds. Preferably both ends of the circuit under test should be available at the one location. As in the case of the transmission testing machine, the instrument may employ highly stable frequency generators together with suitable synchronizing means so that measurements from two separate ends of the circuit may be made.

CARRIER TELEGRAPH MEASURING INSTRUMENTS

The techniques of carrier current telegraphy have now been studied for many years and a wide variety of measuring instruments of commercial manufacture are readily available. Although it has been necessary from time to time to develop instruments of specialized design for unusual applications, most of the measuring instruments now employed in connection with carrier telegraph equipment are of standard commercial types. These include vacuum tube testers, oscilloscopes, beat frequency oscillators, frequency meters, vacuum tube voltmeters and, of course, the highly useful multimeter. Descriptions of the more important of the specialized instruments follow.

DB Meter

The advent of carrier current telegraphy, following the era of d-c telegraphy, brought with it the need for somewhat specialized measuring instruments applicable to the voice-frequency and immediately higher frequency range. For making carrier current measurements, the versatile DB Meter 1-A[9] was introduced in 1931 and it has been followed by a series of DB meters essentially the same but differing in sensitivity, frequency range, ruggedness and cost as required to fit various specific applications. DB Meter 3-A, for example, consists of a d-c microammeter, a rectifier and an adjustable attenuator serving as a meter multiplier. This instrument measures levels reaching from minus 20 db to plus 35 db where zero level corresponds to one milliwatt. Its impedance is 600 ohms and it is customarily used by introducing it as a line termination or load. With some loss of accuracy, this DB meter may also be used as a voltmeter and in circuits of differing impedance. The instrument covers the frequency range up to 10 kc, and with the aid of a correction curve produces reliable measurements to 20 kc. It is, however, rather delicate and costly, and it has been superseded largely by instruments of somewhat more rugged type.

Carrier Transmission Test Set

The channelizing equipment of radio relay terminals presents a wider scope of quantities to be measured and for this purpose a type of DB meter was adopted which is in fact a modification of a standard commercial instrument.[10] This device, which includes an internal amplifier, has input impedances of 135 and 600 ohms and a dbm range of minus 60 to plus 32 over frequencies from 0.020 to 250 kc. It also includes a number of other useful testing features.

Instruments for measuring quantities over a frequency scale of course require a source of test frequency. A selection of variable oscillators have been designed and widely supplied for furnishing frequencies within the carrier telegraph channel field. A Standard Frequency Generator 6516-A was designed to produce frequencies for checking the translating frequencies used in subband modulators.[11] This oscillator is of secondary standard accuracy and utilizes a 200-cycle tuning fork with a harmonic generator to produce 1000 and 3600 cycles output frequency. In another case a standard commercial product was modified to produce a companion oscillator for the Transmission Test Set previously mentioned.

Delay Measuring Instrument

Although it is a popular concept that electricity always travels over wires at 186,000 miles per second, the fact is that in most long circuits, as found, electrical signals undergo a delay measurable in microseconds or milliseconds. In most instances of one-way transmission, such delays do no harm if all frequency components of the signal are delayed alike so that the received waveshape does not depart significantly from the waveshape as transmitted. However, if the electrical delay is not independent of frequency, a signal wave envelope when composed of a multiplicity of frequency components will arrive in distorted form. The distortion is usually more pronounced where a large amount of repeating, translating or terminal equipment is included in the circuits. The foregoing situation is particularly serious in connection with facsimile and high-speed data transmission since the signal frequency range may extend several octaves through the full width of a voiceband or farther, depending upon the speed of transmission.

For the purpose of measuring the envelope delay characteristics of lines and equipment items, Western Union in 1952 undertook the development of a Delay Measuring Instrument[12] which, in its current form, is designated No. 7782-C. The general aspect of this test set is shown in the instrument readily can be used for the measurement of absolute delay. Where the two terminals of the circuit are separated, it is customary to measure the relative delay since, as previously mentioned, that part of the absolute delay

Photo R-10,024

Figure 9. Delay measuring instrument—regulated power supply and sweep oscillator

Photo R-10,027

Figure 10. Delay measuring instrument—transmitter and receiver

Figures 9 and 10. At the same time, a variety of delay compensating networks were developed.

While methods for measuring envelope delay were known, design and operation of the 7782-C instrument is so adapted to the practical measurement of circuits as to yield a tremendous saving in time and operating skill, with a maximum of convenience to the operator. With this instrument, in conjunction with the delay equalizing networks referred to, long circuits can be equalized with respect to both amplitude and delay in a matter of hours where formerly days or weeks of time were needed.

Delay measurements involve always a comparison of the arrival time of a received signal with either the time of transmittal or, instead, some highly stable reference of frequency or time. This instrument uses the latter method, consisting of a highly stable fork generator included in each test set. Means for making fine frequency adjustments of the forks permit exact synchronism so that an auxiliary circuit between the transmitting and receiving ends of the circuit to convey this reference standard is unnecessary. Where both ends of the circuits under measurement are available at one point, which is constant with frequency of itself causes no signal distortion.

In making measurements, a carrier frequency from an oscillator is swept slowly over the frequency band to be measured and this frequency is then transmitted over the line under test after being 50 percent modulated by a 25-cycle sine wave derived from the highly stable fork generator. At the receiver this 25-cycle envelope is recovered and is compared from instant to instant with the local 25-cycle reference frequency. Hence, although it is the displacement of the 25-cycle envelope which is measured, the time delay at any instant is that peculiar to the momentary carrier frequency. As the carrier frequency is swept across the band, a meter indicates the delay from instant to instant, or the delay reading may serve as ordinate for a curve on an oscilloscope screen while the frequency of the swept carrier provides the abscissa.

In circuits utilizing the frequency range from zero to 20 kc, wherever transmission delay is a serious factor, this instrument in conjunction with the appropriate correction networks has filled a long-felt need both in Western Union and in other companies.

FACSIMILE TEST DEVICES

The transmission of graphic material by facsimile involves the basic processes of scanning, transmission and recording. Considering first the transmission factors, —since the frequency range and bandwidth are similar to those employed in carrier telegraphy, and since the facsimile signal, before modulation, is somewhat analagous to a very high-speed d-c telegraph signal,—the measuring procedures previously referred to in the field of carrier telegraphy and d-c telegraphy are generally applicable to facsimile transmission facilities as well. The measurements

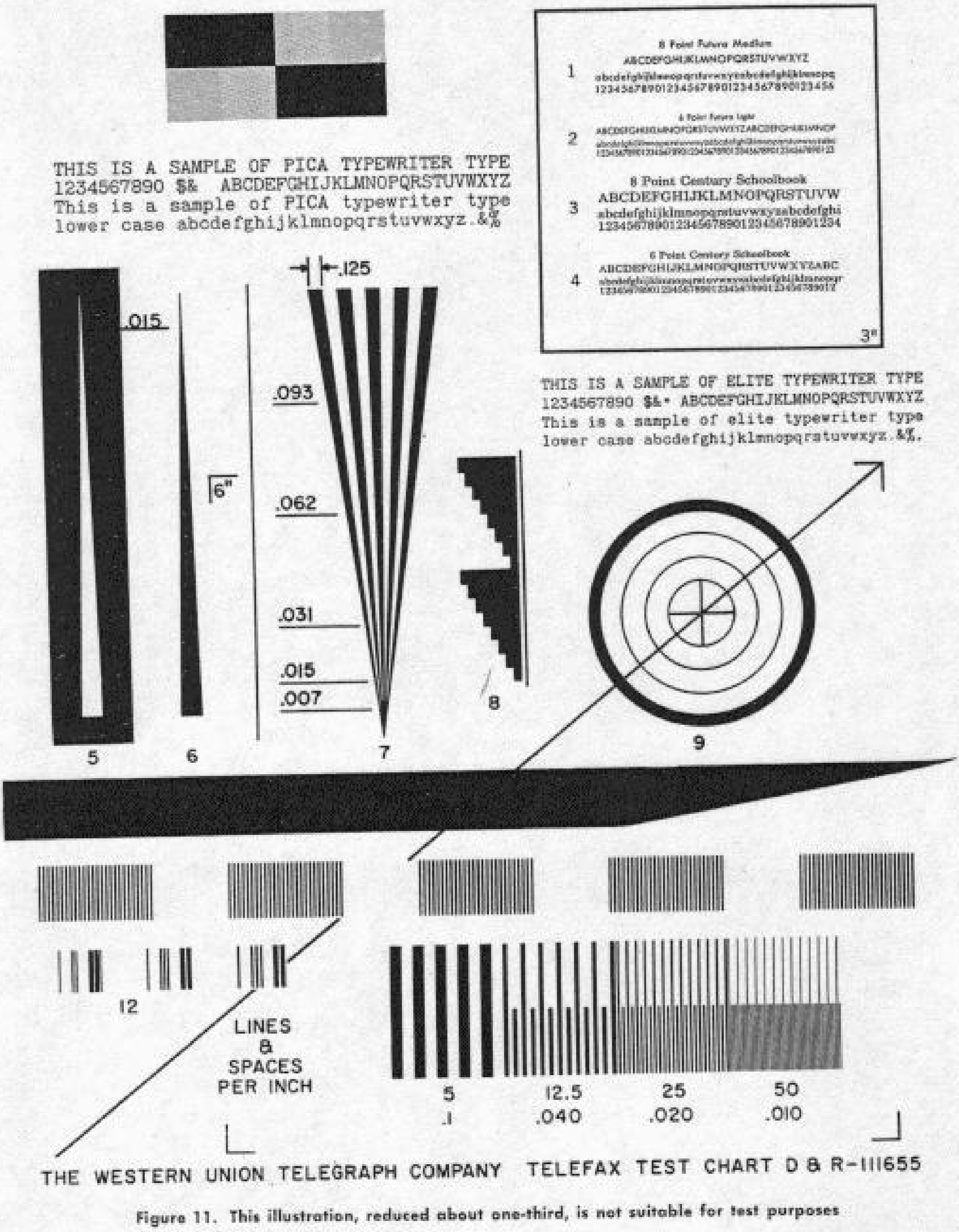


Figure 11. This illustration, reduced about one-third, is not suitable for test purposes

of attenuation, noise, and in particular time delay, are the ones most commonly called for.

Facsimile scanners and recorders, however, present a totally different set of circumstances. These devices combine optical, mechanical and electronic operations to the end that reasonably legible copy is ultimately produced, and while it may be speculated that step-by-step measurements could be made of a succession of circuit components while sending standard test signals from a signal generator, it is clear that such measurements alone do not assure production of satisfactory copy. The ultimate measurement must encompass both the initial scanning machine and the final recording machine.

Facsimile Test Charts

For these over-all tests resort is made to transmission from scanner to recorder of facsimile test charts such as that shown in Figure 11. These charts contain a wide variety of type, figures and patterns which, when scanned, transmitted and recorded, yield to the discerning eye a measure of the various properties of the over-all facsimile circuit.[13] It is granted that such a test is quite subjective in character, but this is a case where the proof of the pudding lies in the eating. The following table indicates the various properties which may be checked by means of suitable test charts:

Test Chart Figure	Property Measured
1. Series of type samples of gradually diminishing size	Legibility, resolution, general quality
2. Series of lines of type or figure patterns of gradually diminishing density	Contrast, received level amplifier linearity, adherence to prescribed pattern of nonlinearity
3. Negative, positive and multiple wedges	Resolution
4. Density step pattern	Received level, linearity. Voltage regulation and recovery time in amplifiers and power supplies
5. Pattern of concentric circles	Index of cooperation, linearity of scanning rate and line feed
6. Wide horizontal bar	D-c restoration, clamping
7. Groups of evenly spaced line patterns	Signal envelopes for oscilloscope observation
8. Groups of unevenly spaced line patterns	Circuit transmission characteristics
9. Groups of evenly spaced lines but with graduated spacing from group to group	Quantitative measurement of resolution
10. Vertical lines generally	Jitter, skew
11. Diagonal lines	Irregular line feed, nonlinear scanning rate
12. Large squares	Index of cooperation

It is believed that all of the properties mentioned in the foregoing two columns are self-explanatory, except possibly the term "index of cooperation." This term relates the horizontal and vertical dimensions of the copy sheet. To be compatible with each other a scanner and recorder should have the same index of cooperation although the received copy need not necessarily be the same size as that scanned.

Facsimile test charts are not merely a display of random, meaningless figures run off by whatever duplicating process is at hand. This graphic gibberish is the result of long study and test, and the charts must be printed and reproduced by very exact methods in order to maintain the necessary degree of accuracy.

Test Tables

A variety of highly useful testing assemblies are found in a range of Telefax test tables of which No. 6554-A is typical. This table embraces the major components of a Telefax Concentrator 176-A each of which may be readily disconnected and another one of the same item substituted for tests. Hence, transmitters, recorders, inverters, amplifiers, and so forth, may be tested and adjusted readily under normal operating conditions. This is a testing procedure which has proved extremely helpful in the maintenance of this rather complex equipment.

TEST EQUIPMENT FOR RADIO RELAY SYSTEMS

Western Union radio relay systems provide a useful bandwidth of 150 to 200 kc and this bandwidth provides a pathway for a vast multiplicity of conventional carrier telegraph channels. Test equipment for the channel terminals and the multichannel modulation equipment as found at the radio relay terminals has already been referred to. The microwave terminal and repeater equipment, however, is of an entirely different character, a notable feature of which is that interconnection of components is by waveguide or, on occasion, coaxial cable, and obviously it is not feasible to insert miscellaneous measuring equipment into these circuits at will as can be done with other types of equipment. The practice, rather, is to build test facilities into the equipment initially which produce at test points a d-c voltage or current which can be indicated readily on appropriate scales.

A setup for making microwave tests or measurements directly is scarcely practicable outside the laboratory. For example, the test of Klystron tubes requires a considerable array of waveguide-connected microwave components in addition to several conventional but uncommon items of test equipment.[14] However, for use by maintainers and in terminal repair shops a wide variety of instruments, usually of commercial type, are found. These include RF signal generators, radio communications receivers, crystal testers, vacuum tube voltmeters of different types, oscilloscopes, and the like.[15]

AT-2 Wavemeter

Since there are relatively few occupants of the common carrier microwave bands, few commercial radio manufacturers cater to this market. Hence it is often necessary for the users to design and manufacture the equipment of the special types called for. Typical of such items is the AT-2

Photo R-8916

Figure 12. Complete wavemeter with carrying case and calibration charts

John R. Hyneman graduated from Purdue in 1921, after a two-year interruption due to World War I, and joined the staff of the Apparatus Engineer in June of that year; he transferred to the Research, later Transmission Research Division, in 1926. Since that time Mr. Hyneman, now Manager — Patents, has specialized in the technical, inventor contact, patent review and licensing areas of Western Union patent matters, filling a liaison position between our Research and Engineering and Patent Departments. Intensive contact with most of the company's engineering activities over a long period has equipped the author for the present assignment. Mr. Hyneman is author of the digests of current Western Union patents which appear regularly in the Review.

Wavemeter.[16] Shown in Figure 12, this instrument comprises a metallic cavity tunable by a variable plunger provided with a vernier scale. In order to maintain the high order of accuracy required, suppress unwanted wavemodes and prevent losses harmful to the "Q" of the instrument, an extraordinarily high order of dimensional accuracy in the cavity and in the adjustable movement is imperative. Connection to the instrument is by means of a short length of coaxial cable. It is designed to operate in the 4000-mc range and yields readings in steps of 25 kc. A "Q" of 40,000 is obtained.

Wavemeters too are subject to their aberrations and from time to time must be calibrated against a standard. In this country the frequency authority is the emissions at certain frequencies from Radio Station WWV at Beltsville, Maryland, operated by the U. S. National Bureau of Standards. These few emissions of course are inadequate for all purposes and it becomes necessary for calibrating laboratories to provide a secondary standard of frequency which can be synchronized or compared by some means with a WWV emission, and from this to produce any desired local standard frequencies. These standards are quite elaborate affairs and one has been in use for some years in Western Union's New York laboratories where it provides standard frequencies for calibrating wavemeters, oscillators and other equipment ranging from voice to microwave in frequency.[17] A somewhat less elaborate standard, also based upon the WWV emissions, is located at the Water Mill Laboratories.

*   *   *   *   *

The foregoing parade of subjects has called attention to a variety of equipments many of which exhibit considerable ingenuity in design, and most of which have come into widespread use in Western Union telegraph offices. Some were designed to isolate a quantity or property to be measured, and to give an indication of the magnitude and character thereof. Others were primarily a convenient assembly of components for making repetitive measurements. Instruments of this latter type are found in many forms in laboratories, maintenance shops, and in the kits of material inspectors. These same motivations will continue to add variety to the list while obsolescence will relegate others, as may be noted herein, to museums and to the historical reviews.

Reprints of this informative article on Telegraph Measuring Instruments and Test Sets are available without charge. Requests should be addressed to the Committee on Technical Publication.

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Robert Steeneck, after graduation from Stevens Institute of Technology in 1926, joined Western Union on the staff of the Apparatus Engineer. In 1928 he transferred to the Engineer of Automatics to assist the Ticker Group in the development of the newly established Teleregister service. He was later responsible for the development of the company's line of Sport Timers; he assisted in the development of the varioplex system, and worked on the Navy Radar Contact Trainer project at the Water Mill Laboratories. In 1954 he was transferred to the Switching Development Engineer's division to develop an electronic one-wire cross-office control for the Air Force switching system. Mr. Steeneck was in charge of the "Dingbat Project" which won for its sponsor one of the five highest citations awarded for the year 1955 by the Department of Defense. At present he is engaged in data handling developments.

ROBERT STEENECK, Assistant to Manager—Data Equipment and Systems

Error Checking Possibilities Concealed Within the 5-Unit Code

ALTHOUGH the 5-unit Baudot code has withstood the test of time in the printing of telegraphic messages, it appears susceptible to some improvement if this same code is to be used for data communication. Analysis confirms that when the code was established the simpler combinations were assigned to the most used characters and printer functions. If the combinations are arranged in order with the simplest combinations first, as shown in Figure 1, it will be noticed that the assignment follows quite closely the ETAOIN SHRDLU CMFWYP layout used on the linotype keyboard which was arranged in the order of frequency of language use of alphabet letters. Although this assignment has been quite satisfactory for telegraphic plain text messages considerable improvement can still be made, as will be pointed out later on in this article.

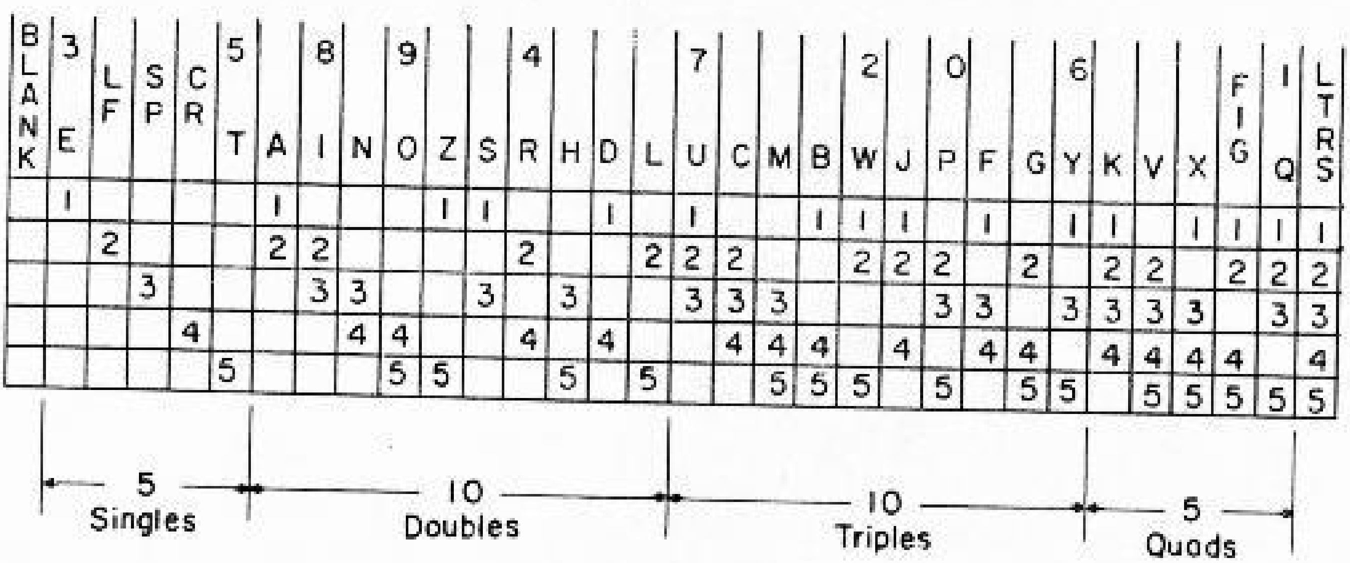

Figure 1.

The assignment of code combinations to the ten numerical digits, however, quite definitely is not well suited for data handling. It obviously was determined by the combination already found on the top letters line of the standard typewriter keyboard, namely QWERTYUIOP. In telegraphic communication, the disadvantages of this assignment were never very objectionable because, first of all, figures were generally spelled out as words in message texts. If figures were included in a telegram confirming figures always were sent at the end of the message for an accuracy check.

In data transmission, however, figures are usually the most important part of the information being transmitted, because figures generally represent quantities of something which in the end is the equivalent of quantities of money. An undetected figures error in data transmission is therefore the most serious error that might occur within the message structure.

A quick analysis of the figures code assignments will show why this present code arrangement is not entirely satisfactory for data purposes. Let us examine the digit 1, for instance. Digit 1 has pulses 1, 2, 3 and 5 marking and pulse number 4 spacing. Now if we subject this combination to the most frequent type of error, namely, the loss of a single marking pulse, we of course will get an error. If the error we get produces an asterisk, a question mark, or some other upper case character, the error obviously can be detected easily. In all of the four possible errors produced by the loss of a single marking pulse the digit 1, however, is always converted into *another digit*. Thus digit 1 by the most common of errors can become either 2, 6, 7 or zero, depending upon which pulse was lost. In fact, under actual tests, when handling figures alone, the standard Baudot code produced on the average one such undetected error for every six errors that were obvious.

This shortcoming of the Baudot code can be remedied by reassigning some 6 or 7 of the 10 digits to new code combinations. Referring to Figure 1, it will be noticed that the 32 code combinations can be divided into 5 groups according to the number of marking pulses contained in each combination. It is quite obvious that, in any one group, it is impossible to create any error that will produce any other character *in the same group*, unless there is both gain and loss of the same number of marking pulses in the particular errored combination.

This, of course, is the heart of the fixed ratio code error checking technique used in both the IBM transceivers and the RCA overseas radio error detection system. It will be noticed from Figure 1 that there are two fixed ratio groups each containing ten combinations in the 5-unit Baudot code. If the ten digits are assigned completely to either of these groups, loss of marking pulses alone can never print wrong *digits*, but instead can print only meaningless upper-case combinations that may easily be recognized as errors.

The loss of a complete digit, of course, is not prevented by any code arrangement. This problem, however, becomes a simple matter of message format quite common in many data systems. Zeros or other marks are often used to fill out numerical data groups so that all will contain predetermined numbers of numerical characters. The loss of a complete digit then becomes quite obvious. As in all error detecting schemes, it is also quite possible to fool this system too, but either pulses must be received in the wrong slots or pulses must be both lost and gained to produce an error detection failure.

Some Test Results

In the laboratory, tests were run to determine how often such a breakdown of check would occur if, first of all, pulses were received in the wrong slots. In this test the receiving printer was set on the very edge of its range on a marginal line. Even with this unusual condition over 100 errors were detected before one nondetected errored combination was produced. In the second case, a marginal circuit was used subject to both dropout and gains of pulses. Even under this condition 500 errors were recorded before one error that would not be detected was produced. These tests obviously are not conclusive but indicate the merit of the system even under adverse conditions. Under normal conditions the system has already proved its merit in the IBM transceiver and the RCA overseas radio error detecting system.

Special reassignments of 5-unit digit combinations to minimize errors have been used occasionally by both Western Union and the International Business Machines Corporation. In Europe, however, teleprinters for reliable transmission of numbers have been developed by both the Lorenz and Siemens companies. The Lorenz printer designed for Telex operation is unique in that the protected numbers are printed in italics from a third shift level built into the printer. In this level all combinations outside the three-marking two-spacing group, assigned to protected figures, print an asterisk easily recognized as a received error. The other two shift positions have standard teleprinter code assignments and can operate with machines not equipped with the third shift feature.

The Lorenz keyboard has a fourth row of keys assigned only to the protected numbers. This row is locked out until the third shift key has been depressed.

In the Siemens' system no compatibility with standard code operation has been provided. All but eleven of the 32 5-unit code combinations have been completely reassigned to obtain the desired protection of numerical information. As in the Lorenz system the three-marking two-spacing code group has been used for this purpose.

The European committee working on telephone and telegraph standards (C.C.I.T.T.) is now considering proposals to make some code change, employing fixed ratio combinations for numbers, standard for 5-unit data handling.

In alphabetic code combinations, the order of assignment is not too important since plain text communication errors generally result in unintelligible words.

Some improvement in character assignment could be made by bringing all vowels into one of the groups shown in Figure 1. An errored vowel would then most generally result in the printing of a consonant which would make the word unpronounceable and would be easily recognized as an error. Thus "six brown cups" could not become "six brown caps."

An analysis of consonants also might show the desirability of grouping those with somewhat similar sounds so that errored consonants would again tend to produce nonsensical words. To do this of course would involve a detailed study of word structure.

A Practicable Program

If in the Baudot code we reassign some six or seven digit combinations only we can obtain simple effective error protection for all numeric information, which is an essential requirement in data systems. To make such a conversion on all teleprinters would be a great task but even this would be nowhere near the task involved in converting to 7- or 8-unit fixed ratio data codes.

There is, however, no need at present to convert the entire telegraph world. Data transmission is now mostly over private wire systems where relatively few pieces of equipment are involved. The Type 28 page teleprinter can be converted quickly to accept almost any 5-unit code by merely inserting a new box of type in the printer. In keyboard transmissions, four-bank keyboards have already been designed with lockout features that will allow either the proposed data code transmission or present telegraph code transmission to be generated from the same keyboard.

Should it become necessary to handle data over the Western Union public message system, only the preamble and the end of the message must be in the present Baudot code. The body of the transmission may be any jumble of 5-unit combinations provided these combinations do not produce the cutoff signal which at present is two consecutive carriage-return combinations. In some private wire systems, Figs-H-Ltrs or a combination of four consecutive N's are used to signal the end of a message. It is possible to avoid all of these conflicts by using the three-marking pulse combination group for the ten digits. This involves reassignment of only six digits to produce a simple effective numerical error detecting code. The digits are 1, 3, 4, 5, 8 and 9.

It should be realized, however, that this change only scratches the surface in tapping the error detection potentials that now lie hidden in the 5-unit permutation code.

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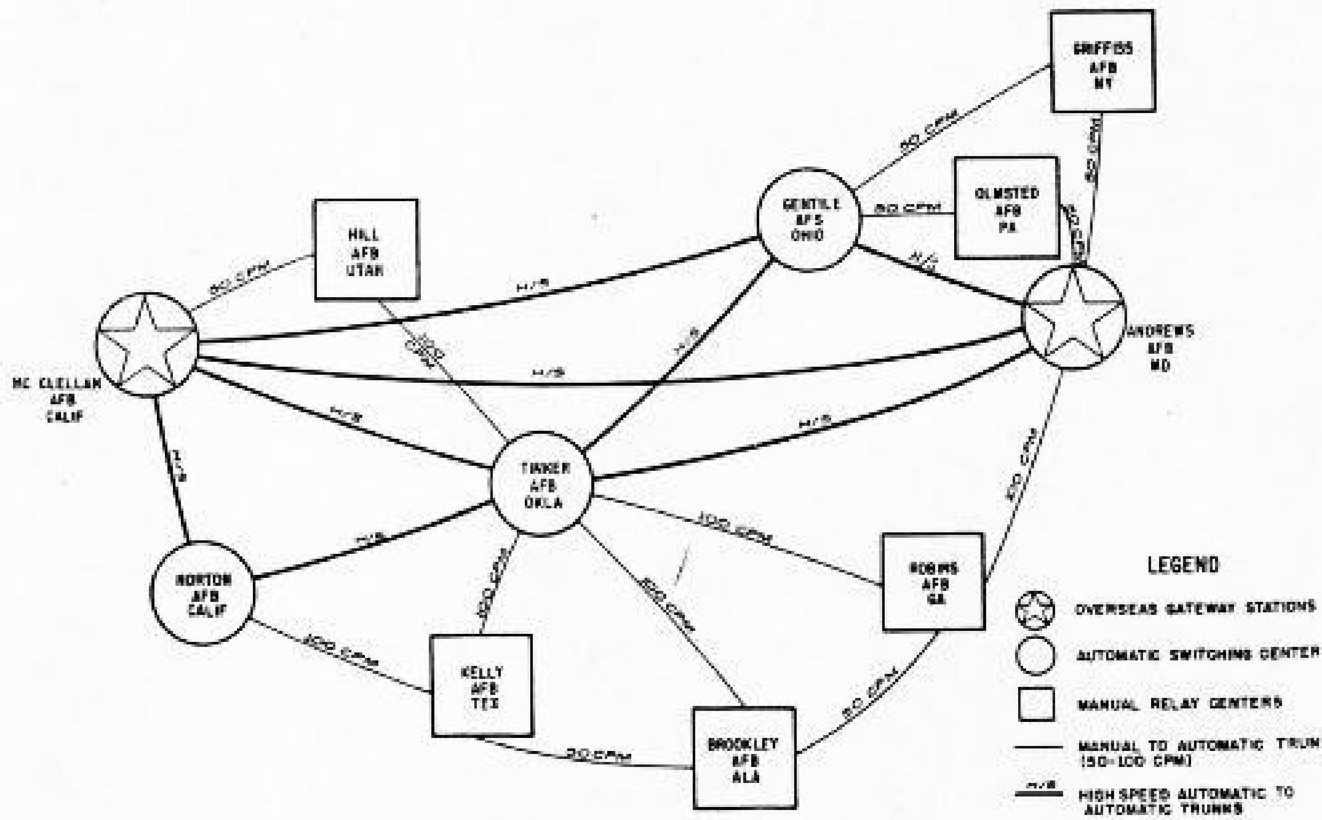
Telegraph Switching for the USAF Combat Logistics Network

NEW DATA transmission systems of special advanced design are being developed for the U. S. Air Force by Western Union. One of these systems is a high-capacity transcontinental communication facility to serve Air Force needs for broadband data transmission and involves the construction of a microwave beam network coast-to-coast. The capacity of this network will be of such magnitude that in addition to the Air Force data system, 12,000 telegraph channels can be operated simultaneously.

Growing use of business machines by the Air Force, brought about by the speeding up of supply operations and the monetary savings that could be achieved by the expanded use of such methods, caused Air Force commanders to examine carefully the situation that would exist some few years in the future, and it became obvious to all concerned that better efficiencies and larger savings could be achieved if automatic telegraph switching methods were applied to logistics data operations.

COMLOGNET, as the Air Force combat logistics network is designated, is an automatic, fully electronic, transistorized, high-speed data transmission and switching network. It will be the world's largest and most advanced digital data system, and will provide for more efficient control of Air Force personnel and materiel. The system's initial capacity will be sufficient to transmit about seven million punched cards, or equivalent, daily, and will initially link 240 air commands, bases, mate-



USAF Combat Logistics Network

A paper presented before the New York Section, Armed Forces Communications and Electronics Association, January 1960.

riel areas, depots, contractors, and other authorized installations. Data originating at overseas locations will be connected into the domestic network via facilities provided by the Air Force, and switching plant will be provided for this purpose at the gateway installations. COMLOGNET will have the capability of transmitting any form of digitalized information, including graphics such as facsimile messages or weather maps. Also, arrangements will be provided for processing a large amount of administrative traffic utilizing teletypewriter equipments. Since COMLOGNET is an integral part of the USAF Communications Complex, known as AIRCOM, it will be capable of interchanging traffic on a compatible basis with other Air Force and similar military networks.

Modular Expansion

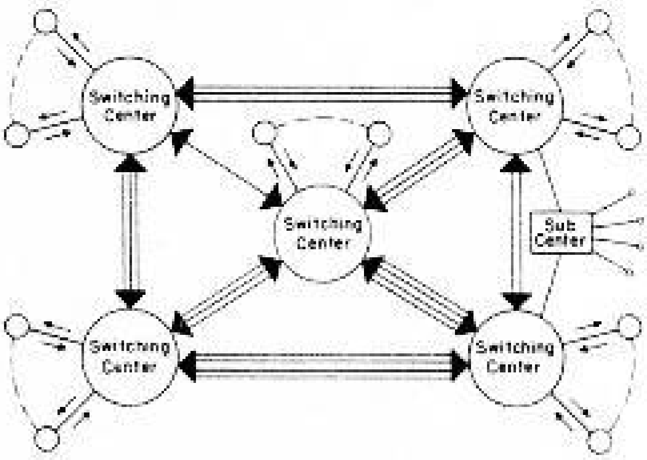
The initial system layout will consist of five switching centers, four of which will operate initially with 50 tributary or trunk circuits, and the fifth with 100 circuits. By modular expansion in economic increments, each of the five centers can be made to accommodate at least 100 circuits. It is planned to take advantage of avoidance routing where possible. The trunk circuits will have a frequency bandwidth of 3000 cycles, operating at the highest bit rate obtainable at the current state of the art.

Perhaps the best way to explain comprehensibly just how COMLOGNET will operate is to enumerate the devices comprising the input and output of the system. These are: punch card readers and punches, magnetic tape transports, digital computers, teletypewriters, paper tape transmitters and perforators of various kinds, and digitalized graphic receivers and transmitters. The switching centers must obviously accommodate exchange of traffic of similar form between like terminal devices in the alphanumeric or symbolic codes native to each, but there are several important exceptions such as transmitting from a card reader at one end to a teleprinter at the other, or from a magnetic tape output of a computer at one end to a card punch at the other.

Another standard adopted by the Air Force is the transmission rate required for various communication channels. All COMLOGNET channels will be operated at 75, 150, 300, 600, 1200, 2400 or 4800 bauds initially. An additional capability will be provided by adding proper modules operating at bit rates up to 50,000 bauds. The switching centers also will permit interconnection with designated commercial and indigenous transmission facilities, such as overseas channels, at modulation rates for which these channels already are equipped.

Circuit Switching

While the basic function of the switching center equipment will be to accept, store and retransmit data messages from one location to another, accomplishing signal code and rate conversion when necessary, the center also will be designed to permit automatic interconnection of station to station, station to trunk, and trunk to trunk, sometimes on a tandem basis, thus providing user-to-user service on a circuit switching basis. Such circuit switching will be monitored by the switching center attendant to limit such use to approved conditions.



Schematic circuit layout—each switching center is the hub for a number of tributary circuits

Most telegraph and business machine equipments in present use operate with 5-, 6-, 7- or 8-level digital codes that designate letters of the alphabet, numerals, punctuation marks and machine functions. For example, IBM transceivers operate on a 4-out-of-8 code, Teletype machines on a 5- or 6-level code, and

Flexowriter equipment on a 5-, 6- or 7-level code, while computers generally operate on different types of 7-level codes. To permit these various equipments to transmit to and from one another it is necessary to accomplish code conversion or translation and sometimes format translation. Since it is a fundamental concept of COMLOGNET that these machines be permitted to communicate intelligently with one another, it is necessary to provide a common language code for the system. Perhaps the most obvious reason for a common language code is that the switching center must be able to read instructions given to it as to how a following transmission is to be handled. However, this does not mean that language translation must always be accomplished at the switching center. It probably will be necessary to accomplish a part of the translation at tributary stations. The Air Force has decided that the common language for COMLOGNET shall be a code consisting of eight equal elements of which seven elements shall be used to designate up to 128 character permutations and the eighth element shall be used for parity check. The character designations will be in accordance with the binary oriented field data code recently adopted by the Air Force.

The message format to be employed with COMLOGNET requires that each message shall contain a message heading, followed by the text material and terminated by a message ending. The message heading will contain the required control information to cause the switching center to perform switching, routing, and other processing functions. It will consist of the precedence indicator, message type indicator, security classification, content indicator, originating station indicator, station serial number, date-time group (optional), group code or card count (optional), and addressee station indicator. The indicators employed will be in accordance with JANAP 117-C.

The switching center will provide for three types of message routing; that is, single address, an unlimited number of multiple addresses, or a group address based upon a predetermined distribution list. The design will permit changes in the distribution list at will when authorized. In the case of multiple address transmission the address designations, other than the one to which an individual message is being transmitted, are automatically deleted.

Format

The text material will consist of a wide variety of information in various forms depending upon the type of input equipment. In certain instances, the text material will consist of a stream of binary signals of no particular code or language. In other instances, the text will consist of material encrypted prior to its entry into the system, and in this case while the heading and end-of-message portions of the format are readable by the equipment, the text is not readable by either the equipment or a person. Normally the maximum message length will be 4088 characters; however, some messages will greatly exceed this length, for example, a magnetic tape reel. Regardless of the type of text material to be accepted, stored and relayed to a delivery point, the switching center must perform its functions in such a way that the arrangement of the text bits or characters is preserved accurately. In other words, there can be no additions or deletions in text material.

The end-of-message indicators will consist of a single character in the case of a single punch card; in the case of all other messages, four characters. For teleprinter messages, the end-of-message indicators will be preceded by two carriage returns and four line feeds which, taken with heading indicators, insures compatibility with the format employed in the Western Union developed and supplied Plan 55 automatic system now being used by the Air Force in its world-wide teleprinter network for which ACP 127-B procedures were specified.

A data message may consist of a single card in which the first few columns will contain the heading and the last column the end-of-message indicator. In the case of a deck of cards, the first card will be the header card, and the last card will be the end-of-message card. A similar technique will be used to transmit from a magnetic tape.

Priority Recognition

Another important function to be performed by switching centers is to control the flow of messages to and from all tributary stations on a predetermined basis, but without appreciable delay. It is necessary that transmission and reception of traffic shall be on a virtually continuous basis, but it is also necessary to recognize the six levels of priority that have been established, namely, flash, emergency, operational immediate, priority, routine and deferred, and to cause the messages to flow in the order of their priority. To accomplish this, the switching centers will arrange the outgoing traffic in the right order, but tributary stations must transmit a "request to transmit" and receive a "permission to transmit" signal prior to sending each message to the switching center. Likewise, the switching centers will send a select signal and receive a start signal prior to sending each message to an outstation, but this is done for another reason, namely, to make certain that every station is in operating condition before dispatching traffic to it. However, provision to waive this requirement will be incorporated in the event that it is impossible to maintain the return side of a duplex facility because of technical or other difficulties. Control of this situation will be the responsibility of the controller, who can use judgment. To program for automatic resolution of all possible contingencies would complicate the design tremendously.

It also will be a normal operating routine to permit the attendant to effect automatic storage of traffic for one or more tributary stations or trunk circuits when any of them are known to be out of service, such as closed for the night, and subsequently to transmit such traffic when the circuit again is open for service. Suitable visual audible alarms will be provided to indicate the transfer of precedence I and II messages to such storage.

The switching center equipment will be arranged to permit the attendant selectively to withdraw from switching storage a perforated tape and/or a page-printer copy of any message for subsequent reintroduction into the switching center. To accomplish this the attendant will set up an alternate routing for any tributary station or trunk channel, and in this manner the messages will be recorded at his local traffic position.

Perhaps in the beginning it should have been emphasized that in COMLOGNET, speed, accuracy and reliability will be attained to a degree never before achieved. From the foregoing it can be seen that the speed requirements of the system will be met by the use of high-speed line channels and transistorized electronic circuitry at the switching centers.

Accuracy is required because the primary function of COMLOGNET is the transmission of text material where the mutilation of one character can change the whole meaning of a message. High accuracy will be obtained by the use of error detection codes and error correction arrangements, which will insure that each time a message is transferred it is received correctly at the receiving point. The incoming and outgoing line facilities, tributary stations, and the switching centers will incorporate automatic accuracy control equipment to assure that not more than one error in 10^7 characters goes undetected. The switching center will be arranged so that it will automatically correct detected errors or it will set up alarms which must be manually released by the controller after the trouble has been cleared. Processing of all other messages will continue during alarm conditions, and the message in trouble will automatically be presented in an appropriate manner for action by an attendant.

A number of other safeguards are provided, such as automatic surveillance of the processing of each message, and the recording of the number of detected errors for statistical purposes and to make certain that a faulty piece of equipment is taken out of service before it can begin to make errors frequently. Any message delayed beyond a predetermined time interval established for each precedent will be brought to the attention of the attendant for expedited handling.

Magnetic Storage

Reference magnetic storage will be provided, at each switching center, of sufficient capacity to store all information that originated at or was transmitted to each tributary station. This storage will make it possible to gain high-speed access to message traffic in the unlikely event of trouble in any part of the switching complex. It also is the means of checking performance of equipment and of making traffic load studies, and stored information may be shipped in whole or in part to another similarly equipped switching center where the information can be extracted for any subsequent use.

Another special feature is the provision of incoming and outgoing journals. These message journals store and present, on demand, synoptic information on each message sufficient to identify it, to record how the message was processed, where and when it was sent to an outgoing line. Journal information will be retained for 30 days in inactive storage, and sufficient active storage will be maintained for a period to be determined by operational requirements.

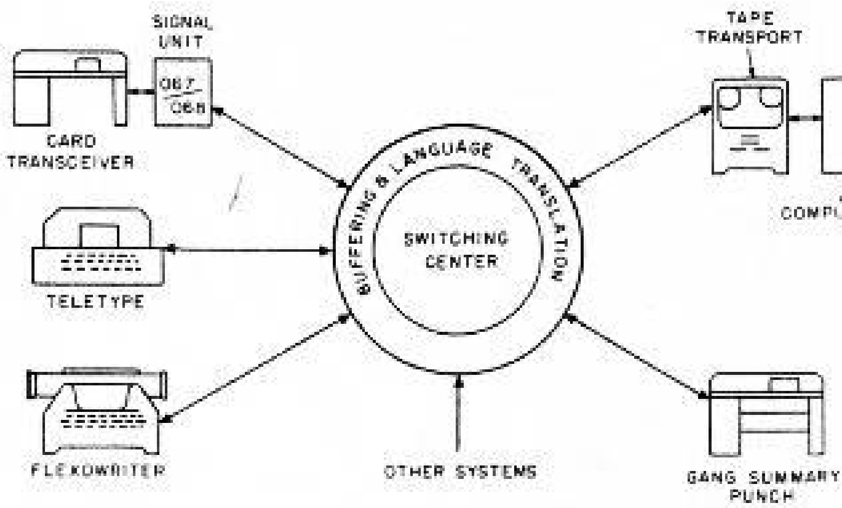
Switching centers will have the capability of collecting and storing, for "on demand" presentation, statistical information so that the controller can determine channel utilization factors and the number of messages awaiting transmission by precedence for each circuit.

As in previous Air Force automatic switching systems, each COMLOGNET center will be equipped with a technical control position. Here the input and output channels and circuits are set up or rearranged to meet in the best possible manner the operational requirements and to effect coordination of the switching center functions and circuit facilities. Means will be included to determine, on an immediate access basis, circuit and channel quality status. Also, critical point-to-point channels may be monitored continuously.

Code and speed translation functions will be performed, if required, in the buffer units. However, perhaps a better understanding may be reached if the buffer units and the sampler unit are thought of as both being parts of the accumulation/distribution unit, which is called the ADU. The principal functions of the ADU are:

1. Sample incoming channels.
2. Perform code conversion.
3. Temporarily store incoming and outgoing information.
4. Provide automatic accuracy control.
5. Control and coordinate outstation and trunk transmission, including the stepping of output signals under control of external time synchronous devices and, alternatively, with synchronizing information from a station master clock or frequency standard.

The next unit is the central processor unit which is duplicated so that two are available for alternate use when required.

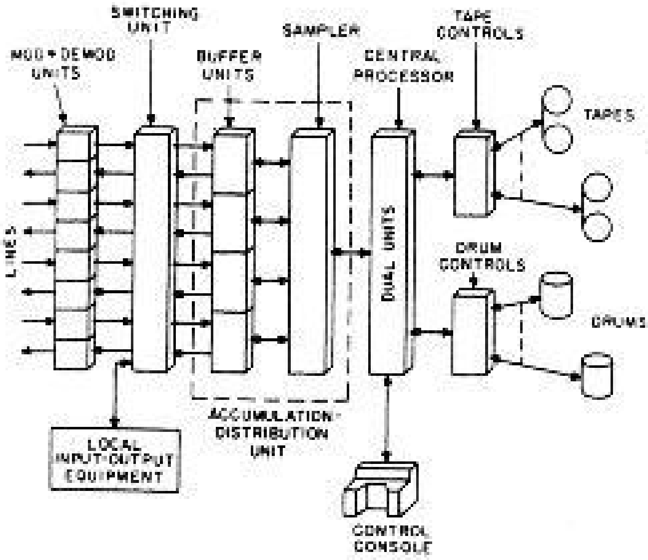


Various kinds of data equipments at the tributary stations

The principal elements of the CPU are:

1. Program control
2. Data processor
3. High-speed core memory for
   a. Programs
   b. Routing doctrine
   c. Priority doctrine
   d. Temporary store for intracenter traffic transfers

It might be of interest to trace a data message incoming from one of the lines through the switching center and to a local data-processing center. The message would arrive on one of the circuits leading through the switching unit to one of the buffer units, where one character at a time would be stored temporarily. Buffers for higher speed channels may have two or three characters of storage. In each scan by the ADU, one character is extracted from the buffer (and all other buffers) and loaded into a temporary high-speed store in the ADU. The capacity of this store is equivalent to a few seconds of transmission. The central processing



Simplified block diagram tracing the flow of data messages through a switching center

unit performs a similar scan of the ADU and transfers any traffic which may have been stored into the high-speed memory. The information contained in the heading is read by the central processor which in turn refers to its internal program storage and determines how the message should be handled. After accuracy check the sampler unit then pulls the message out of storage, accomplishing any code conversion necessary, and routes the text information through one of the tape control units to an appropriate magnetic tape unit for use by the computer at a later time. The particular tape reel selected will depend upon the processing instruction, since one of the functions to be performed is the sorting of information into appropriate categories; for example, different weapons systems, different types of supplies such as fuel, engines, air frames, and so forth. In some cases, the equipment will be required to read the information contained on certain of the numbered columns in a card and, depending on what instructions are found there, sort the cards into finer categories.

A data message which is to be relayed through the switching center to one of the tributary stations or to another switching center would follow a somewhat similar procedure, except that in this case the central processor would not set up the routine to record the transmission into one of the tape units, but instead would record it on one of the high-capacity drum units where it would be held in what is called "in transit" storage. The central processor meanwhile has set up the orders for routing and queuing the message for one or more of the outgoing lines. As soon as the message reaches the head of the queue (which is maintained by precedence), it is read off of the drum and as far as the central processor is concerned the transaction is complete. After accuracy comparison and when the line circuit becomes available, the message is transmitted to the next point in the system.

Continuous Operation

That the best available components and equipment items be furnished for COMLOGNET, and that emergency or stand-by power equipment be provided, are essential elements of high reliability. The term takes on added significance when the system design engineer comes face-to-face with the Air Force requirement that when a power failure or surge occurs, no part of any message in storage or being processed shall be lost or modified. Also, the design of the equipment will be such as to require a minimum of temperature and humidity control. These safeguards are in themselves quite a challenge to the designer, but he will need all the tricks in the bag to cope with the requirement that COMLOGNET switching centers shall be capable of continuous operation. No scheduled down time of the switching center for maintenance purpose will be permitted. This means that all common circuits will be duplicated with comprehensive cross-checking, disconnect and automatic switch-over features provided. Suitable isolation and alarm features will indicate faulty units and these will be replaced immediately.

Maintenance will be facilitated by the incorporation of preventative and corrective maintenance features, and by the use of accessible plug-in modular units and built-in noninterruptive self-testing devices. A stock of spare modules and a bench testing technique employing go-no-go test sets will be employed. Finally, a set of maintenance manuals will be written. Western Union will supply engineering and maintenance supervision at each location on a 24-hour 7-day-a-week basis and Air Force personnel will be trained to do their assigned tasks.

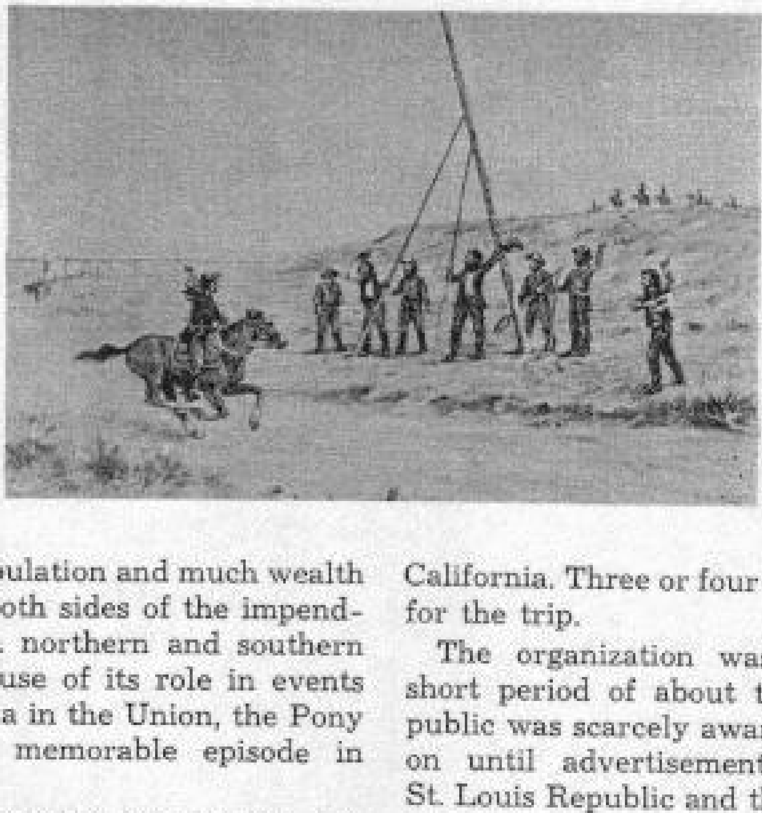
COLONEL JULIAN Z. MILLAR, a graduate in Electrical Engineering of the University of Illinois, has been with Western Union since 1923, starting as an engineering apprentice in Washington, D. C. In 1926 he was transferred to the Water Mill Laboratories where communications electronics became his field of work. Colonel Millar served with the Signal Corps Board at Ft. Monmouth, N. J., from March 1941 until April 1944, when he was assigned as Signal Officer, Normandy Base Section, and later Signal Officer, Loire Section, European Theatre. At the end of the war he returned to Western Union and was appointed Radio Research Engineer. He became Director of Research in 1949, and Assistant Vice President in 1953. Colonel Millar has served as a Consultant to the Department of Defense; he is presently a member of the Scientific Advisory Board of the NSA, and a member of the Air Force Scientific Advisory Board. He is a Fellow of IRE and a member of AFCEA, AIEE, SMPTE, and American Management Association.

Western Union and the Pony Express

1860 - 1960

FLEET forerunners of the transcontinental telegraph, galloping Pony Express riders first headed westward from St. Joseph, Missouri, 100 years ago on April 3, 1860. According to one California newspaper it was "Simply inviting slaughter upon all foolhardy young men who had been engaged as riders." Fortunately, however, only one rider actually was killed while on duty and only one dispatch packet was lost in the 16 months before telegraphy outdistanced these fast-riding horsemen.

This year marks the 100th anniversary of the start of the famous Pony Express service which, although short-lived, was of vital importance because it came into being at a time when travel was slow and when a great national crisis made it imperative to have fast communication between east and west. California had considerable population and much wealth greatly desired by both sides of the impending conflict between northern and southern states. Largely because of its role in events which kept California in the Union, the Pony Express became a memorable episode in American history.



The Pony Express was founded by the firm of Russell, Majors and Waddell as a part of their "Central Overland, California and Pike's Peak Express Company." This firm had for several years been operating trains of prairie schooners carrying tons and tons of goods over the Santa Fe, the Oregon, the Mormon and other pioneer trails.

Alexander Majors, a man of deep religious convictions, was in charge of the new venture. He would look over the applicants very carefully and those that were chosen were obliged to make this pledge:

> "I do hereby swear before the great and living God that, during my engagement with Russell, Majors and Waddell, I will under no circumstances use profane language; that I will drink no intoxicating liquors; that I will not quarrel or fight with other employees of the firm's and that in every respect I will conduct myself honestly, be faithful to my duties, and so direct all of my acts as to win the confidence of my employers. So help me God."

After signing the pledge the rider was presented with a small leatherbound copy of the Bible. At the height of its activity, the Pony Express line used 400 station men and helpers, 80 riders and 420 horses. Prior to the Pony Express the usual route for sending mail was by steamship from New York to the Isthmus of Panama, across the Isthmus and thence by ship to California. Three or four weeks were required for the trip.

The organization was completed in the short period of about two months and the public was scarcely aware of what was going on until advertisements appeared in the St. Louis Republic and the New York Herald stating that:

> "Telegraph messages from all parts of the U. S. and Canada in connection with the point of departure will be received up to 5 o'clock on the day of leaving and transmitted over the Placerville and St. Joseph telegraph wire to San Francisco and intermediate points by the connecting express in 8 days."

The announcement added that the first carrier would depart on Tuesday, April 3rd at 5 p.m. from the Missouri River at

St. Joseph, Missouri, and that weekly service would follow.

At the same time the rider started from St. Joseph a rider started from Sacramento eastward up the Sierra slopes toward snow-clogged mountain passes. Without telegraphic communication there was no way of following the progress of the riders on the trip and there was considerable doubt that they would ever get through. Nearly ten days elapsed before the question was answered. The riders from each end of the line had successfully completed the initial trip.

The Pony Express route between St. Joseph, Missouri, and Sacramento, California, was a distance of 1966 miles. Rested horses and fresh riders were ready at 190 intermediate stations 10 to 15 miles apart where two minutes were allowed for changing mounts. The average speed in summer was ten miles an hour including stops. In winter, snow lay on much of the trail and the average then was eight miles an hour.

Mark Twain on his trip west in 1861 showed keen interest in the Pony Express and in his "Roughing It" he describes what he saw in this fashion:

"We had a consuming desire, from the beginning, to see a pony rider, but somehow or other all that passed us and all that met us managed to streak by in the night, and so we heard only a whiz and a hail, and the swift phantom of the desert was gone before we could get our heads out of the windows. But now we were expecting one along every moment and would see him in broad daylight. Presently the driver exclaims: "Here he comes!"

"Every neck is stretched farther and every eye strained wider. Away across the endless dead level of the prairie a black speck appears against the sky, and it is plain that it moves. Well, I should think so! In a second or two it becomes a horse and rider, rising and falling, rising and falling— sweeping toward us nearer and nearer—growing more and more distinct, more and more sharply defined—nearer and still nearer, and the flutter of the hoofs comes faintly to the ear—another instant a whoop and a hurrah from our upper deck, a wave of the rider's hand, but no reply, and man and horse burst past our excited faces and go swinging away like a belated fragment of the storm."

Before the Pony Express had been placed in operation, a telegraph wire had been strung 250 miles eastward from San Francisco through Sacramento to Carson City, Nevada. Important official business from Washington was, therefore, sent by wire to St. Joseph and forwarded by Pony Express to Carson City where it was telegraphed to Sacramento or San Francisco. Later, during the existence of the Pony Express, a wire was extended from St. Joseph to the military post at Fort Kearney, Nebraska. Government dispatches such as Lincoln's Inaugural Address then were carried by pony rider from Fort Kearney to Carson City. Other important dispatches included news of the firing on Fort Sumpter and of the seizure of Harper's Ferry.

Even before the start of the Pony Express, consideration was being given to a transcontinental telegraph line. Finally, on June 16, 1860, the Pacific Telegraph Act providing a Government subsidy of $40,000 annually for ten years became law. The contract was let on September 22, 1860, to Hiram Sibley, then president of Western Union, who was the project's most ardent supporter and who, on his own behalf, was the only bidder. Sibley and his associates set about to carry this work to its successful completion. Sibley was anxious to have the Pony Express continue its service until the new line was constructed but the management of the pony line were unwilling to do this because they were incurring large operating losses and, of course, there was no hope of profit in the future because early completion of the telegraph line was a foregone conclusion. It was necessary, therefore, to subsidize the Pony Express to keep it in operation and Sibley arranged for this subsidy to be paid by telegraph interests. The telegraph line, completed on October 24, 1861, only a little over four months from the start, was successful from its very beginning and ultimately was incorporated into the Western Union system.

During the building of the telegraph line the Pony Express riders rode only the distance between the ends of the newly constructed lines which finally met at a point near Salt Lake. The Pony Express service officially ended on October 26, 1861, two days after completion of the telegraph line linking the east and west.—ALDER F. CONNERY, Manager—Technical Control, Project Engineering.

FRANK J. HAUPT, Project Engineer, Digital and Printing Equipment

Direct Camming Tape Transmitter

Application of well-known printing telegraph techniques to accomplish the objectives of newer and faster data processing procedures has required numerous equipment modifications. Studies which provide the basis for these design changes give careful consideration to interrelationships of mechanical action, electrical circuitry, timing and other factors.

TAPE TRANSMITTERS or tape readers as they are now called have, like old-fashioned lawn mowers, been with us for a long time. Both require close adjustments for satisfactory operation.

The new direct "camming" transmitter departs radically from the conventional transmitter design in much the same way as the rotary blade lawn mower departed from design traditions. Both new devices have further similarity in that they require fewer parts and need less adjustment than their predecessors.

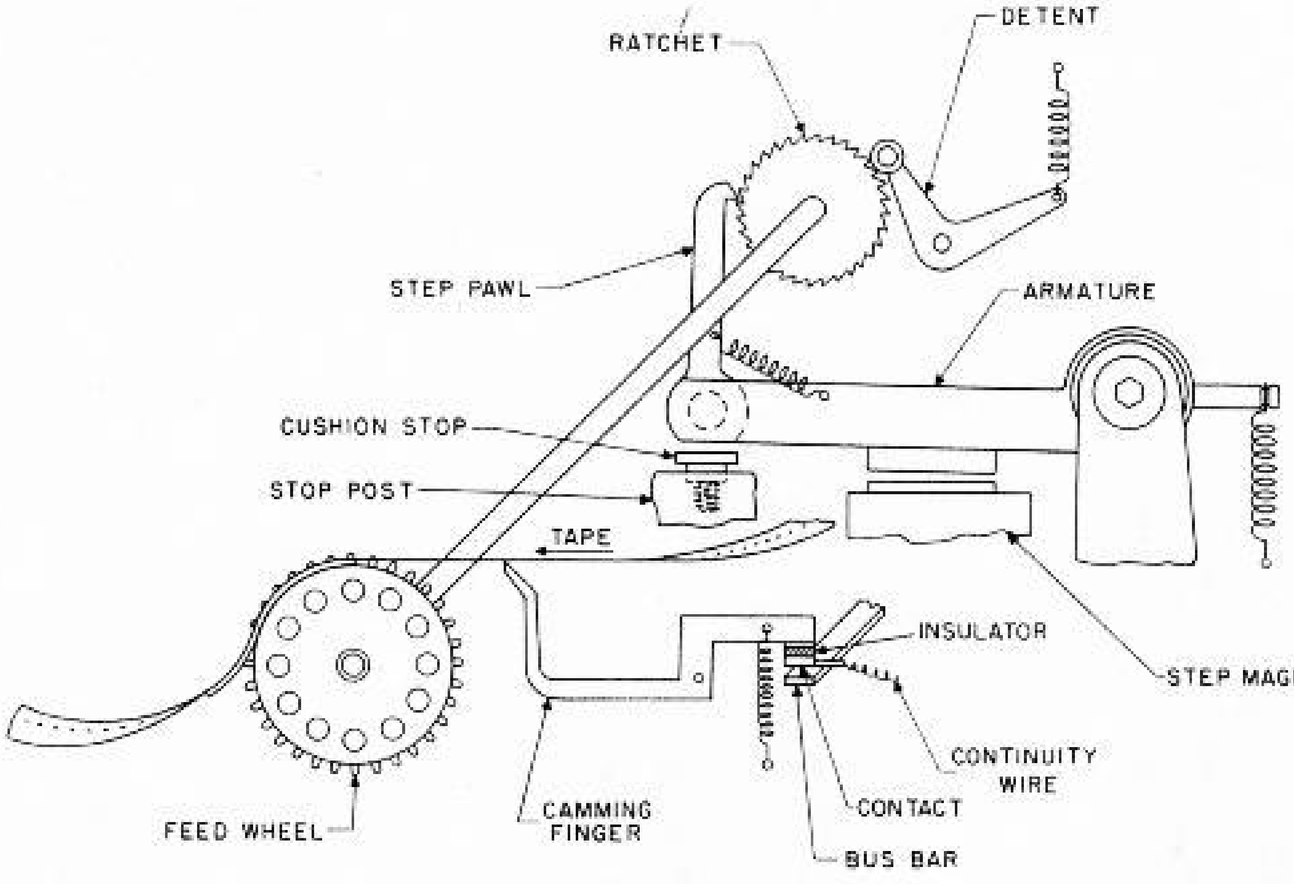


Figure 1. Reading and stepping mechanism

Mechanical Action

In all tape transmitters, except those of the optical type, that have been designed since the advent of punched tape communication, the presence or absence of holes in the tape has been detected by allowing pins to probe for the holes. This usually requires the removal of the pins from holes before the next tape combination can be advanced to the reading position.

The removal and insertion of the reading pins not only consumes time but makes necessary mechanical linkages to the reading contacts, which sometimes becomes quite complex. These linkages often introduce undesirable inertia into the reading mechanism, resulting in considerable contact bounce, which further limits the speed of tape reading. When higher speed reading became necessary, faster transmitters were built but the same reading pin design was still followed, except of course in the family of optical readers. Linkages were made considerably lighter and the reading pins were sometimes pivoted so that the tape could be advanced before the pins were completely withdrawn. Motor-driven and clutch operated cams were sometimes employed to obtain precise timing during each reading operation. Such design changes did result in higher operating speeds but the pin withdrawal function still consumed about one-half of the read cycle time. Extreme care in adjustment had to be exercised to prevent further shortening of the useful read time. High-speed clutching, when required, introduced additional adjustment and wear problems.

In the direct camming tape transmitter no reading pins are employed; camming fingers are used in their stead. They ride on the underside of the tape, under pressure of light springs, probing for code holes and directly actuating reading contacts whenever code holes are detected. The camming finger is shaped as shown in Figure 1. The upper tip is smooth and slightly rounded, and this surface is kept in contact with the tape which acts as a cam and determines the position of the finger.

In this camming process the finger rocks about its pivot and raises its attached contact from the marking bus bar. Should a hole be found when the next tape combination is advanced to the reading position, the camming finger will fall in, by spring action, and lower the contact back to the bus bar. Should no hole be present the contact will remain in its raised or cammed-out position. Thus the presence of a hole produces a contact closure against a common bus bar while the absence of a hole produces an open circuit.

Circuitry

Most high-speed tape readers incorporate rather complex motor-driven mechanisms for feeding the tape character by character. The simple electromagnet and pawl feed has apparently been discarded in these designs as being too slow. This is quite true if conventional practices are followed. However, by employing a simple stepping circuit network (or its equivalent) shown in Figure 2 considerable gains in operating speed can be obtained. This network peaks the operating current at the start of the step cycle and reduces it at the end, which not only shortens the magnet pull-up time but improves the armature release as well. The use of 40 mfd and 400 ohms results in approximately 5-millisecond improvement in armature pull-up time alone. Since the time of a complete cycle at 600 words per minute is only 16-2/3 milliseconds, the 5-millisecond improvement by current shaping becomes an important factor at these speeds.

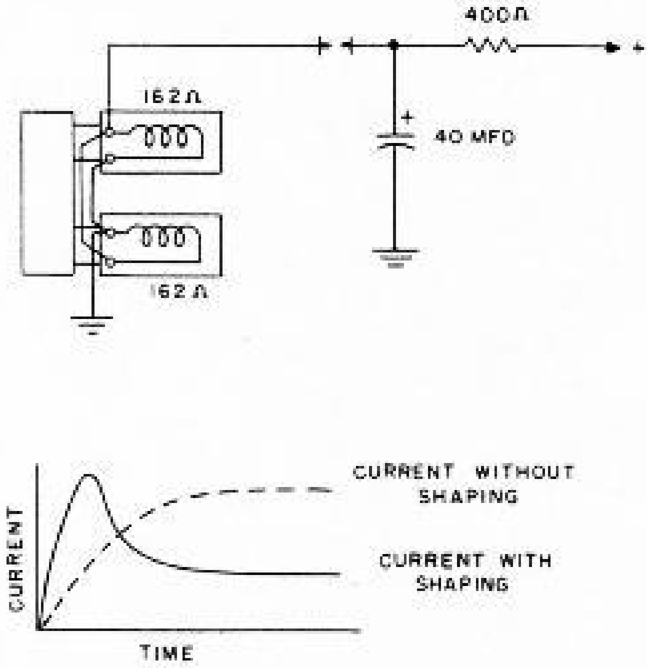


Figure 2. Current shaping circuit

To further assist the operation of the armature at these higher speeds a compression spring located in the stop post becomes effective 1/32 of an inch before the armature reaches its final stop (Figure 1).

The spring not only absorbs the kinetic energy of the armature at the end of its stroke, but uses this energy to hasten the return of the armature on the release stroke. By also incorporating core slotting and other well-known magnet design techniques, it is possible to obtain a reliable high-speed electromagnet drive.

The feed wheel has 32 pins, eight of

which are always engaged with the tape, dividing the load created by the action of the camming fingers. The feed wheel is located in advance of the fingers, to pull rather than push the tape. Individual adjustment of the marking contacts is not necessary, since the camming fingers are jig machined insuring precisely the same height for all contacts. The marking bus bar is adjustable and set with a jig designed for the purpose.

The tape latch (Figure 3) is unique in that it provides a definite closure under the pressure of a detent roller and spring. This eliminates the smallest amount of play between the top surface of the transmitter and the underside of the latch. The underside of the latch is grooved to accommodate either chad or chadless tapes.

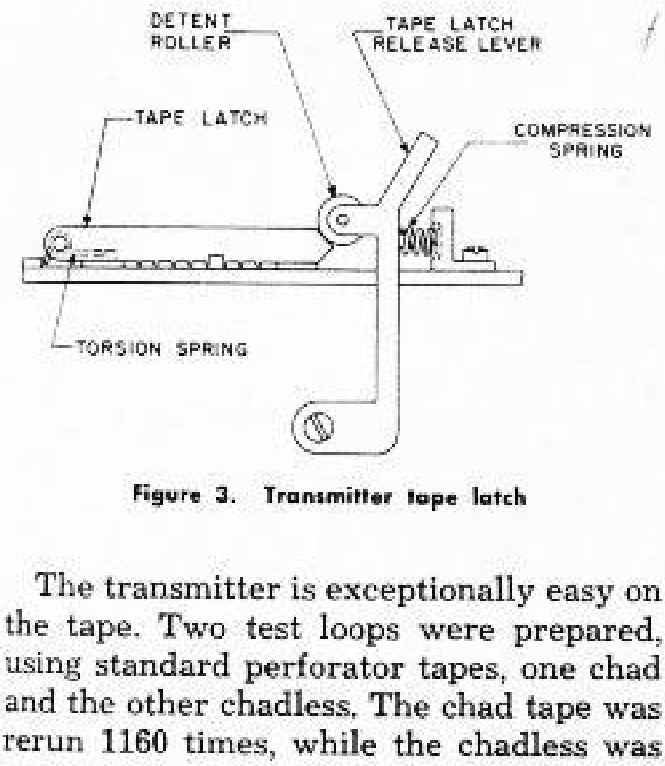


Figure 3. Transmitter tape latch

The transmitter is exceptionally easy on the tape. Two test loops were prepared, using standard perforator tapes, one chad and the other chadless. The chad tape was rerun 1160 times, while the chadless was rerun 1880 times before failure. In both cases failure was due to worn feed holes rather than mutilated code holes. The longer run of the chadless tape was due to the fact that it was produced on the Type 28 printer-perforator where the feed holes are pricked into the tape and fit more snugly around the transmitter feed-wheel pins.

Timing

Figure 4 shows an oscillogram of the output signal from the conventional Type 1-A transmitter running at 300 words per minute. From this figure it is obvious that only about 30 percent of the total cycle represents useful read time. Almost 60

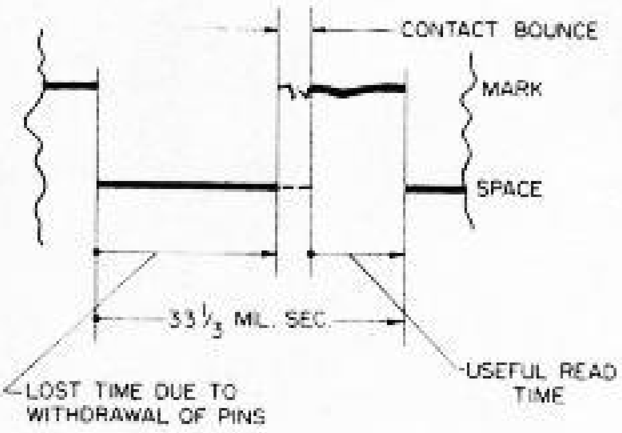


Figure 4. Oscillogram of a signal from a Type 1-A transmitter

percent of the time is lost by having to withdraw and return the reading pins during each cycle. The other 10 percent disappears in contact bounce. The total lost time is about 24 milliseconds.

Figure 5 shows an oscillogram of the output from the direct camming transmitter operating under identical conditions. Here at least 85 percent of the cycle is useful reading time. This resolves itself into about 4-1/2 milliseconds of unuseable time during each cycle.

To show that the ultimate speed of this type of transmitter is limited by the step-

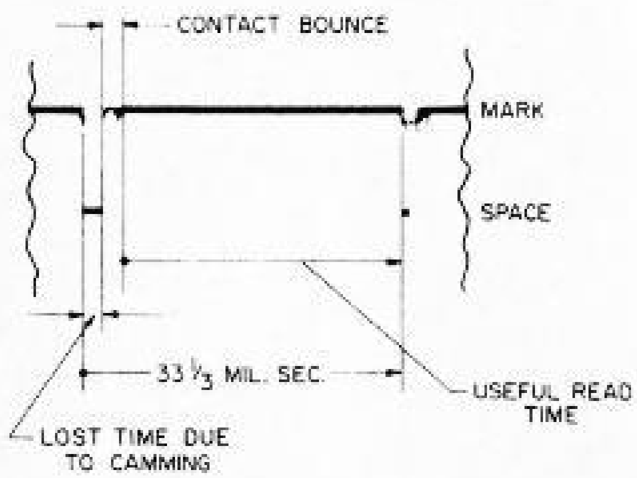


Figure 5. Oscillogram of a signal from direct camming transmitter

ping function and not by the reading function, another test was made in which tape was drawn over the camming fingers continuously without stepping, at a rate well over 1000 words per minute. The resulting oscilloscope patterns were as good as those shown in Figure 5.

It is quite possible to design a start-stop transmitting system so that the period of time unuseable for reading in any transmitter occurs during the rest and start periods. Under these conditions no storage of tape information is necessary and the transmitting system becomes quite simple. However, where this period of unuseable time is large as in the Type 1-A, the speed of operation must be slow to fit this time into the start and rest pulse periods.

Theoretically, by having a perfect match of time a maximum of 130 words per minute start-stop transmission speed could be realized with the Type 1-A transmitter. Actually a system has been built delivering 100 words per minute using this transmitter with no bit storage.

Along the same lines of reasoning the direct camming transmitter with a period of unuseable read time of only 4-1/2 milliseconds has a maximum theoretical limit of 725 words per minute. A 600-word transmission with no bit storage has been accomplished in the laboratories.

FRANK J. HAUPT entered Western Union service in 1910 in what was then the Metropolitan Traffic Department, where he worked in various positions including that of Multiplex Technician. In 1926 he joined the Engineering Department as Assistant to the Laboratory Supervisor, and a few years later transferred to the ticker engineering group as a laboratory assistant. In 1944, after being actively associated with the basic design of most of the units of equipment used in the Western Union public message switching network, and assuming vital responsibility in all cutovers of switching centers, he was promoted to the grade of Engineer. Mr. Haupt holds many patents on reperforator and other equipment necessary in public message and printer wire systems. He was actively associated with the Dingbat Project which won for its sponsor the highest award for the year 1955 that could be made by the Department of Defense. He is now engaged in the design of equipment to fit in with today's trend for the handling of information at higher speeds.