WESTERN UNION Technical Review

Submarine Cable Repeaters

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Central Office Engineering

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Signal Bias Meter

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Traffic Routing

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Standard Frequency Generator

VOL. 5 NO. 3
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CONTENTS

PAGE

Submerged Repeaters for Long Submarine Telegraph Cables . . . 81
C. H. Cramer

Central Office Engineering of Modern Telegraph Offices . . . 92

A Teleprinter Signal Bias Meter . . . 102
H. F. Wilder

Traffic Routing . . . 107
M. L. Mosley

A Standard Frequency Generator for Carrier Telegraph Offices . . . 115
T. F. Cofer and R. C. Taylor

Telecommunications Literature . . . 120

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Submerged Repeaters for Long Submarine Telegraph Cables

C. H. CRAMER

UNTIL RELATIVELY recent years, the applications of electronics to submarine cables have been limited to equipments installed at the cable terminals. During the past decade, however, there has grown an increasing awareness of the potentially great benefits to be derived from the use of intermediate submerged repeaters. The initial proposals[1] and practical applications[2, 3] of such devices have been in the field of wide-band circuits involving the use of new coaxial-type cables and repeater spacings of 50 miles or less. This paper describes an experimental installation of a submerged repeater in a long transoceanic cable, the first application of such a repeater to an existing low-speed d-c or noncarrier telegraph cable.

The repeater was installed during September 1950 by the cable ship *Cyrus Field* on one of The Western Union Telegraph Company's North Atlantic cables, 1PZ, extending from Bay Roberts, Newfoundland, to Penzance, England. Figure 1 shows the repeater on board ship with cable attached. This cable, 2148 nautical miles in length, has been operated in recent years with a signal-shaping vacuum tube amplifier at the receiving terminal, the cable station at Bay Roberts. Prior to the installation of the repeater, the westward simplex or one-way printer operating speed of the cable was 50 words per minute. With a single repeater inserted in the cable at a point 170 miles northeast of Bay Roberts, just beyond the Newfoundland Banks and in a depth of 270 fathoms, an operating speed of 167 words per minute was obtained.

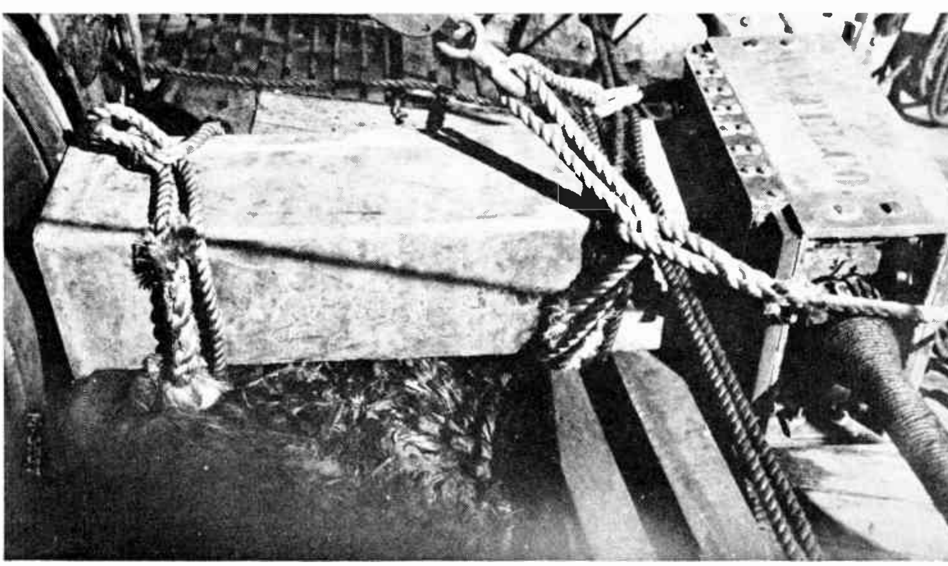

Figure 1. Repeater on board ship with cable attached

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Transmission Factors of Submarine Telegraph Cables

The principal factors which determine the satisfactory maximum operating speed of a submarine telegraph cable are: (1) the signal sending level, the over-all cable attenuation, and the level of extraneous disturbance or noise at the receiving terminal—in combination the signal-to-noise ratio; (2) the inherent heavy characteristic signal distortion and the degree to which it can be equalized at the terminals while minimizing the susceptiveness of the receiver to interference — conditions which are somewhat incompatible and call for judicious compromise; (3) on duplex-operated cables, the level of the residual duplex unbalance which adds to the interference and reduces the signal-to-noise ratio.

The signal-to-noise ratio, determined largely by the cable parameters and the specific electrical conditions surrounding the cable, can be controlled only in minor degree at the cable terminals. Characteristic distortion and duplex balance are also directly related to the cable parameters but a considerable degree of control or compensation can be applied at the cable terminals: for characteristic distortion, a receiving signal-shaping network provides a characteristic approximately the inverse of the cable characteristic; for duplex balance, an artificial line can be made to match the cable electrically to almost any desired degree of accuracy.

In the past 15 or 20 years, signal-shaping amplifiers and duplex-balance methods and networks have been developed to a point approaching a practical limit of efficiency.[1] These developments have been applied generally in the Western Union cable system. This program of terminal equipment improvements brought about higher quality signal transmission at increased speeds. A significant end result was the complete conversion of Western Union's North Atlantic system from the traditional cable code operation to 5-unit code printer operation, along with a net increase in message capacity of about 30 percent. Following completion of this program, it soon became evident that any further important improvement of transmission on the existing nonloaded cables could be obtained only through measures applied directly to the cables and departing radically from previous practices.

In the course of the developments just outlined, sending voltages had been increased to about double their original conservative values. On transatlantic nonloaded cables, the signaling frequency can be increased only 15 to 20 percent when the sending voltage is doubled. Brief consideration of this fact eliminates increased sending voltage as a means of obtaining substantial speed increases. In such a process, a condition hazardous to the cable insulation would soon be reached and serious difficulties with sending relay contacts would be encountered.

The continuously-loaded cables, developed and laid in the decade ending in 1930, are notable for the large reduction in attenuation gained from the use of permalloy and similar magnetic alloys. Furthermore, the loaded cables have exceptionally low interference levels by reason of long bicore terminal sections in which the second core serves to carry the receiving earth to a point beyond the shallow coastal waters. The message capacities realized with the loaded cables were about four times the capacity of a typical nonloaded cable at that time.

It was perhaps inevitable that consideration would be given to the application of long receiving earths and inductive loading to the existing nonloaded cables. Although re-examined periodically, the long sea earth has remained comparatively unattractive. Large expenditures would be required to lay two new bicore end sections for each cable, since distances up to 100 miles or more are involved. Aside from the matter of costs, even though very low interference levels were obtained, a corresponding increase of signaling speed would not be possible because of conditions which limit the maximum practical gain of terminal amplifiers. These conditions include local noise from other electrical systems as well as effects inherent in high-gain amplifiers.

Inductance loading could be applied to the nonloaded cables either by substituting sections of continuously-loaded cable for nonloaded cable or by inserting loading coils at regular intervals. An investigation of coil loading indicated that the design and the effective application of submarine loading coils would be technically feasible. It also appeared that a coil-loading system would be less costly than one utilizing continuous loading. However, considerations of cost and the out-of-service periods imposed on the cables during installation of coils would dictate a program of gradual installation incidental to routine cable repair operations. At the normal rate of cable repairs, such a program would provide a substantial transmission improvement only after many years. As prospects became brighter for the development of a practical submerged repeater for low-frequency cable circuits, it soon became apparent that transmission improvements of the same order or even better than those available with coil loading could be obtained at lower cost and in a considerably shorter time.

Principles Underlying the Submerged Repeater

The following discussion of the submerged repeater will be related specifically to 1PZ cable for the sake of directness, but the principles involved are of general application.

1PZ, one of the slowest-speed cables of the Western Union system, was laid in 1881. The original cable was of types 350/300* and 450/270. Currently, original cable in circuit is 428 nautical miles or about 17 percent. During repairs and renewals, Type 650/375 cable has been used extensively and is now the major type, about 39 percent of the total length. The average age of the cable is 25 years. The attenuation of the cable, without repeater, is given in Curve A of Figure 2. At a frequency of 6.25 cycles per second, corresponding to a speed of 50 words per minute, the attenuation is 71 decibels, while the attenuation at 20.83 cycles,

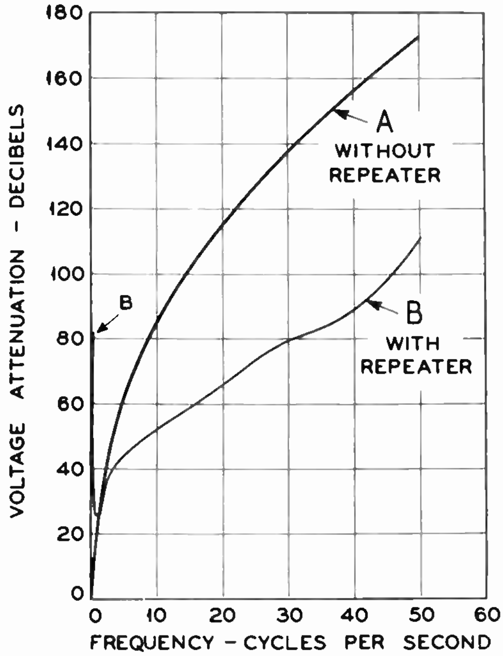

Figure 2. Attenuation of 1PZ cable

corresponding to a speed of 167 words per minute, is 117 decibels.

As used in this paper, signal frequency is defined as one-half the dot frequency. In 5-unit code printer operation on Western Union cables, signal impulses of unit length are so attenuated in transmission that they are essentially missing in the received signals.[4] The receiving networks are adjusted for optimum reception of signals two units in length, and the missing dots are interpolated synchronously. With respect to cable transmission character-

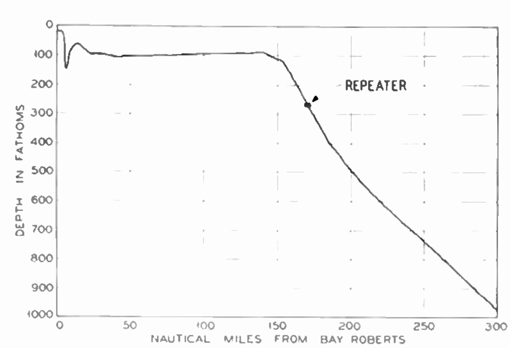

Figure 3. Profile of 1PZ cable

* (Weight of copper) / (weight of insulation) in pounds per nautical mile.

istics, the fundamental sinusoidal component of the signal frequency is used.

The profile of the ocean bed east from Newfoundland along the route of 1PZ is shown in Figure 3. The cable profile is of particular significance with respect to the disturbance level on the cable. Electrical disturbances originating in the atmosphere and induced on the surface of the ocean are attenuated in propagation downward through the seawater.[5] The attenuation increases with frequency as indicated by Figure 4, which gives the magnitude of attenuation per fathom for sinusoidal disturbances through the range of cable telegraph frequencies. Thus at a depth of 250 fathoms, 20-cycle disturbance has undergone attenuation of about 80 decibels. Knowing the cable profile and assuming uniform distribution of potential on the surface of the ocean, the relative amplitude of the disturbance induced in various sections of the cable conductor can be evaluated. Summation of the sectional disturbances, taking into account the attenuation and phase characteristics of the cable, gives a relative amplitude of total disturbance level at the cable terminal. For 1PZ, with Bay Roberts as the receiving terminal, the curve of Figure 5 shows the portion of 20-cycle disturbance originating in the section of cable beyond any point X miles from Bay Roberts. For example, if X is 150 miles, then of the 20-cycle disturbance level at Bay Roberts only 0.1 percent originates in the 2,000 miles of cable east of X. For distances greater than 150 miles, the residual disturbance decreases rapidly as indicated by the curve. An amplifier can be introduced in the cable 160 or more miles from Bay Roberts without appreciably increasing the terminal disturbance level.

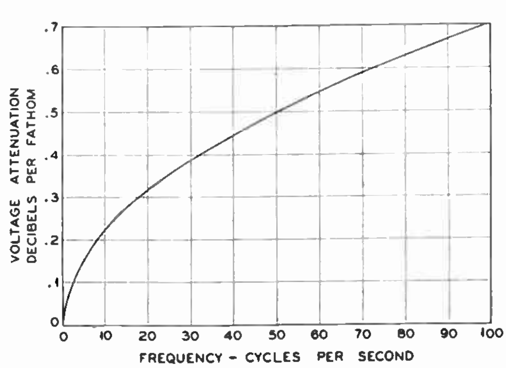

Figure 4. Attenuation of sinusoidal disturbance in seawater

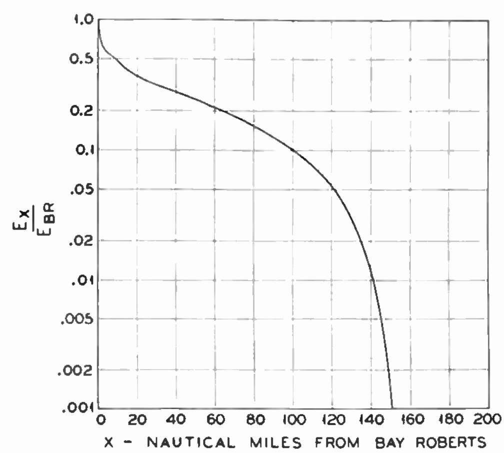

Figure 5. Ratio of 20-cycle disturbance, Ex, originating beyond any point in 1PZ X miles from Bay Roberts to total 20-cycle disturbance, E_{br}, at Bay Roberts

The Repeater

Electrically, the repeater, shown schematically in Figure 6, comprises a 3-stage push-pull resistance-capacitance coupled amplifier with input and output transformers. A simple tuned signal-shaping network precedes the input transformer. Type 5693 tubes are used in all stages, with two tubes in parallel and operated as triodes in each side of the output stage, providing theoretical undistorted output of 0.25 watt. The effect of the output transformer circuit is to reduce the net output of the repeater to somewhat less than 0.25 watt. The required output is determined principally by the low-frequency components of the signals.

The receiving or input-earth connection of the repeater is carried back along the cable for some distance through a bicore section and earthed on the armor wires. The repeater case and adjacent cable armor are utilized for the other earth

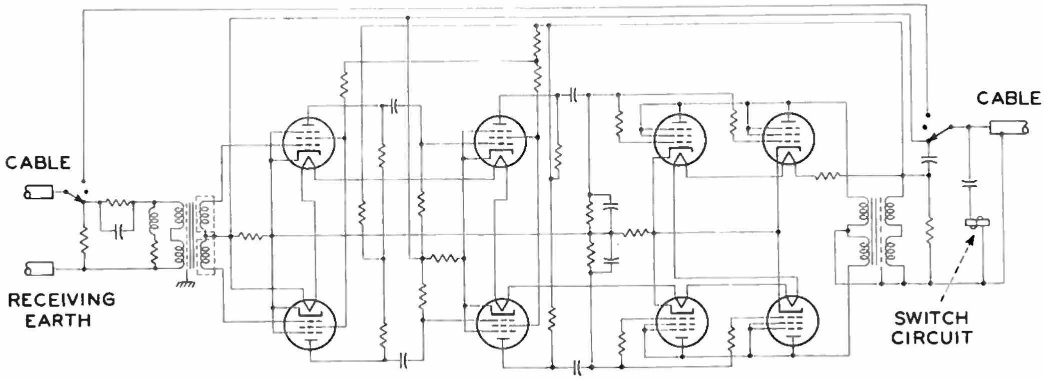

Figure 6. Schematic diagram of repeater

connection. This arrangement was provided to avoid feedback troubles which might develop with an earth connection common to the input and output circuits of the repeater.

The power requirements of the repeater, 0.32 ampere at 125 volts, are supplied from Bay Roberts over the single cable conductor which also serves as the signal transmission medium. The impedance of the power supply is relatively high, including resistance of 550 ohms at the terminal and 170 miles of cable having resistance of about 295 ohms. This condition tends toward repeater instability which is heightened by the narrow range available for discrimination between power supply and the low-frequency signal components. Measures taken at the repeater to provide stable performance include a high-capacitance by-pass, careful selection and matching of vacuum tubes, and utilization of negative feedback.

The frequency-response characteristic of the repeater, Figure 7, increases with frequency to a maximum at about 42 cycles per second where the gain is 67 decibels. With the repeater in circuit, the over-all frequency-attenuation characteristic of 1PZ is as shown in Curve B of Figure 2. The transmission benefit derived from the repeater is strikingly illustrated by the level charts of Figure 8. Curve A shows the circuit levels without repeater and with sending battery of 90 volts for sine-wave transmission of 6.25 cycles per second (operating speed, 50 words per minute). For Curve B, with repeater, the sending battery is 60 volts and the frequency is 20.83 cycles (operating speed, 167 words per minute). The disturbance level indicated on the chart refers to disturbance of natural origin and is the

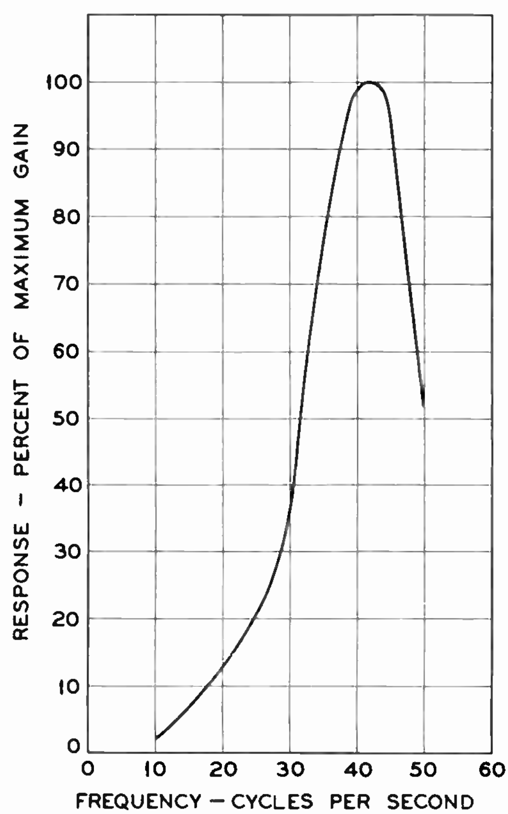

Figure 7. Frequency-response characteristic of repeater

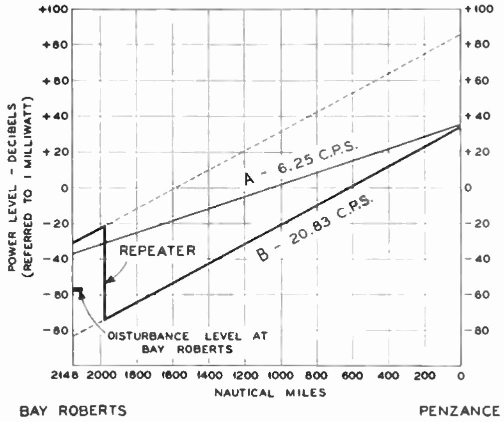

Figure 8. Signal power level chart for sine-wave transmission on 1PZ cable:

A. *Without repeater; 6.25 cps, corresponding to 50 words per minute; sending battery, 90 volts*

B. *With repeater; 20.83 cps, corresponding to 167 words per minute; sending battery, 60 volts*

same for the two conditions. No change of disturbance level is observed at Bay Roberts when the repeater is switched into the circuit. Crossfire resulting from a crossing with another cable some distance east of the input side of the repeater was effectively reduced by a low-pass filter in the sending circuit of the offending cable. It is of interest to note that without repeater, the received level of 20.83 cycle signals would be 27 decibels below the disturbance level. On the other hand, to obtain a satisfactory receiving level at 20.83 cycles without repeater, a sending level of plus 85 decibels (316 kw) would be required. It is important that the required output level at the repeater be low because of the limitations imposed by available vacuum tubes and by the power supply. To satisfy this requirement the repeater should be located as near to the receiving terminal as consistent with natural and crossfire disturbance conditions. Aside from considerations of signal power level at the repeater, the power supply voltage imposed on the cable at the terminal increases as the repeater is moved away from the terminal by reason of the greater voltage drop in the cable.

The repeater includes a rotary ratchet-stepped switch which has two principal functions: (1) to disconnect the repeater and join the cable through for operation without repeater or for cable testing purposes; (2) to "swap" vacuum tubes in the event of a tube failure. Three complete sets of tubes are provided and can be utilized in 18 different combinations. The switch is operated as required from Bay Roberts by trains of 60-cycle sine-wave alternating current. The operating winding of the switch, in series with a capacitor, is permanently connected from cable to ground at the repeater.

Mechanical Design of the Repeater

Since it was planned to install the repeater in a depth of between 200 and 300 fathoms, the major requirement to be met in the mechanical design was suitability for extended operation under hydrostatic pressures up to 750 pounds per square inch. Components for low-frequency communication equipments are

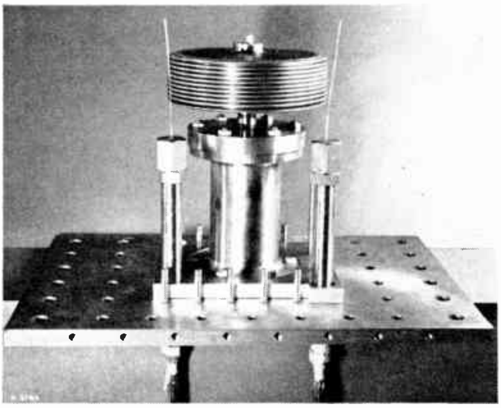

Figure 9. Pressure equalizer and cable entrance glands

inherently bulky. It thus appeared inadvisable to attempt to design a housing of the size required in which the interior would be at or near atmospheric pressure. Instead the repeater is filled with oil and a pressure equalizer automatically adjusts the internal pressure to the external pressure within a few pounds per square inch. The equalizer comprises a tandem arrangement of a piston-cylinder and a bellows, Figure 9, both of corrosion-resistant metals. The outer end of the cylinder is sealed to the cover plate of the housing while the inner end opens into the bellows. A hole in the cover plate admits seawater to the outer end of the cylinder and a piston transmits the external pressure to the oil which fills the remainder of the cylinder and the bellows. In turn the bellows transmits the pressure to the oil within the housing. The equalizer has sufficient capacity to take up any small voids resulting from incomplete filling of the housing and to compensate for the relatively large volumetric temperature coefficient of the oil. At sea bottom, particularly in areas and depths involving arctic currents, the temperature may be as low as 30 degrees Fahrenheit. To minimize the change of volume and thus the capacity of the equalizer, metal filler is utilized to reduce the amount of oil required.

Since the external-internal pressure differential is small, a gasket of synthetic rubber provides an adequate seal between cover and case.

The repeater components are mounted on a rectangular chassis, Figure 10, occupying a space approximately 10 inches by

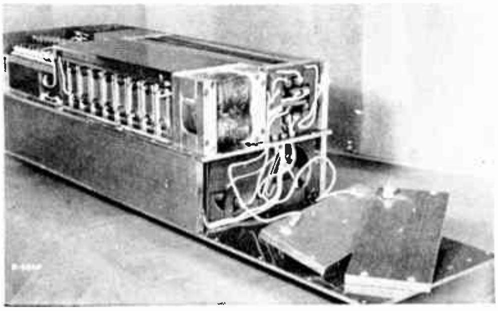

Figure 10. Repeater chassis with components in place

11 inches by 26 inches. Certain of the components are subjected directly to the full hydrostatic pressure. These are: (1) the capacitors which, with the exception of small by-pass capacitors, are all of the oil-filled paper-foil type; (2) the inductor and the transformers which are of the wound-core type, having windings impregnated with Acme compound; and (3) most of the resistors which are wire-wound and spiral metal-film types.

The vacuum tubes are in standard metal-shell bulbs which are not of sufficient strength to withstand the hydrostatic pressure encountered. The tubes, together with certain related resistors, are mounted in steel cylinders, six tubes to a cylinder. Figure 11 shows a tube

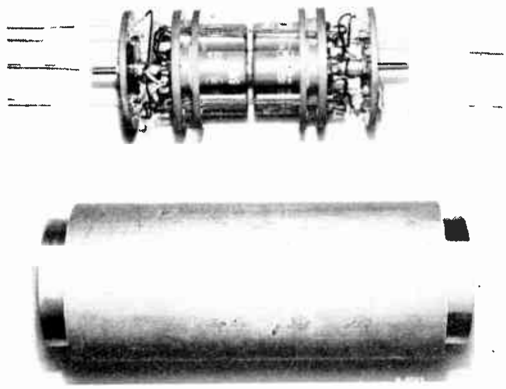

Figure 11. Vacuum tube unit

cylinder and a completed tube chassis, ready for insertion. In completing the assembly, steel plugs are pressed into the ends of the cylinder, and fins on the plugs are soldered to corresponding fins on the cylinder. Connections are brought out through high-pressure terminals in the end plugs. Four tube cylinders are provided, one each for the first and second stages, and two for the output stage.

The rotary switch, Figure 12, also is enclosed in a cylinder identical in design with the tube containers, except that it is somewhat longer. The switch operating mechanism is balanced so that it will function in any position.

The repeater chassis is fastened to the cover plate. The two cable leads and the receiving-earth lead are brought out through glands mounted in the cover plate as shown in Figure 9. The monel metal parts of a gland and the components of a high-pressure terminal used at the inner end of the gland are shown in Figure 13. In assembling the gland, a short piece of standard polyethylene cable core is used. A "pudding" of the same insulating material is formed near one end of the stub and this enlarged section is inserted in the outer portion of the gland which is then sealed by means of a packing nut. Within the gland the cable conductor is spliced to a smaller wire which extends through the high-pressure terminal at the inner end of the gland into the repeater chassis. A rigid insulating sleeve surrounds the bare conductor in the lower part of the gland. Before sealing off the high-pressure terminal, the voids within the gland are filled with Vistac.

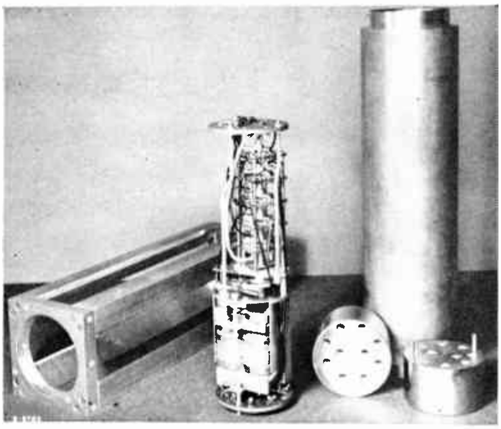

Figure 12. Repeater switch

As shown in Figure 14, a cable entrance chamber is mounted on the top of the cover plate. Holes (not shown in this photograph) are provided in the end channels for the entrance of fully armored cable stubs, one in each channel. A concentric circle of small holes permits the individual armor wires to be looped back through the channel and firmly secured to the cable. The cores of the stubs are spliced to the gland cores within the entrance chamber. Side plates and a top plate complete the enclosure of the chamber, allowing entrance of seawater but protecting the unarmored cores within from mechanical damage. A heavy lowering eye on the top plate provides a means of eliminating hazardous strains on the cable at the points of attachment to the repeater. For each of the two cable stubs, a chain extends out from the eye followed by a stranded steel rope which is spliced to the cable armor about 15 feet from the repeater in a manner to allow some slack in the cable between that point and the repeater.

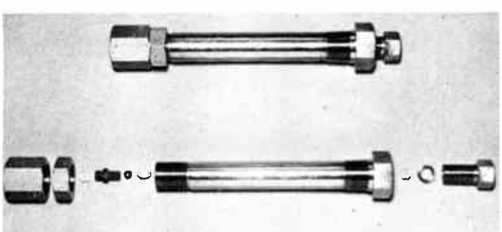

Figure 13. Cable entrance gland

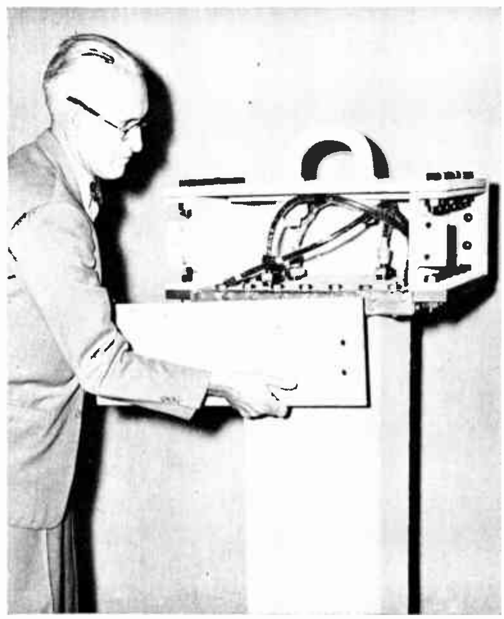

Figure 14. The author examines cable entrance chamber of repeater

The repeater case proper is 12 inches wide by 11 inches deep and the corresponding dimensions of the cable entrance chamber are somewhat larger. The over-all length is about 51 inches. The complete repeater weighs 1140 pounds.

Installation of the Repeater

At best, the operations involved in splicing a structure of the size and weight of the repeater in a submarine cable and placing it safely on the bed of the ocean depart considerably from the normal operations of cable ships. Unfavorable weather conditions introduce further complications. In one method, perhaps the least difficult, the ship would pick up the cable as in a normal repair operation, heaving to at the planned repeater location with both ends of the cable on board. After completion of the splices, the repeater would be lowered. This procedure is not desirable, however, because the resulting slack cable might loop on the bottom so as to cause feedback effects in the repeater. Such effects are avoided in the method actually used. The cable was picked up at a point more than a mile east of the repeater location and the end of the eastward section was buoyed. The ship then proceeded to the repeater location, picking up the intervening cable. At that point, the cable was cut and the required splices were made. Figure 1 shows the repeater ready for laying following completion of the splices. It was then lowered over the bow sheaves, Figure 15, the ship got under way and, paying out cable as in a normal repair operation, proceeded to the buoy where the final splice was made. In this method, once the repeater is free of the ship its weight is supported by the cable, except in the short sections on either side of the repeater where the load is transferred to the steel cable and chain arrangement described previously. It is desirable that the position of the final splice be sufficiently distant from the repeater to insure that the repeater is resting on the bottom and is not in suspension during the final splicing operation. That the measures described were fully effective is confirmed by the fact that after the repeater was first lowered to the bottom, it was success-

Figure 15. Repeater passing over bow sheaves

fully picked up and brought on board ship. The installation was carried out under rather unfavorable weather conditions and the final result is indeed a tribute to the staff and crew of the cable ship, where skill and efficiency of a high order are traditional.

The Terminal Equipment

The receiving terminal circuit at Bay Roberts is shown schematically in Figure 16. The arrangement is similar in general to a standard duplex cable terminal, except that the bridge arms are resistors instead of capacitors. Power for the repeater is supplied by rectifiers and fed into the apex of the bridge, while a standard signal-shaping amplifier is connected across the diagonal of the bridge and functions in the usual manner. The bridge is balanced by an artificial line which simulates the section of cable between the terminal and the repeater and the impedance of the repeater to ground so that the terminal amplifier is unaffected by noise components in the power circuit. Since the current required at the repeater is 0.32 ampere, the drop in the bridge arm and cable totals approximately 275 volts and an emf of about 400 volts is normally applied between apex and ground to produce 125 volts at the repeater. Automatic controls maintain the power current

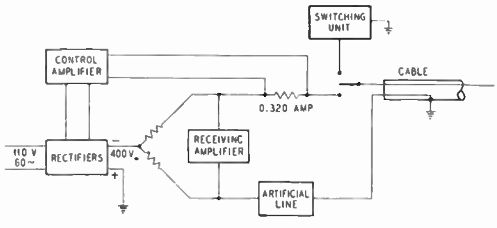

Figure 16. Receiving terminal and repeater power supply circuit

at a constant level despite power voltage fluctuations and in the presence of a wide range of earth potentials. When earth potentials exceed the range of the controls, or if for any other reason the power current approaches a predetermined safe limit, a circuit breaker functions to protect the repeater. The rack-mounted installation of rectifiers and control equipment is shown in Figure 17.

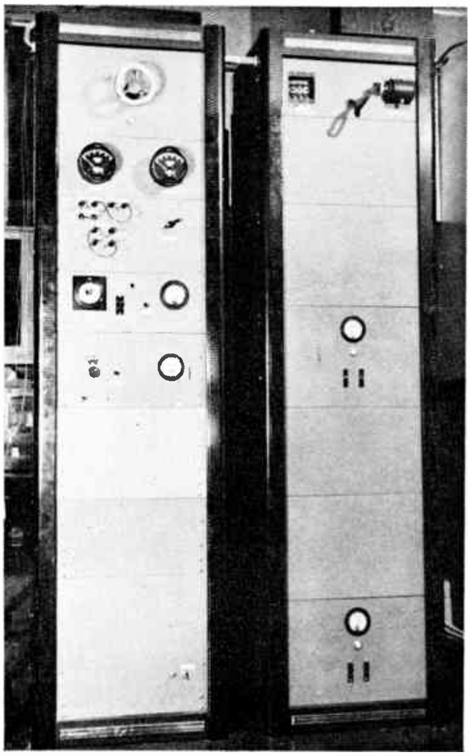

Figure 17. Power supply and control equipment

Conclusion

Thus far only one repeater has been constructed. It was installed without having been tested previously under hydrostatic pressure because pressure-testing equipment was not immediately available and because early operating trials were desired. During the service tests, the predicted speed of 1,000 letters (167 words) per minute was obtained without difficulty and excellent performance has been obtained in traffic operation as part of a London-New York varioplex circuit. The soundness of the principles upon which the development was based has been fully confirmed, justifying plans for further development and application of the repeater. As might be expected, certain improvements of both the repeater and the terminal control equipment have been suggested by the experience with this initial installation. The most important, perhaps, is that future repeaters should be suitable for installation in greater depths. Present indications are that, on the input side of the repeater, it is desirable to avoid near-by crossings with other cables because of crossfire conditions. On congested cable routes most of the crossings occur in the two coastal areas. In general, repeaters should be located beyond the crossings at the receiving end of the cable. The crossings near the distant sending end are unimportant from the standpoint of crossfire, since the signal level in that section of the cable is very high. On many cables, as compared with the installation on 1PZ, such a requirement can be fulfilled only by installation in deeper water and at greater distances from the receiving terminal. The cables suited to application of repeaters are of various lengths and types so that there is a relatively wide divergence in transmission characteristics among individual cables. For this reason, repeater design cannot be standardized in all respects. For example, the optimum signaling speed of an individual cable depends upon the cable characteristics and the terminal disturbance level, and the design of the repeater network must be carefully predetermined for the chosen speed since there is no opportunity for readjustments after installation.

There is no experience upon which to base predictions of repeater life. It can be confidently expected that longer life will be realized as designs are refined and improved components become available. In any case, aside from the cost of manufacturing a repeater, the cost of an installation is little more than the cost of a routine cable repair operation. It appears, therefore, that while an ultimate life of 5 to 10 years or more is desirable and can probably be achieved, the increase in signaling speed is large enough to support renewals at intervals of two years or less.

A project now actively under way provides for installation as rapidly as practicable of nine additional repeaters in Western Union's North Atlantic cable system. Upon completion, four cables between Newfoundland and the British Isles and one New York-Newfoundland cable will be equipped for reversible high-speed operation.

Valuable contributions to this development were made by a number of people throughout the research, cable and engineering organizations of Western Union. The major technical role should be credited to Philip H. Wells, one of a small group of which the author is leader and which carried on the development from initiation of laboratory transmission studies through design, construction and service trials.

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C. H. CRAMER'S biography and picture appeared in the January 1948 issue of Technical Review

Central Office Engineering of Modern Telegraph Offices

The Committee on Technical Publication is indebted to the Central Office Engineering group (now operating under the Director of Installation, Plant and Engineering Department) and particularly to Messrs. B. Beardsley and E. Harvey for furnishing the detailed information upon which this article, prepared by Miss Nell Organ, is based.

THE DEVELOPMENT of Western Union's nation-wide system of high-speed switching centers and the design of circuits and equipment have been fully described in these volumes.[1] The design and development of some special items of apparatus have been covered,[2, 3, 4, 5] and the lesser-known phase of operational planning was delineated in still another article.[6] These are the more engrossing and thus more publicized aspects of telegraph switching, but there is another engineering function which is fully as requisite to the over-all success of the system, and indispensable to the well-being and hence to the efficiency of the employees.

This function is the "Central Office" engineering, which includes the design and engineering of such essential adjuncts to switching operations as the power supplies, message conveyor belts and pneumatic tubes, ventilating and air-conditioning systems, cabling and wiring and so forth, as well as the physical layout of the office itself and all its appurtenances. Observing a modern switching center such as the several pictured herein, one is prone to admire it as a whole, to be impressed by the array of equipment, but to think not at all of the effort that went into its physical planning. There are many ramifications to this seemingly simple function, because a modern large telegraph office—either manual or reperforator—is an intricate installation comprising a multiplicity of complicated telegraph apparatus with a truly vast amount of wiring and cabling; also because of the various considerations of lighting, acoustics, decorating, flooring, ventilating and air-conditioning, which directly affect the employee. All of these must be kept in mind while aiming at the ultimate goal of an office that will provide maximum efficiency of both equipment and personnel, and still be comfortable and attractive within the bounds of economy.

Office Layout Planning

Planning must start long before the installation is scheduled, often before the design of circuits and equipment has been finally determined, and it proceeds along the lines developed in the theoretical studies resulting from collaboration of Plans and Methods and Operations engineers. Planning for manual and reperforator offices is essentially the same, therefore a brief description of the routine steps common to both will be given, with a later more detailed account of the establishment of the newest reperforator office at Portland, Oregon.

Once a location for the new operating room has been selected, careful study must be made of the building structure to determine permissible floor loading since the new type of telegraph equipment presents greater weight concentration than the old, and also to ascertain the feasibility of cutting holes through floors for cable shafts, ventilating ducts, and so forth. Then, if the new operating room is in the same building as the old, a complete survey of available space must be made and reassignments of existing equipment determined, so that cutover from the old to the completely equipped new operating quarters may be accomplished with ease and expedition.

Physical Appurtenances

The Telegraph Company, in common with industry in general, realizes that pleasant and comfortable surroundings greatly increase employee content and productivity, hence care is observed to attain these ends in modern telegraph offices. The study of color has led to the recently standardized scheme of painting operating room ceilings flat white, walls and columns light yellow or suntone, with window frames painted out, and equipment light green, all of which creates maximum light reflection consistent with comfort. Studies of acoustic treatment for ceilings have shown that it mitigates the effect of the noise caused by mechanical equipment to such an extent as to reduce operator fatigue appreciably, hence it is Company policy to install acoustic treatment in new operating areas where, because of the concentration of mechanical equipment, the noise level otherwise would be excessive. This program to reduce the noise level in operating rooms is of course accompanied by efforts to lessen the noise at its source, namely, the equipment itself.

Lighting studies, continuing over the years, have resulted in a high Telegraph Company standard of intensity at the working plane for both incandescent and fluorescent lighting. Careful thought is given to the choice of fixtures and the intensity of the light source, and lighting layout is considered in relation to bays, columns, partitions or other architectural features. A prime consideration is of course avoidance of conditions which might create eye strain. Examples of modern lighting installations are shown in Figures 1 and 2, as well as in later illustrations.

General illumination is improved also by light-colored flooring chosen because of its non-light-absorbing qualities. Study and experiment have disclosed that the most practical flooring, from cost and maintenance viewpoint, is one composed of asphalt-base mastic tile blocks, laid in alternate colors, which has good light-reflecting qualities and can be replaced easily in blocks. In reperforator switching aisles where operators walk back and forth constantly, a resilient cork flooring as shown in Figure 2 has been found most advantageous from the standpoint of com-

Figure 1. Cincinnati reperforator switching center with fluorescent lighting suspended below ceiling

fort. Figure 3 pictures a good example of mastic tile flooring.

Air-conditioning has become almost mandatory for the latest switching offices, to filter the fresh and recirculated air, and to remove dust and lint particles in order to improve dependability of relay-operated circuits. Air-conditioning also reduces the temperatures which are engendered by a concentration of electronic and electromechanical equipment, and permits of humidity control which has eliminated practically all trouble formerly encountered in operations with perforated tape. Operating areas other than reperforator are provided with ventilating equipment which changes the air every two or three minutes in accordance with modern practices, and T. & R. rooms with large carrier installations are provided with a special exhaust system for drawing off excess heated air. Engineering work in connection with the design and installation of ventilating and air-conditioning plant includes heat load calculations, selection of proper type of mechanical equipment, and planning for the layout of the equipment and duct work. Special problems arise frequently, demanding special engineering treatment. Ceiling ventilating outlets may be seen in Figures 2 and 3, while Figure 4 shows

Figure 2. Flush fluorescent ceiling lights, cork flooring and ceiling ventilating outlets—Philadelphia switching aisle

Figure 3. Mastic tile flooring, flush fluorescent ceiling lights and ceiling ventilating outlets—Philadelphia

ventilating, lighting and wiring ducts before installation of the dropped ceiling.

Coincident with planning and layout of these facilities, it is necessary to (1) arrange for fire protection apparatus in conformance with national and local codes, as well as for light beam smoke detecting systems[7] where the rotary switching equipment is located in a separate unattended room; (2) specify method of mounting, wiring and installation of clocks in such locations that every operator can easily check the time from her position; (3) arrange for the location of electrically controlled time stamps and associated time stamp control cabinet, and for proper wiring between them, either direct or through the power zone cabinets; and (4) make arrangements for ample rest room facilities.

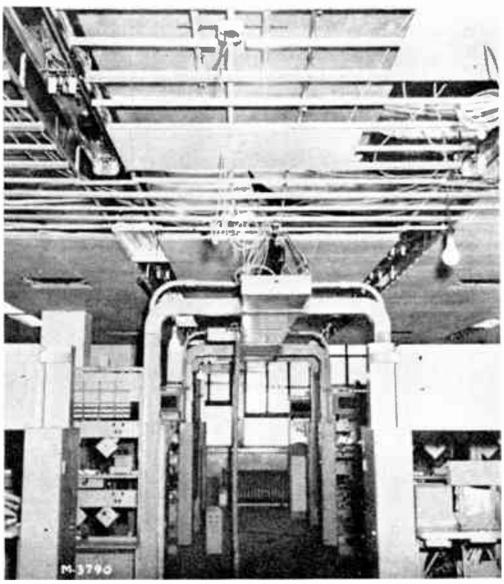

Figure 4. Installation of ventilating duct, dropped ceiling, acoustic treatment and lighting fixtures—Philadelphia

Operating Facilities

A certain amount of engineering for the installation or rearrangement of pneumatic tubes is necessary for every central telegraph office, but in reperforator offices this consists primarily of arranging for the discontinuance of branch office tubes, and augmenting the house tube system connecting the distributing center with various building offices. Pending installation of switching systems in some large terminal offices, branch office pneumatic tubes continue to be largely used, and in New York

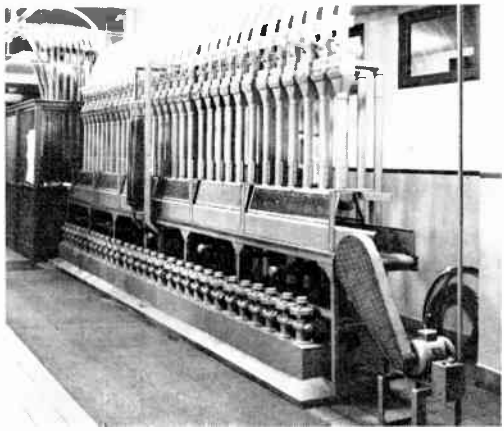
Figure 5. Pneumatic tube receiving terminal—New York

there are 37 such offices connected by tubes to the main office with approximately 122,000 pair feet of underground tubes. Figure 5 shows a tube receiving terminal in the New York office.

Belt conveyor systems have always been essential items of telegraph office equipment, serving as a means of speeding the incoming messages automatically from operators to a central distributing point and then to the outgoing message wire. In the new switching offices belts are

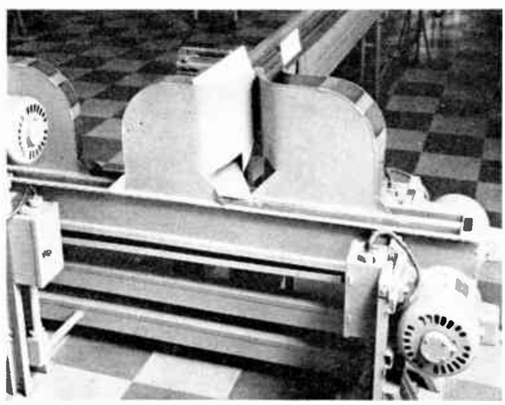
Figure 6. Typical arrangement of "V"-belt conveyor, gravity transfer and motor drive

naturally confined to the manual operating sections. Figure 6 shows a typical arrangement of "V"-belt conveyor, gravity transfer, and motor drive.

One most important responsibility of the central office engineers is the provision of telegraph power that will be as constant and dependable as possible, at all points of a universal telegraph system serving all parts of the country 24 hours a day. Judicious consideration goes into engineering the generating and conversion equipment and planning power distribution to the operating equipment. In many offices, storage batteries are installed with automatic throw-over devices so that in a momentary stoppage of city supply the battery takes over the load. Emergency generators also are often provided to carry the load in case of a prolonged power stoppage. Figure 7 shows the emergency generator plant especially engineered for the Cincinnati office.

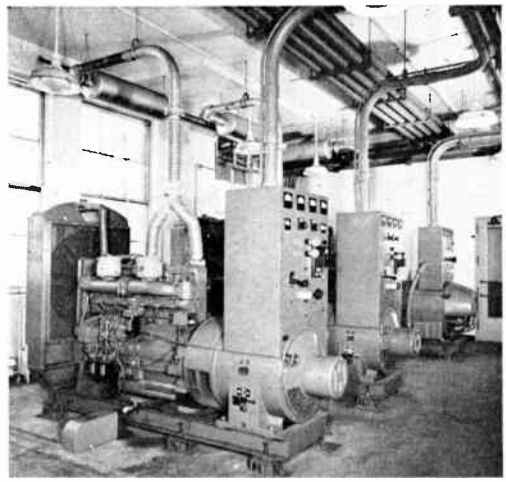

Figure 7. Emergency engine generator plant—Cincinnati

Special cabling and wiring racks and ducts have been and continue to be designed to fit the diverse needs of each new telegraph office. Incoming lead cables are carried overhead on specially designed heavy racks to the distributing frame. Between the frame and the switchboard, and from the frame to the various equipment racks and tables, wires and cables are carried on lighter racks or ducts of special design. Final plans are drawn up only after consideration of the relation of racks and ducts to telegraph equipment, and of possible methods of hanging from ceiling or equipment racks. Figure 8 which pictures the special cable duct system at Atlanta, and Figure 9 showing that at Philadelphia, indicate clearly that

Figure 8. Special cable duct system—Atlanta reperforator switching aisle

with competent engineering it is possible to achieve a compact design giving the optimum in efficiency, and still retain an agreeable effect of spaciousness and symmetry.

Figure 9. Overhead cable duct system—Philadelphia

Detailed instructions are prepared to cover this interconnecting wiring and cabling. and also the assignment of each wire terminal. Standards have been developed wherever possible to reduce the multitudinous amount of detail work necessary in connection with the latter item. Figure 10 illustrates impressively the mass of cabling and wire connections involved at a distributing frame.

In plotting a layout for Testing and Regulating rooms, through which wire facilities are interconnected and switched, the distributing frame on which incoming underground cables and office cables are terminated is located if possible along the interior wall of the room, with the switchboard parallel to and directly in front of the frame. The switchboard, in addition to its switching functions, affords a test point from which access can be had to all of the wire and repeatering equipment, both physical and carrier. Repeater tables and racks generally are located perpendicular to the line of switchboard to facilitate operation and supervision.

The layout of equipment in the manual section of a reperforator office, just as in large terminal offices, must be engineered in such a manner as to provide quick and economical pickup and delivery of messages. The distributing center generally is located near the center of the room, with operating tables placed at right angles to the building wall to give the best possible light and to obviate the necessity for operators to face windows any more than necessary.

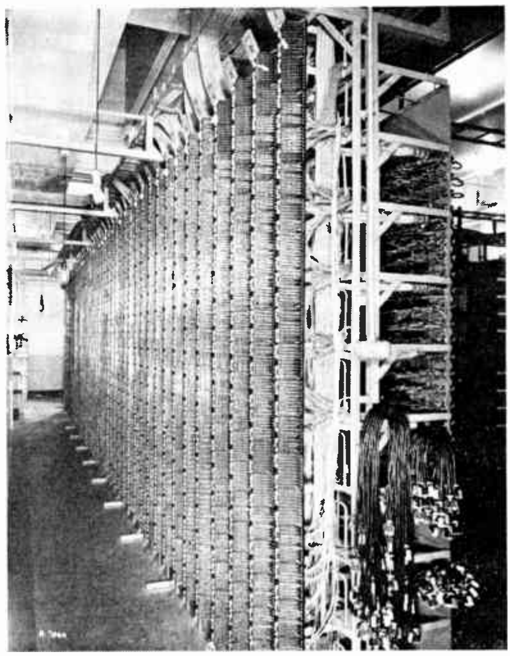

Figure 10. Typical distributing frame, vertical side

Portland Reperforator Office

A chronological description of central office engineering preparatory to the cutover of the latest reperforator switching center, at Portland, Oregon, may make more clear the scope of the work briefly described above. When it was definitely decided to make Portland the switching center for the northwest area comprising the states of Washington, Oregon, Montana and Idaho, it was necessary to prepare preliminary estimates of the space required during the installation of new equipment and for personnel training, as well as for ultimate requirements, as a basis for the negotiation of extra space.

Originally Western Union occupied the entire sixth and fifth floors of a 6-story building, a portion of the second, and parts of the ground floor and basement. The most logical course was to acquire additional space in the same building and negotiations for the fourth floor, the only one then available, were started and space assignments and equipment layouts devised to show tentative utilization of space. In this installation, as in many others, difficulties arose and it appeared for a time that it would be necessary to move some departments to another building. Further reassignments and negotiations, however, secured the third floor also for the Telegraph Company and made more expensive moves unnecessary. "Moves and Space Assignment" plans were made accordingly.

Careful planning was necessary in order to avoid expensive rerunning of incoming cables and establishing of a new distributing frame and switchboard, with the necessary interconnecting cables, and of course due consideration was given to permissible floor loading where added repeater, carrier, and air-conditioning equipment was to be installed. Architects' plans of the building construction were perused, and proper spacing of tables, racks and other facilities was calculated to insure that there would be no overloading at any point. Where holes through the floors were unavoidable, reinforcing means were developed and specified so that the load-carrying capacity of the floors remains essentially as before.

When it was definitely agreed that the Company would occupy the entire four top floors and portions of the ground floor and basement, final layouts were determined, and miniature plans showing original, interim and ultimate space assignments were worked out for the benefit of all departments, and included in specifications describing the sequence of moves necessary to bring about the desired ultimate result. As soon as the over-all requirements for circuits and the general scope of the work were determined, assemblies and detailed items were listed for all reperforator switching requirements for the main as well as tributary and branch offices, in order that manufacturing and assembly work could be carried on concurrently with the engineering of the office itself.

Figure 11. Fifth floor switching aisle at Portland, showing resilient cork flooring and fluorescent lighting

Next steps in the preparation of the new quarters were the determination of and arrangement for necessary building structural readjustments; devising partition changes that could be accomplished as economically as possible in conformance with building codes; and specifying the most suitable flooring, lighting, acoustic ceiling and painting. Flooring in the new operating room was the aforementioned asphalt-base mastic tile blocks, laid in alternate light and dark shades of tan and green. Resilient cork flooring was chosen for the switching aisles on the fifth floor for ease of walking. (See Figure 11.)

Fluorescent lighting, which previous studies had shown provides the best all-around illumination for such areas, was specified in practically the entire fourth and fifth floor operating rooms. These areas were also provided with acoustic ceiling of a fire-resisting type. The air-conditioning plant comprising the necessary compressors, fans and so forth, was installed on the fifth floor to cool and ventilate the operating rooms on both floors. Water supply and waste disposal systems were checked before making arrangements for drinking water on each floor and for rest room facilities.

With the reperforator switching system, branch office pneumatic tubes were no longer used at Portland, but it was necessary to redesign and augment the house tube system due to additional functions in the main office, and to revamp the house tube center on the fifth floor. A belt conveyor installation comprised of a number of standard V-belts serves the manual operating tables on the fifth floor, and a two-way "drag" conveyor carries telegrams between the new telephone room and the distributing center.

It was necessary to design practically a complete new power plant and wiring distribution system, due to the greater size and capacity of the reperforator office as compared to the manual office. Entrance facilities were provided in a special room in the basement to accommodate both alternating- and direct-current services. In this particular case, a previous investigation had disclosed that the basements in this area are in danger of being flooded under extreme weather conditions. Entrance facilities were therefore placed at a greater than usual height from the floor, and new emergency generator units, together with a new main ac-dc telegraph power switchboard, were located on the ground floor.

Complete new wiring was necessary from the power entrance room to the power switchboard, and from the latter to the a-c and d-c power cabinets on the fourth and sixth floors. Wiring from these cabinets was carried to newly installed zone cabinets on the fourth, fifth and sixth floors, thence to the various items of telegraph equipment. In addition to the regular power leads from the first floor power board to the upper floors, duplicate fall-back leads were carried up via a second route, a practice which is being followed in all recently installed offices.

Some idea of the engineering involved in telegraph cabling was given by Figure 10, but a clearer idea will be conveyed by the statement that at Portland, extending from the verticals of the reperforator distributing frame to the various items of telegraph equipment, are a total of 318 cables comprising 24,300 individual wires. In all, more than 1,000,000 soldered wire connections were necessary in the Port-

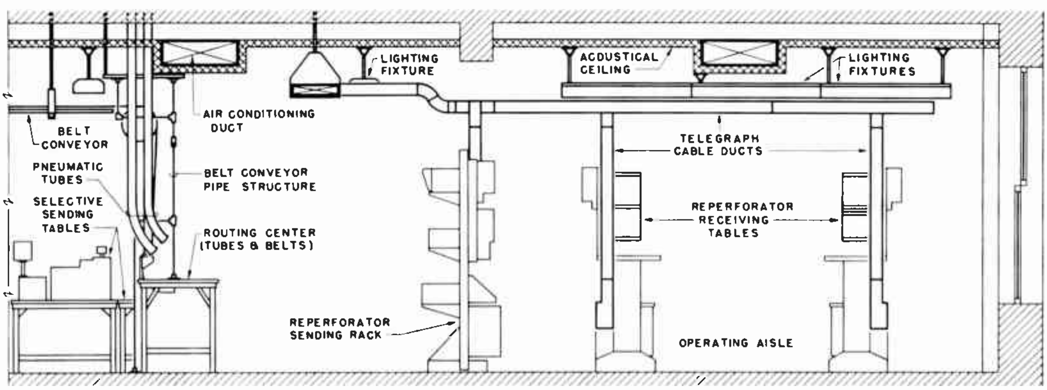

Figure 12. Partial fifth floor elevation—Portland

land center. There was in addition a large amount of interconnecting cable and wiring between the various units of equipment. Data for all this cabling could not be compiled until after the equipment layout and the cable runs were determined and design of the duct work decided. Termination of the multiplicity of wires here involved was facilitated by the use of standards which had previously been set up by the central office engineering group to cover terminations of all interconnecting cables and cross-connections at the reperforator distributing frame, and which include forms for compiling cross-connection records.

addition to providing for cable runs, it was necessary to plan duct work along the ceiling for fresh air and exhaust inlets for the air-conditioning installation, and for overhead power ducts and conduit. Also, supporting means had to be designed for suspending the ducts and racks from the ceiling, all the while keeping in mind the location of lighting fixtures and the acoustic ceiling. Many intricate composite plans were prepared before arriving at the best over-all, workable and yet not unsightly arrangement for all these facilities. This arrangement is shown in Figure 12, which depicts a partial view of the fifth

Figure 13. Sending racks—Portland switching center

The engineering of cable ducts and racks at Portland consisted primarily of planning and specifying the proper units for handling the cable runs for the new operating quarters, although it was necessary in addition to design new units to meet local conditions. Furthermore, the problems involved in coordinating the ceiling work were manifold, since in

floor at Portland that is generally typical of operating quarters, and which also indicates the impressive array of telegraph switching and associated equipment involved.

Meticulous study was necessary to arrive at the best possible arrangement of the racks, tables, reperforator switching equipment, distributing frame and other facilities, always remembering the desirability of holding down installation costs, but never at the expense of efficiency in operation and maintenance. The switching layout at Portland differs from that of some earlier reperforator offices in that the switching aisle which was shown in Figure 11 is placed adjacent to the manual section on the fifth floor, while the sending racks pictured in Figure 13, and the switch racks, are on the fourth floor. In other offices the switching aisles were located adjacent to the sending racks, with switch racks in a separate room, but it was decided in this instance that placing the switching aisle in the vicinity of manual positions would facilitate interchange of personnel and simplify supervision.

The reperforator distributing frame, on which are located the load distributors and transmitter finders for the multichannel circuits, panel patching board, and terminal facilities for cabling from all the various units of equipment, was located on the fourth floor as close as possible to the sending racks, to which the greater portion of the cabling is carried. The inside maintenance force is quartered on this floor also, to be close to the bulk of the reperforator apparatus.

The foregoing has outlined the major phases of the engineering work involved in the installation of the Portland office. As it was installed in a former manual office building, engineering work on some routine items already installed was unnecessary; additional items, however, included equipping and installing the maintenance shop, and installation of a trouble signal system, and of a loudspeaker system.[8]

Conclusion

Coordination is of course the basis of any successful operation, telegraph or otherwise, but it is the keystone of central office more than any other phase of telegraph engineering. Coordination, and a working knowledge of over-all telegraph operations, reperforator or manual, are prime requisites to the task. Central office engineers cooperate with planning, research and development, and design and assembly engineers and, through the planning section, with the operations engineers; lastly, they supervise the installation itself.

It is such interdepartmental cooperation that has achieved the successful development of new switching systems, and the successful integration of each new installation into the Telegraph Company's nation-wide network.

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A Teleprinter Signal Bias Meter

H. F. WILDER

IN TIME-DIVISION telegraphy intelligence is transmitted from one station to another by a prearranged code relating the symbol to be transmitted to a combination of unit time intervals. At the station of origin these combinations are set up by the contacts of the operator's keyboard, and upon reception at the distant terminal reappear in the magnet of the receiving teleprinter. But in a modern complex telegraph system, these simple states exist only at the sending and receiving points, and in transmission over the various media now available the fundamental form of the signal impulse will very likely be translated into one or more other forms of electric energy as the useful frequency spectrum of the interconnecting facility is subdivided to obtain the maximum number of individual channels of communication. This maximum usefulness can be achieved by frequency subdivision where the original signal disappears in the modulation of a carrier frequency that in turn is channelized by frequency selective networks, or the facility may be subdivided on a time division or multiplex basis, or a combination of both processes. On the other hand, the frequency spectrum of the line between the stations may be so narrow that only a single teleprinter channel can be accommodated, and if this line is long electrically, the make-break signals will be converted to the two-current or polar form at the relaying stations for best operation.

Irrespective of the manner of transmission, the unit time intervals will, after frequency selection and demodulation or time selection, be distributed to the receiving teleprinter in the form of single current or make-break impulses. These unit intervals have two dimensions—the magnitude of the operating current and its time of duration, and while the teleprinter exhibits considerable tolerance to variations in these dimensions, either the wide-band telegraph system or the relatively simple d-c telegraph line presents opportunities for changes to occur, either in the modulation and demodulation processes in the more complex systems, or simply because of lack of symmetry of response of relaying devices in the case of the narrow-band line.

Since all receivers have the same impedance, the magnitude of the operating force can be pretty well regulated by adjusting the current in the teleprinter lines to a uniform level, and current regulation is readily effected with the line milliammeter and rheostat. This article describes a somewhat more elaborate meter by means of which the second dimension of the signal unit interval, its time of duration, can be as simply and easily measured as the first, and without the necessity of special test signals or the interruption of the normal flow of traffic. With the aid of this meter, the operating technician can also reduce any consistent distortion in time of the unit intervals, familiarly known as signal bias, to zero or tolerable limits.

The greatest number of the basic or unit signaling channels in use at the present time are designed to have a pass-band sufficiently wide to permit operation of a single teleprinter circuit. In teleprinter or semi-synchronous signaling, the intelligence of a single character is contained within the various combinations of the 5-unit Baudot code with each group preceded by a start impulse or open line interval to initiate operation of the receiving device, and followed by a closed line interval to bring all apparatus to a stop in anticipation of the next character. Any character, therefore, consists of a total of seven unit intervals, and there are two variations of this code of suffi-

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cient importance to be met by the teleprinter signal bias meter. In the uniform 7-unit code, all unit intervals are of the same time of duration when transmission is continuous at a maximum rate of 396 characters per minute; for the nonuniform 7.42-unit code, the stop interval is made 42 percent longer than the preceding six impulses and the maximum rate of transmission is reduced accordingly to 368 characters per minute. A little calculation will show that irrespective of the code of the signals, a single spacing or open line unit interval will have a normal time of duration of 22 milliseconds, and so to have general use the bias meter has been designed to measure the time length of spacing impulses alone. Any departure from the norm is indicated as marking or spacing bias, depending on whether the unit spacing intervals are consistently shorter or longer, respectively, than 22 milliseconds.

A circuit frequently employed for the measurement of time intervals is a series combination of a resistor and a capacitor where elapsed time after the application of a battery can be determined by a measurement of the potential developed across the capacitor. This device is used in the teleprinter signal bias meter with an added refinement to increase the precision of measurement. If one is practical about the magnitude of the signal biases he may expect to encounter and reduce, the range of the bias meter may be limited to the measurement of signal bias not in excess of 25 percent spacing or marking, and the charging of the timing capacitor need not begin until the signal unit interval has persisted for three-quarters of its normal time of duration (16.5 milli-

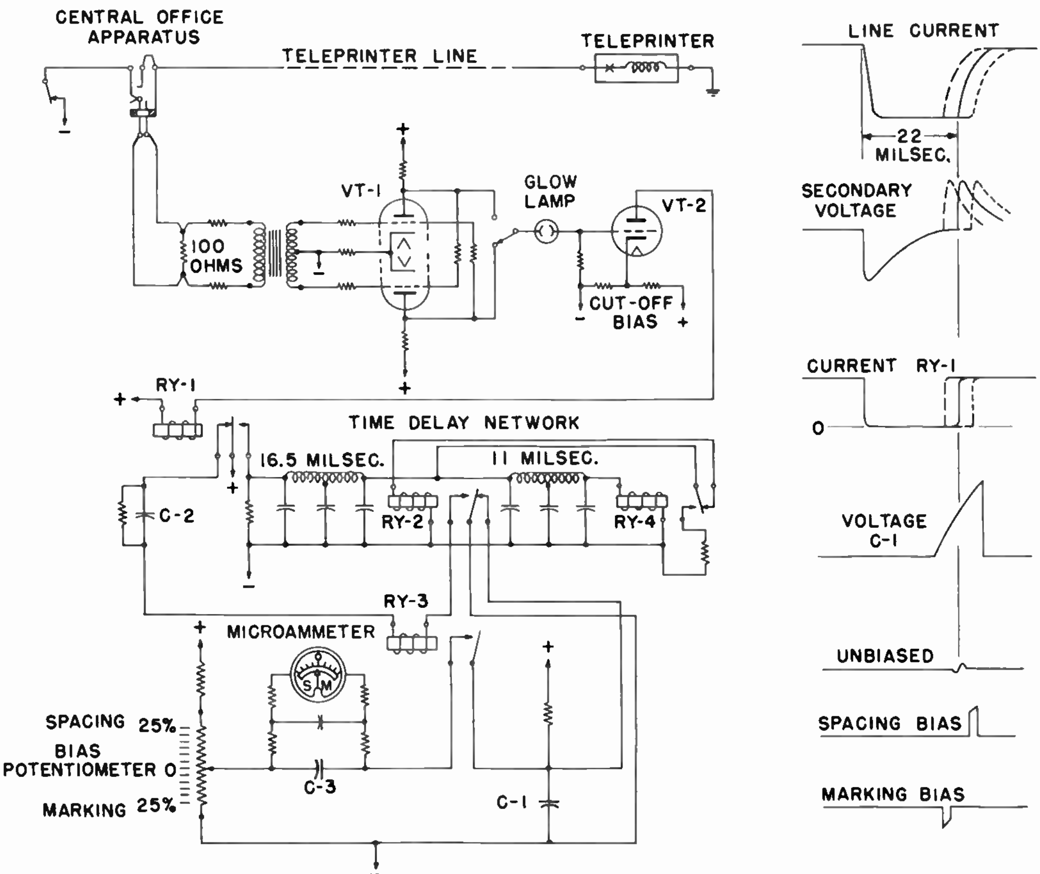


Figure 1. Theory of operation of teleprinter signal bias meter

seconds). If this restriction is accepted, and it is an eminently practical one, the rate of buildup of voltage across the capacitor at the end of a normal length spacing impulse is nearly three times more rapid than if charging had been initiated at the beginning of the signal impulse. The resulting accuracy of observation is about 2 percent and sufficient for proper circuit maintenance.

In order that the response of the bias meter shall be unaffected by the waveform or magnitude of the teleprinter line current, and therefore independent of the amount of cable or the number of teleprinters in the line, the actual time measuring circuit components are operated by an electronic relay. The latter is a trigger or balanced flip-flop vacuum tube circuit characterized by possession of only two stable states; one tube or the other can alone be conductive. This electronic relay is coupled by a transformer to a 100-ohm resistor inserted in the teleprinter line, and the choice of circuit constants is such as to produce in the secondary winding of the transformer voltage impulses whose maximum amplitudes occur when the line current begins either to build up or to decay. These abrupt discontinuities marking off the second dimension, or time of duration, of the signal unit interval are always present in the line current waveform except on lines of exceptional length.

The essential circuit details of the teleprinter signal bias meter together with some waveforms of interest are shown in Figure 1; its operation is as follows:

When the signal bias meter is placed in series with the teleprinter line between the central office apparatus and the remote teleprinter, any isolated spacing signal impulse produces steep fronted voltage transients in the secondary of the coupling transformer driving the trigger tube VT-1. These waveforms are displayed at the upper right hand of the figure. By means of a switch, the correct anode of the dual triode trigger tube is selected and the grid of the relay drive tube VT-2 made subject to the swings in potential of this particular anode. In response to the corresponding changes in anode current of the relay drive tube, relay RY-1 operates or releases coincident with the initial portions of the buildup or decay of the teleprinter line current.

Upon the decay of the line current, at the beginning of a spacing signal unit interval, relay RY-1 is released and impresses positive battery potential on the previously de-energized two-section time delay network. After a delay equal to three-quarters of a normal length unit interval, the junction of the network becomes energized and relay RY-2 is operated. Operation of this relay removes the short circuit on capacitor C-1 and prepares a path to negative battery for relay RY-3 which remains unoperated since relay RY-1 is still released. Capacitor C-1 now begins to charge and the voltage on its upper terminal rises exponentially with time in a positive direction. It is this voltage that is to be compared, at the instant the teleprinter line is reclosed, to a predetermined normal voltage obtained from the bias potentiometer.

For a single unbiased spacing signal unit interval, the re-energization of relay RY-1 will occur exactly 22 milliseconds after its release, and the restoration of the armature of this relay to its front contact will then charge capacitor C-2

Figure 2. Teleprinter signal bias meter

through the operating winding of relay RY-3 and the previously mentioned front contact of relay RY-2. Because the charging current to capacitor C-2 is of extremely short duration, the contacts of relay RY-3 close only momentarily, and at this instant the voltage across capacitor C-1 is compared to the voltage at the potentiometer. In the presence of unbiased signals, the voltage across the capacitor will have an average value equal to the voltage obtained from the potentiometer when set for zero bias and there will be no energy transfer. If the teleprinter signals are biased to spacing, however, the spacing signal unit intervals will be longer than normal, and re-energization of relay RY-1 and the instant of comparison will take place when the voltage across capacitor C-1 is greater than the voltage at the bias potentiometer. Under this condition, current will flow from capacitor C-1 towards the potentiometer and as a result of this current flow a charge will be stored on capacitor C-3. The successive increments of charge stored on capacitor C-3, one for each isolated spacing signal impulse, will be dissipated in the bias indicating microammeter connected in shunt with this capacitor, and the meter will be deflected to the left to indicate a spacing bias. The deflections of the meter are damped by the resistive-capacitive network coupling the meter to capacitor C-3 to eliminate what would otherwise be an objectionable susceptibility to sporadic unit intervals of different than average time length, but because the number of isolated spacing signal units arriving from time to time will vary with the intelligence transmitted, the magnitude of the microammeter deflection will, nevertheless, be variable and indeterminate. Now if the operating technician so wishes, he may reduce the bias to zero by adjusting the bias control on the telegraph apparatus until the microammeter remains undisturbed at zero; or he may measure the magnitude of the signal bias by similarly nulling the microammeter by obtaining from the bias potentiometer a potential equal to that developed across capacitor C-1 at the instant of comparison. The signal bias in percent is then read off the calibrated dial of the potentiometer.

H. F. WILDER, the author, joined the Engineering Department of the Telegraph Company in 1929, after graduation from Northeastern University. He has since been concerned primarily with the design of signal shaping amplifiers and other terminal apparatus for ocean cables. During the past two decades these international facilities of the Western Union have been converted to multiplex operation with a resulting improvement in message capacity and flexibility of channel extension. The extension of multiplex channels after translation to teleprinter signals brought about the author's interest in electronic teleprinter signal regeneration and bias measurement. Mr. Wilder is a member of the AIEE.

If the signals have a marking bias the instant of comparison occurs early, and since the voltage across capacitor C-1 is then less than normal the flow of current will be away from the potentiometer. Consequently, the increments of charge stored on capacitor C-3 will be of the opposite polarity and the microammeter will deflect to the right.

To prevent a false indication from a spacing signal two or more units long, a relay RY-4 is arranged to remove the operating coil of relay RY-2 from the network junction 11 milliseconds following its initial operation. The release of relay RY-2 opens the operating circuit of the comparison relay RY-3 so that the ultimate re-energization of relay RY-1 does not effect an unwanted voltage comparison.

For use by operating technicians, the components of the bias measuring circuits just described have been assembled in the form shown in Figure 2. The complete assembly is 15 inches high and weighs 26 pounds. The bias potentiometer knob and scale are at the right of the sloping face of the instrument. Above the bias potentiometer is the signal polarity neon glow lamp coupling the trigger tube to the control grid of the relay drive tube. To be certain that the correct sense of the signal bias is indicated, the technician observes that this lamp remains *on* during a stop period in signal transmission; if it does not, the switch below the potentiometer is thrown to the opposite position.

The four single current relays used in the bias meter are of the mercury wetted contact type and are not susceptible to adjustment. The small differences in the operating characteristics of individual relays necessitate recalibration of the meter following the replacement of a relay. Recalibration is readily done by nulling the bias meter on signals known to be unbiased and then rotating the scale slightly to coincide with the new zero.

A power polarity lamp, a neon glow lamp shunted by a rectifier, is located above the bias indicating microammeter. This lamp glows steadily when the power cord plug has been correctly inserted in a d-c 115-125-volt convenience outlet. The current consumption is 0.44 ampere.

Although this description has emphasized the monitoring of single current or make-break teleprinter lines, in which service the teleprinter signal bias meter has already been received with great favor by operating personnel, the bias meter responds equally well when inserted in the polar current ring or dummy circuit of a telegraph network repeater system. In this strategic position, the operating technician is able quickly to determine if the separate teleprinter lines radiating from the hub are transmitting unbiased signals into the network and, if not, to remove temporarily the offending leg from the network until the condition is corrected.

IVAN S. COGGESHALL HONORED

On June 17, Ivan S. Coggeshall, General Traffic Manager of the Western Union International Communications Department, received an honorary degree of Doctor of Engineering from Worcester Polytechnic Institute, with the following citation:

"A member of the Class of 1918, Ivan Stoddard Coggeshall began his career as an apprentice in automatic telegraph engineering in the Boston office of the Western Union Telegraph Company and was soon transferred to the home office of that company in New York as an engineering assistant. Today, he is the General Traffic Manager of Overseas Communication of that great organization.

"Ever alert to the advances in electronic methods and devices for transmitting thought and word, his activities in their utilization in the telegraph and submarine cable fields, are widely recognized. . ."

The citation further states: "He has performed, also, valuable service to his country as an officer of the United States Naval Reserve in the Second World War.

"He is a Fellow of both the American Institute of Electrical Engineers and of the Institute of Radio Engineers, the latter being the largest world-wide association of scientists and engineers in this field. In recognition of his contribution to the advancement of the theory and practice of radio telegraphy, he has recently been elected president of the Institute of Radio Engineers. . ."

Dr. Coggeshall is Vice-Chairman of the Western Union Committee on Technical Publication. He has written numerous articles on telecommunications subjects. One such article, "Testing and Regulating—Overseas", and a brief biography of Dr. Coggeshall, appeared in the January 1951 TECHNICAL REVIEW.

Traffic Routing

M. L. MOSLEY

WHEN A CUSTOMER files a telegram to his home folks in Hidden Corners or in Lost Center, pays his tolls, and walks away confident that the message will be duly delivered, he is unknowingly trusting a great deal to the efficiency of the men and women of the Routing force. They already have explored and plotted out the best and quickest path by which to send messages to and from any one of some seventy-five thousand places. Additional locations are being listed all the time, one outstanding reason being that young men in the Armed Services send so many telegrams to isolated home towns from far camps and stations that it becomes desirable to enter their villages and hamlets, no matter how small, in the routing lists known as "route charts".

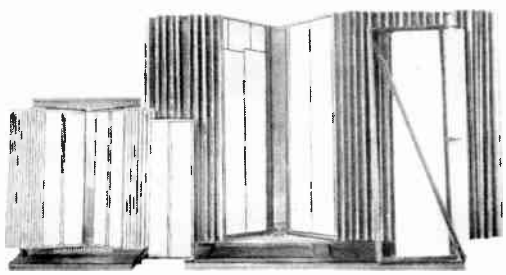
Since the routing work goes on behind the scenes, the public generally is not aware of it and some may think that a special wire connection must be set up between origin and delivery points to carry each message. Because telegrams can be written on a piece of paper or punched as holes in a paper tape, so that the message intelligence may be relayed at high speed, such direct connections are, of course, entirely unnecessary. But an exact knowledge of the proper points where the written or punched message may be transferred from circuit to circuit, if necessary, is mandatory to efficiency of operation in the Telegraph Company.

Historical Background

Today the ready availability of telegraph message routing information in the Western Union system is almost taken for granted, thanks to the efficient operation of a central Routing Bureau. It was a different story 30 years ago when every telegraph office made its own route chart, usually by marking and cutting pages from a tariff book.

First of many aids to greater accuracy was a weekly Routing Circular of the early 1920's and before, showing traffic routing changes necessitated by circuit layout shifts. Then came publication of State Route Guides with designation of Major Relay offices which laid the foundation for a modern route chart system. Before long all important telegraph offices were provided with their own routing display racks, for which new printed lists as needed were supplied weekly by the Routing Bureau.

It was contemplated initially that standard route charts would consist of visible index equipment displaying typed cards and the first chart of this type was installed and maintained experimentally at Philadelphia. It was found practicable, however, to do a better and more economical job by adopting specialized letter-press printing techniques.[1]



Experimental route chart of 1925 (right) displayed typed visible index cards under glass in heavy iron frames. Newer chart (left) with printed lists, no glass, had same capacity

General Routing Bureau

With the exception of city route charts which are prepared and maintained locally, all other route charts are prepared and the required number of copies for display in each office are printed and distributed from a central bureau in New York. Some 1400 different route charts, including the large city charts at the New

York main office, are serviced from the routing bureau.

For this purpose, a print shop equipped with a type casting machine, presses and storage facilities for the charts, in type form, is maintained. Thus all charts in use in field offices are held ready in type form to supply additional printed copies or, upon notice of changes, to be corrected with minimum effort and delay for the day to day routing of the large volume of traffic handled in the system.

Most lists are made with (1) 8-point Gothic No. 3 type, a compact legible face. Century bold (2) and Cheltenham bold (3) also are used. Examples follow.

(1) Parks ....MS Muskogee

(2) **PENN ....P—PHILA**

(3) **EAST 28th & 29th STS ..AD-MS**

A column width of 13 ems pica, or about 2 1/8 inches, has been used satisfactorily for single column strips and 3-column 8 1/2-by-11-inch sheets, as illustrated. For greater compactness, 4 columns in 9-pica measure with the Gothic type are practical for selector chart lists.

Switching Systems Bring Changes

In recent years, reperforator switching as a means for exchange of telegrams between cities has required some changes in earlier traffic routing practices although the fundamental problems are just the same. Formerly, the designation of a Major Relay Office for each state, coupled with a directive that telegrams for all points *not listed* in the State Route Guides or in the standard office route charts were to be sent to the major relay office named for the state, provided a practical routing system with a minimum of listings and with consequent space savings and reduced reference or "look up" time. Now, with reperforator switching, 15 cities have become area switching centers, each serving one or more states. In effect, this has reduced the major relay offices from some 40 to 15, and has simplified traffic routing enormously.

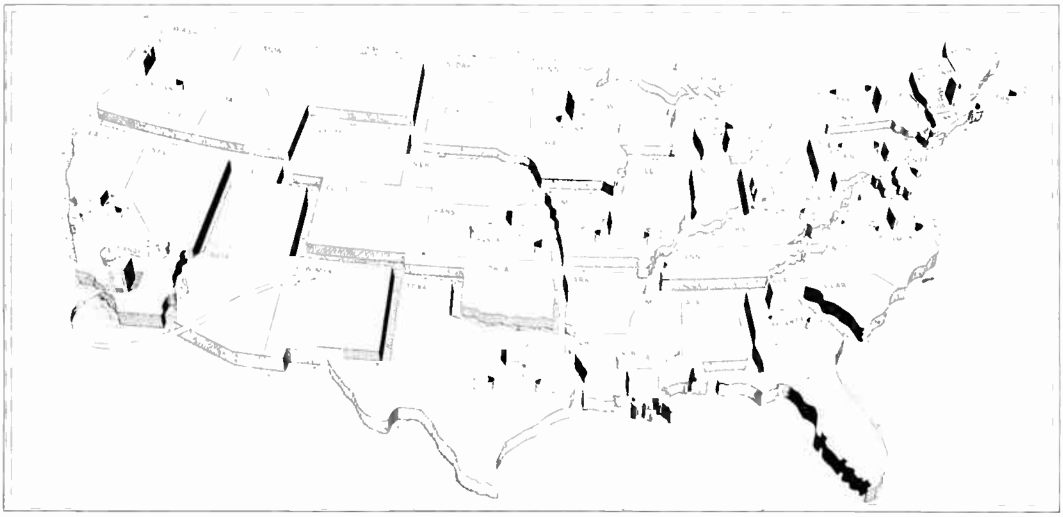
It should be kept in mind, however, that a large proportion of all telegraph traffic consists of business messages between the large, well-known cities. Moreover, experienced clerks and operators soon memorize much routing information and as a result the bulk of the telegrams are forwarded immediately without any need to refer to routing lists.

It is the aim to have each switching center serve every telegraph office in its area so that telegrams to each state may be routed "en bloc" to a designated center, and to a very large degree this has been accomplished. Physical restrictions of practical circuit layout, however, coupled with economic limitations, will not permit full attainment of this objective, so it is still necessary to prepare route charts listing cities and towns for which the routing does not conform to the clear-cut pattern of "block state routing". So it comes about that these "exceptions" comprise the bulk of the material in the route charts.

Each reperforator office does serve, however, most telegraph stations in an area comprising one to six states, and the switching route charts for use in reperforator offices give a listing and route for every city or town shown in the tariff book in each state in the specified reperforator office area.

In general, each reperforator office works a direct circuit with each other reperforator office, although there are a few exceptions where message loads to be interchanged between reperforator offices are not sufficient to justify an interconnecting circuit. Where the interchanged load volume warrants, there are also circuits for direct operation between the larger non-reperforator cities and between these cities and reperforator offices other than the local area reperforator office.

The foregoing covers in a general way the basic pattern for Western Union's system of routing. A more detailed description follows.



Fifteen "block state routing" areas and their switching centers

The Telegraph Company's nation-wide switching system includes two general types of area reperforation offices or centers:

1. Those where switching is push-button controlled—as in Cincinnati and Philadelphia—or is done at plug-and-jack switchboards as in Atlanta, Dallas, Richmond and St. Louis.
2. Those where automatic selective switching to a number of points is available in addition to push-button controlled switching—as in the nine centers at Boston, Detroit, Kansas City, Los Angeles, Minneapolis, New Orleans, Oakland, Portland, and Syracuse.

Routing Outgoing Traffic

In the push-button or "manual" type reperforator office, the switching aisle carries most of the distant routing responsibility and therefore requires the latest

Routing lists are displayed above operating positions in Philadelphia switching center and best routing information available, with a chart which indicates a route for all possible destinations, including local city addresses. Generally, for a telegram destined to a state *outside the local area,* transmission to a specific switching center serving the area of destination is indicated. For a message addressed to a teleprinter-operated tributary office *within the local area* or to a place relayed by such an office, transmission to that point is indicated on the route chart by the call letters of the tributary office.

Local Distribution

Messages destined to teleprinter-operated branch offices within the home city of the switching center are similarly routed by office call. Messages for teleprinter tie-line customers are routed to the "TL" section for further handling, and those for Telefax tie-line patrons are routed to the "TFX" section. All the rest of the local telegrams which are to be delivered directly from the main office by messenger or by telephone, or which must be further transmitted by Morse wire, are routed to "LL" or local positions. Here the telegrams come out in printed form on a page, called "hard copy", suitable for perusal and checking by Company employees before being passed along to the addressee.

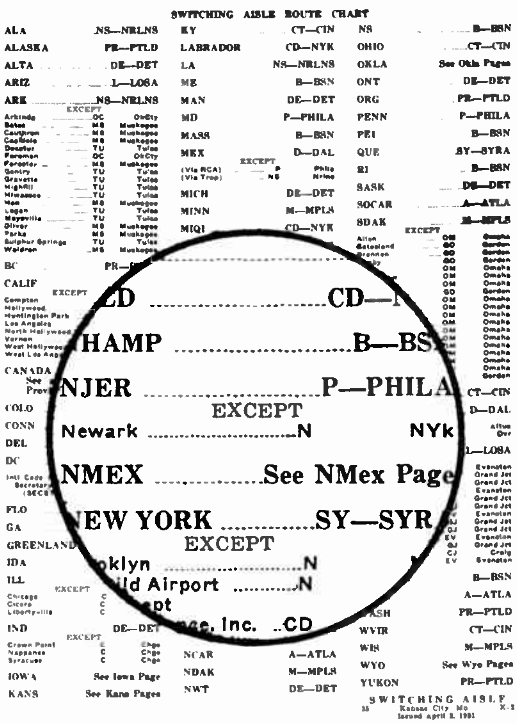
These hard copy messages, produced at the LL (local) positions, all are passed through to a distributing center where another route chart is required. While this chart shows routing for all towns within the home-office state and for states in the home-office area, somewhat similar to that shown on the switching aisle chart, it is more detailed with regard to those destinations served locally. (The regular route charts are supplemented by Atlas maps, railway guides, telephone directories and other aids to finding the best method of delivering a telegram to an obscure locality.) At the distributing center, the required route indicator or office call necessary to effect the routing in the home office is endorsed on the hard copy which is passed promptly to the delivery desk, telephone room or Morse position so indicated.

At distributing center "hard copy" telegrams are sorted for city delivery with the aid of route charts

Messages sent to facsimile-method TFX positions are, of course, converted to hard copy for scanning by Telefax but ordinarily need no further routing. Messages sent to the TL (tie-line) positions may be converted to hard copy or not, depending upon the facilities of the home office for tape-sending to teleprinter tie-lines. At those positions, also, under ordinary conditions extensive routing charts are not needed but tie-line routing instructions and information for routing telegrams after tie-line positions close for the day are provided.

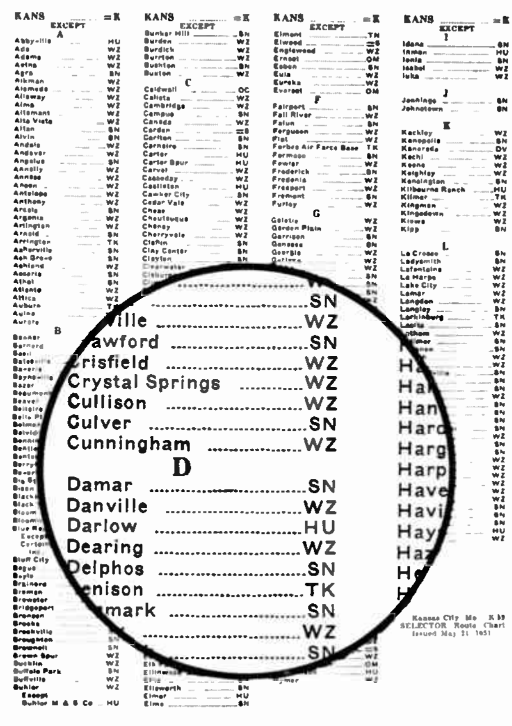
Handling Incoming Local Telegrams

At reperforator switching centers, incoming telegrams arriving over-the-counter at the main office, by telephone, by Telefax, or by Morse wire, move through the distributing center and are, as a rule, punched into tape at local sending positions. At all reperforator centers except Richmond, automatic selection is used for transmission from local positions and the perforated message tape prepared at those positions can initiate the first switching function. When automatic selective switching is provided, the routing responsibility for local incoming telegrams can in large measure be delegated to the distributing center. Using a route chart which shows a routing indicator or office call for destinations in all states, Canada, Mexico, and even foreign countries, the proper selector prefix can be endorsed on the hard copy before it is passed to the local sending position. Telegrams for local destinations do not need to be punched into tape, of course, and can therefore be passed to the outgoing section in hard copy.



Switching aisle routing summary sheet

But it is at the tributaries where the value of the automatic selection of routes is paramount. Tributary offices working only to a single manual-type switching center need no route charts since all traffic is sent to the one center and the necessary routing is done there. Where tributary offices have outlets to more than one manually-operated relay center, at least a rudimentary route chart is necessary to determine which of the available outlets to use for individual messages. On the other hand, with automatic selection available at the switching center, each tributary office has, in effect, almost as many trunk circuits as the switching center. (Any difference in number will be due only to the limitation in number of selections built into the automatic feature.) By the same token, the large number of available trunks necessitates elaborate tributary office routing charts to make full use of the facilities. Thus a small tributary with only one outlet to the switching center can no longer simply send all its traffic to one place, but now requires a routing chart from which the proper selector prefix can be obtained for each telegram. Charts are referred to, however, with ease and rapidity, and in many cases not at all, since the operator soon learns the proper selector prefix for each trunk circuit. The switching aisle at the reperforator center now is relieved of much trunk routing and required to handle mostly the local distribution and messages to points not listed for automatic selection.

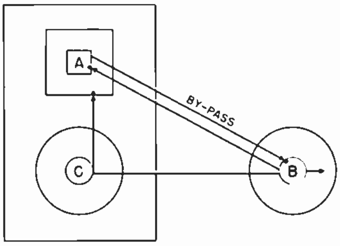


Selector route sheet for Kansas

Routing on By-Pass Circuits

Some large telegraph offices which are not switching centers—for example Milwaukee and Denver—have direct circuits with switching centers outside their own areas. These connections are known as by-pass circuits because traffic on them by-passes a switching center, as follows.

At the office which is not a switching center, "A" (see sketch), all outgoing



telegrams for the distant switching office "B" and its area are routed "en bloc" over the by-pass instead of via the local area switching center "C".

At the distant switching center "B", all messages for addresses within the by-pass circuit terminal city "A" are sent over the by-pass circuit. Messages for points relayed by the terminal city, "A", go via the switching center "C", where a detailed routing list is maintained. Thus by-pass traffic is routed expeditiously with a minimum of effort.

Another type of by-pass which has to be taken into consideration in the routing pattern is that used where two manual offices work direct, thus by-passing both home and distant reperforator offices. The route charts in offices having such direct connections provide generally for sending via such circuits only those messages addressed to the city proper.

Routing to Canada

Telegraph routes to Canada are through certain "gateways" where circuits to the Canadian National Telegraphs and the Canadian Pacific Railways systems are operated. The gateway cities are Boston, Chicago, Detroit, Minneapolis, New York, Portland, Ore., and Syracuse.

The gateway cities Chicago and New York, both non-reperforator offices at present, handle Canadian traffic which originates at or is destined to those cities proper. The five reperforator gateway cities handle primarily the Canadian traffic originating at and destined to the areas served by those reperforator offices, but they also relay traffic originating at or destined to the other reperforator areas which do not have connections to the two Canadian companies. Special switching positions are provided for handling Canadian message traffic.

The routing charts for Canada as displayed at a particular gateway office show the places in the respective provinces which are served exclusively by one or the other of the two Canadian companies, and traffic for such places must route to the proper company. Traffic for places which are served by both companies is divided at the gateway offices in accordance with a predetermined quota which operates as part of the routing procedure.

The route charts at the gateway cities provide listings for the provinces in Canada in much the same manner as for the states in the U. S. A. For example, at Syracuse where circuits are operated to both Canadian company offices at both Toronto and Montreal, the chart shows detailed routing for the provinces of Ontario and Quebec, indicating as exceptions those Ontario and Quebec places which must be sent exclusively to either CNT or CPR, or which do not route to Toronto, Ont., or Montreal, Que. The Syracuse route chart shows that traffic for other provinces in Canada routes via other reperforator offices which act as gateways for the other Canadian provinces.

The provinces reached via the various gateway offices with their Canadian office connections are as follow:

Via Boston, Mass.—Halifax, N. S. and St. John, N. B. (Nova Scotia, New Brunswick, Prince Edward Island).

Via Boston, Mass.—Toronto, Ont. and Montreal, Que. (Ontario and Quebec).

Via Syracuse, N. Y.—Toronto, Ont. and Montreal, Que. (Ontario and Quebec).

Via Detroit, Mich.—Toronto, Ont. and Winnipeg, Man. (Ontario, Manitoba, Saskatchewan, Alberta and Northwest Territory).

Via Minneapolis, Minn.—Winnipeg, Man. (Manitoba, Saskatchewan, Alberta and Northwest Territory).

Via Portland, Ore.—Vancouver, B. C. (British Columbia, Yukon, Alberta, Manitoba, Saskatchewan and N.W.T.).

Routing to Mexico

There are gateways to Mexico which operate on a plan similar to that in effect at the Canadian border except that operation is with only one company, the Mexican National Telegraphs. The gateways are New York City and San Antonio, with San Diego, Tucson, and El Paso as limited or local gateways. The New York City (CD office) gateway works directly with Mexico City, and San Antonio works with Mexico City and Monterrey. Generally states east of the Mississippi River route all traffic for Mexico to CD New York. The remainder of the U. S. routes Mexico via Dallas to San Antonio, except for the few local transfers at the San Diego, Tucson and El Paso gateways.

Other International Routing

Other international telegraph traffic routes via gateways and via international Carriers. The gateways for a given foreign country sometimes are different for the several Carriers serving that country.

In general the principal gateways are New York City, San Francisco, New Orleans, and Miami. The route charts for foreign destinations are set up in a condensed form similar to that used for block state routing with exceptions via certain Carriers being shown with specific routes. Generally the Pacific area routes via San Francisco and the European area routes via New York. An exception to the general route for Europe is via Philadelphia, which has circuits to the New York City offices of American Cable and Radio, RCA and WU International, as well as to the London office of Western Union International system.

Only international messages specifically routed via these international Carriers transit through Philadelphia, except of course all messages originating in the states in the area of the Philadelphia reperforator office.

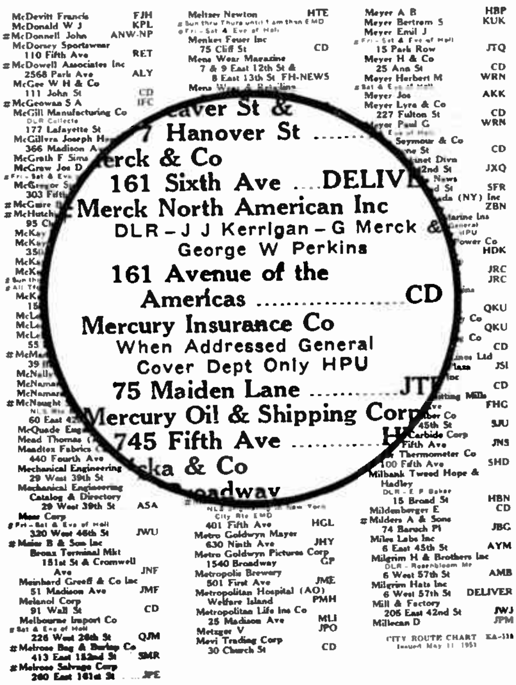
To-City Routing

Except at New York main office, city route charts are prepared locally in each city and briefly they contain three sections for ready reference.

a. Important firms and buildings.

b. Individuals.

c. Streets and addresses.



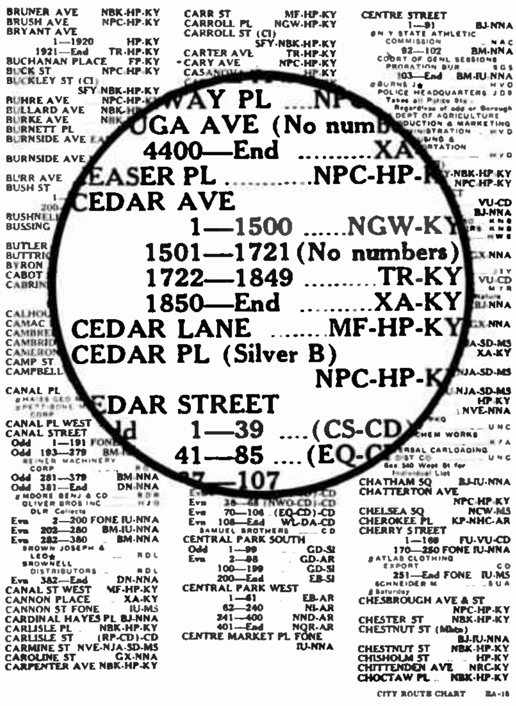
City route list, by business names

The routes shown are, in general, the service branch office call letters, the tie-line call letters, or the telephone number if telephone delivery.

The city route charts also show a second and sometimes a third route to be used after the closing time of the primary and secondary routes. Other special handling instructions are included as required. These city route charts are displayed at switching aisle positions, and in the distributing centers in reperforator offices, and in the distributing centers in other offices.

Miscellaneous Routing Instructions

Other route charts and guides are provided to meet specific situations such as "Exchange Routing", and for night and week-end periods when low traffic loads



Street and number city route sheet

permit closing direct circuits and concentrating loads for fast handlings and for economical supervision and operation.

The exchange routing is to direct the flow of traffic originating in the special network of offices usually located on trading floors of the important cotton, grain and commodity exchanges, which have special circuits for this class of traffic. The principal exchange offices are interconnected and in addition have connections into the reperforator system as well as to other offices as required.

Route charts in these offices show the route to destination by office call of the next relay office or terminating office.

Alternate Routing

Alternate Route Guides are provided at all switching and other multioutlet offices. These guides specify routes to be used when regular routes are interrupted or congested. However, inasmuch as reperforator offices have direct circuits to each other, when it is necessary for non-reperforator offices to resort to the use of alternate routes, a multioutlet office may "overflow" to any reperforator office any traffic except that destined to the area of the home reperforator office.

Conclusion

While traffic routing by reperforator system and the block state plan has greatly reduced the chart listings formerly required, many more route charts are being maintained today by the central routing bureau. The exceptions to the general rule which are still necessary for speed in handling and economy of operation, as well as to meet the requirements of quota and Carrier distribution, make the job of routing one of considerable detail and one requiring the utmost in accuracy.

Reference

1. TELEGRAPH TRAFFIC ENGINEERING, H. MASON and C. J. WALBRAN, *AIEE Transactions*, Vol. 46, 1927.

M. L. MOSLEY, the author, obtained his first experience with Western Union in the Plant Department at Philadelphia as a cable splicer's helper. He subsequently worked with the Bell Company of Pennsylvania, then returned to Western Union as an inspector in the ticker departments at Philadelphia and at Atlantic City. He worked on printing telegraph apparatus and traffic handling in the Automatic Department in Philadelphia, and in Baltimore where he became Assistant Chief Operator. In 1918, Mr. Mosley was transferred to New York as Division Traffic Inspector and later Assistant Chief Operator. In 1921, about the time centralized traffic routing was being organized, he was transferred to headquarters staff in the Circuit Layout and Routing Engineer's office, and in 1942, after having had charge of circuit layout for some years, was appointed Circuit Layout and Routing Engineer of the Traffic (now Operating) Department.

A Standard Frequency Generator for Carrier Telegraph Offices

T. F. COFER and R. C. TAYLOR

Need for Standard Frequencies

The large increase in carrier operation throughout Western Union plant in recent years, particularly the tremendous growth of carrier telegraph terminals operating over leased voice bands, has lately accentuated the need for accurate and trustworthy frequency standards at the larger Western Union offices. Means for testing the operating frequencies of the carrier channels themselves are adequately provided by test sets, but the modulation frequency used for stacking two groups of channels in one voice band was subject to checking only by means of a variable oscillator furnished the carrier switchboards for general testing purposes. During the early periods of telegraph carrier development, physical carrier pairs had been available between Western Union offices to an extent that permitted standard frequencies to be passed along from the Engineering Laboratories in New York to key points in the system. While this arrangement was subject to some difficulties and might not be available at all times, the results were quite satisfactory for a carrier system of the size and complexity of the original.

The substitution of leased circuits has made it impracticable to furnish standard frequencies from New York. The transmission lines between offices are no longer physical pairs but carrier channels derived by splitting up a large frequency spectrum with various steps of modulation. While the translating frequencies used to position the derived voice bands are maintained close to their assigned values, they are not perfectly correct and are not under the control or supervision of Western Union personnel. Such circuits cannot be used conveniently for passing standard frequencies between offices. In fact, the only way Western Union can determine the fidelity of the translating frequencies in these circuits is by comparing standard frequencies available at terminal offices.

The oscillators furnished the carrier switchboards are unreliable from a "standards" viewpoint, as are any variable oscillators. Similarly, the oscillators used for providing translating frequency to the subband modulators have proved to be incapable of maintaining a single frequency of "standards" accuracy in spite of specially designed reactance components and thermostatic controls. Need for a reference frequency source of "secondary standard" quality was indicated, preferably of a type which could be operated in the field without special training of employees.

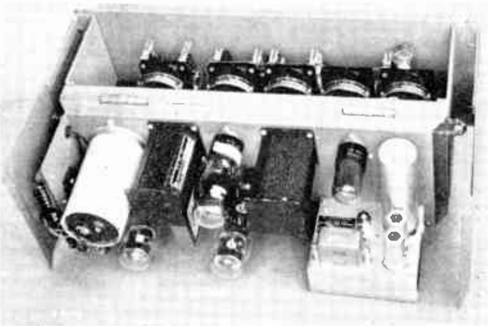


Figure 1. Standard Frequency Generator 6516-A

Desirability of Mechanical Vibrators

The requirements can be met more readily by using a mechanical vibrator as the starting point instead of an electrical one. It is not by accident that recognized primary standards are mechanical oscillators. The pendulum, the tuning fork and the piezoelectric crystal are the outstanding examples in their appropriate frequency ranges. The magnetostriction oscillator is of potential value for frequencies between those for which tuning forks and piezoelectric crystals are used.

The tuning fork was chosen as the most suitable oscillator for Standard Frequency Generator 6516-A, pictured in Figure 1.

A fork changes its frequency principally by changing its elasticity and the amplitude of its vibration. By the use of inverse feedback in the driving amplifier circuit, variations in the driving force and therefore in amplitude can be substantially eliminated. By making the fork of an alloy or bimetal strip with a small temperature coefficient of elasticity and mounting it in a hermetically sealed container, most of the variations due to temperature and atmospheric pressure can be removed. Installation of the assembly in a constant temperature cabinet can produce a source of frequency good to one part in a million.

Such extreme accuracy was not needed in a standard frequency generator designed for field installation. Furthermore, experience with temperature-controlled oscillators had indicated the desirability of furnishing equipment to the field which does not require a long period of waiting for a thermal cabinet to stabilize after power is applied. It was decided therefore to eliminate the temperature control feature and relax the requirements to an accuracy of ten parts per million.

Even the reduced accuracy of ten parts per million is unusual in most phases of engineering other than frequency standards. Some engineering is considered satisfactory if it is within ten percent of the nominal value. A slide rule is usually considered reliable to one percent or one part in one hundred. Standards such as resistance boxes and decade condensers in use in electrical engineering laboratories are seldom adjusted more closely than one part per thousand. Ten parts per million is one hundred times (two whole orders of magnitude) more exact than these; as much more precise than a laboratory standard as such a standard is more precise than a common half-watt resistor. Where such small deviations are concerned, it is not surprising that a change of one percent in the number of air molecules carried along by the motion of the fork can be detected. Fortunately, even a comparatively crude tuning fork can be relied upon to one hundred parts per million, and it is necessary to refine the basic device by only one order of magnitude.

Choice of Fixed Frequencies

Frequencies of 1000 cps and 3600 cps were chosen as the most desirable for use in carrier telegraph testing, and the choice of these fixed the fork frequency as 200 cps, the highest common factor. The 3600 cps was selected because it would permit checking the subband modulator carrier supplies with no more equipment than a db meter using the "zero beat" method. The 1000 cps was selected because it is a mid-band frequency that can be sent through one of the carrier telegraph channels and is also a conventional frequency for lining up long circuits which may pass over many types of facilities, whether leased or Company owned. It is also a convenient round number much to be desired for mental arithmetic problems. It was necessary therefore to arrange for developing the fifth and eighteenth harmonics of the 200-cps fork frequency in the required amounts and desired purity of waveform. Since recent developments in magnetic materials gave promise of simplified harmonic generation by magnetic methods, and available filter theory provided ready means for selecting the individual desired harmonics, further design proceeded in a straightforward manner.

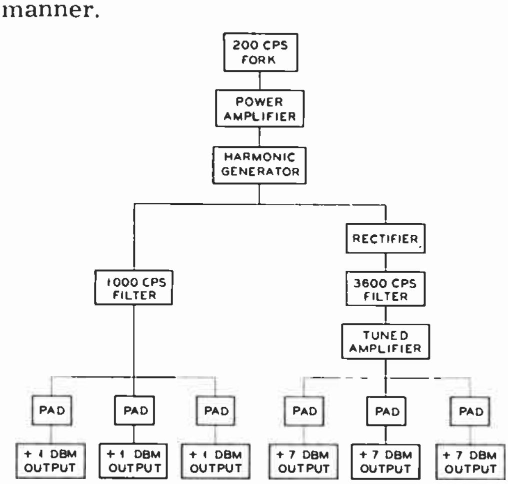


Figure 2. Block diagram of 6516-A oscillator

Description of Operation

A functional diagram of Standard Frequency Generator 6516-A is shown in Figure 2. A block by block description of the device based on Figure 2 is as follows: The low temperature-coefficient 200-cps tuning fork is driven magnetically by a 2-stage negative feedback amplifier. A 2-stage push-pull power amplifier follows, using cathode coupling in the first stage and transformer coupling between stages to supply balanced grid voltages to the pair of 25C6G tubes in the output. This amplifier converts the approximately 100 microwatts furnished by the fork unit into the several watts of 200 cps needed to saturate the Deltamax core of the harmonic generator. The core produces short pulses rich in the odd harmonics of the exciting frequency, from which the fifth harmonic is selected by a 1000-cps filter. A full-wave selenium rectifier in series with the 1000-cps filter converts the odd harmonics of 200 cps into odd and even harmonics of 400 cps at its output, where the ninth harmonic of 400 cps is selected by a 3600-cps filter. The outputs of the filters are amplified where necessary and passed to several 600-ohm load connections through isolating and impedance-matching resistance networks.

The Fork Standard

The fork unit together with its drive is made by American Time Products, Inc. The fork itself vibrates at a very small amplitude and should therefore have a very long life. Its temperature coefficient of frequency is stated to be less than one part per million per degree centigrade from 0 to 60 degrees centigrade, and its plate voltage supply coefficient of frequency less than one part per million per 25 volts from 100 to 320 volts. The unit is shock mounted to be insensitive to ordinary vibration. It is provided with a frequency-adjustment range of approximately 50 parts per million which is given its initial setting by the manufacturer of the standard frequency generator to an accuracy of plus or minus 4 parts per million. This adjustment should not be changed unless a standard more reliable than the 6516-A is available for reference. The frequency is somewhat dependent on position, and hence may change slightly if the fork is tipped more than 5 degrees from its vertical position.

The Harmonic Generator

The Deltamax core is a relatively new product and may justify a more detailed description than other more familiar components. It is a highly developed magnetic core material of the oriented 50 percent nickel—50 percent iron class. Its special properties are two: first, it has a nearly rectangular hysteresis loop with sharply pointed extensions rather than the usual sloping loop with blunt-angled corners (see Figure 3); second, it is rolled to a thickness of 0.002 inch, about half the thickness of the paper this is printed on! Both properties cooperate to make this material a good generator of harmonics. The commercial form most adaptable to general use is a "clockspring" core enclosed in a nylon box on which can be wound any necessary windings to produce a doughnut-shaped or toroidal coil.

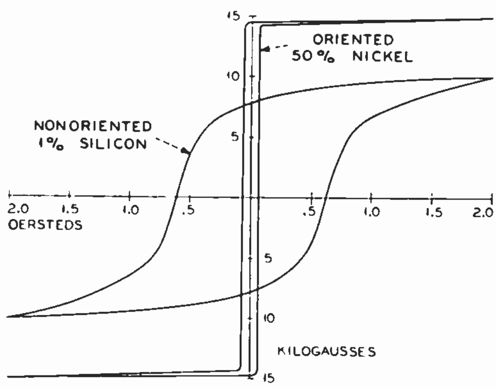


Figure 3. Hysteresis loops

It is customary to study the performance of such harmonic generators in terms of the frequency spectrum generated. However, the closely associated time patterns shown in the upper part of Figures 4 and 5 are more evident in the laboratory. Guided by the mathematicians and confirmed by measurements with frequency analysers, it is possible to show that these repeated time patterns can have frequency spectrums of the "line" type shown in the lower parts of Figures 4 and 5. Each vertical line of the diagram is called a frequency component of the corresponding actual wave and represents one of such sine waves as are shown on the time pattern. Figure 4 illustrates conditions across the Deltamax coil at the point in the circuit where the 1000 cps is obtained; Figure 5 corresponds to conditions following the rectifier where the 3600 cps is obtained. The 3600 cps is zero in the first case, as

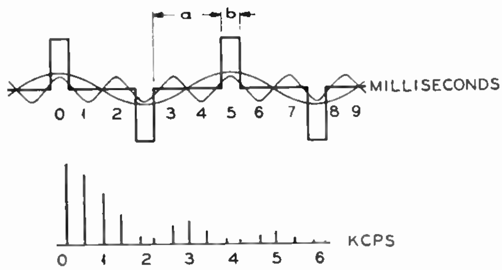


Figure 4. Time and frequency patterns for the 1000-cps source

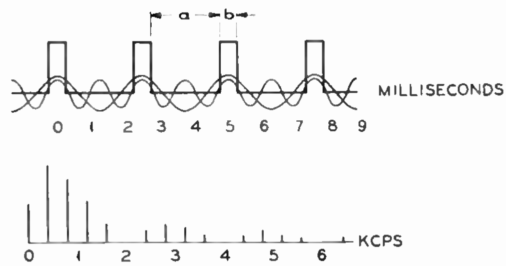


Figure 5. Time and frequency patterns for the 3600-cps source

only odd multiples of the pulse frequency of 200 cps are permitted by the symmetry of the time pattern above and below the axis. In the second case both odd and even multiples of the pulse frequency are obtained since the wave is not symmetrical about the time axis, but these are multiples of 400 cps instead of 200 cps since the wave repeats itself in half the time required by its parent symmetrical wave.

The Deltamax core does not actually produce a perfectly rectangular wave like the drawing but in spite of the slightly rounded corners the most important property (nothing for the long time *a*, followed by a pulse in the short time *b*) is present and the diagrams of Figures 4 and 5 are qualitatively correct. Of course similar results can be produced electronically but the availability of a simple coil, requiring no cathode power and having for all practical purposes an infinite life, makes impractical the use of the more cumbersome and expensive electronic method.

The Filters and Output Circuits

Like the Deltamax core, the filters also perform quietly without power supply or maintenance. Since not only must the desired frequency be precisely maintained, but also the output must have a wave shape close to the ideal sine wave, the selecting filters must make sure that the output will consist almost entirely of the single desired harmonic. All others which may be present at the input to the filters or be generated internally by slight non-linearity of the filter components must be at a much lower level, 35 db or more down from the useful output. The frequency characteristics together with the schematic diagrams of the filters designed especially for this purpose are shown in Figures 6 and 7. By careful proportioning of the losses over the spectrum, the number of coils in each of the selecting filters was held to four while meeting the required ratio of desired frequency to unwanted harmonics. In addition, by the use of "ideal transformer" impedance transformations, the inductance and capacitance values were kept to convenient sizes and the output impedances

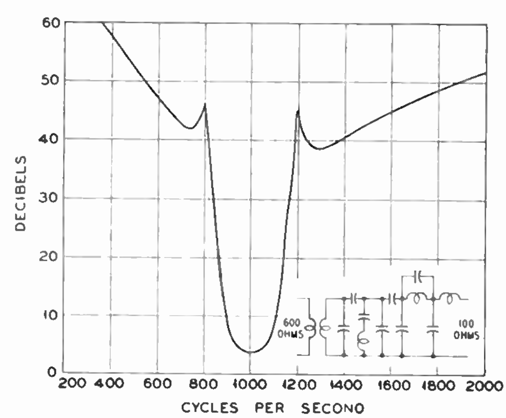


Figure 6. Attenuation curves and schematic diagram of the 1000-cps filter

adjusted to values required by the associated output circuits.

There is an apparent inconsistency in placing the peaks of attenuation at 3400 and 3800 cps in Figure 7, when theoretically the undesired frequencies nearest the pass band should be 3200 and 4000 cps. The peaks were placed at those frequencies to make the device more trouble-free. For instance, if the rectifier input

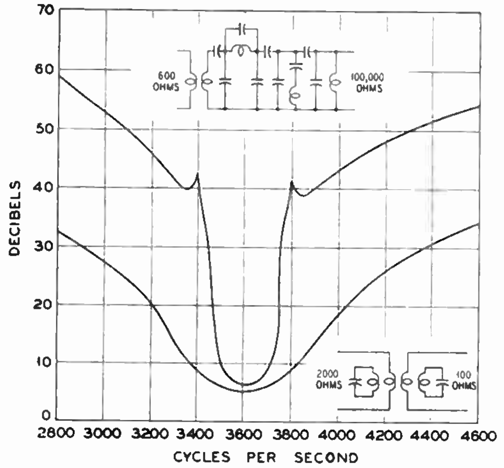


Figure 7. Attenuation curves and schematic diagrams of the 3600-cps filters

wave should become unsymmetrical for any reason, such as an aging tube in one side of the push-pull amplifier, or direct current in the saturating coil, then all the harmonics of 200 cps would be present instead of only the harmonics of 400 cps. In such cases the narrower filter would still remove the nearest harmonics and provide a 3600-cps output of good wave shape. A similar reasoning explains the peaks at 800 and 1200 cps in Figure 6.

The 1000-cps output taken directly from the harmonic generating coil through the filter and network gives a sufficient level for testing purposes so that no amplifier is needed for this frequency. In the case of the 3600-cps output, however, the generating coil delivers less and the applications require more. Accordingly some amplification is required and a single stage designed for the purpose proves entirely adequate. The several outputs of each of the two frequencies are fed through 13-db 600-ohm pads which tend to isolate the loads from each other. Levels of plus 1 dbm at 1000 cps and plus 7 dbm at 3600 cps are available at the loads.

The 3600-cps filter is made to include a voltage step up to the amplifier grid from the input impedance of 600 ohms to the output impedance of 100,000 ohms. This arrangement eliminates the amplifier input transformer. Since an output transformer is required for efficiently coupling the amplifier plate supply to the loads, an opportunity appears for other benefits at little added cost. This transformer is made to isolate the tube plate current, to match impedances and, by selecting the correct coupling coefficient and tuning condensers, to contribute to the purity of waveform. It removes amplifier noise and amplifier-generated even-harmonics as well as further reducing the small 400-cycle harmonics remaining in the output of the filter preceding the amplifier. One can hardly expect even a very special single coil to do as well in this respect as four coils and that is confirmed by the two attenuation characteristics shown in Figure 7. The lower curve, which is for the tuned transformer, has about 60 dbs attenuation at the second harmonic (7200 cps), much more than is required to eliminate tube distortion products. There is a fourth filter in the 6516-A, a plate supply filter consisting of the perennial 110-A choke but associated here with an unusually large electrolytic condenser made necessary by the short heavy pulses of plate current drawn alternately by the 25C6G power stage tubes.

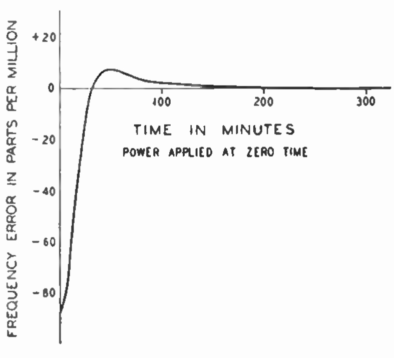


Figure 8. Effect of the thermal transient on frequency

Performance

A series of tests made in the laboratory on a single specimen demonstrated the precision and constancy of the standard frequency generator. The frequency was compared to that of a laboratory standard quartz crystal in a thermostatically controlled oven, with the average result shown in Figure 8. Note that after the first 30 minutes the frequency is never as much as ten parts per million from perfection and this statement was found to hold true for four different sets of tubes in the fork driving amplifier. Even one minute after turning on the power, the frequency deviation was less than ninety parts per million, which is good enough for almost all field operations.

MR. COFER, whose biography and picture appear in the October 1950 TECHNICAL REVIEW, is now Assistant to the Coordinating Engineer, D. & R. Department. **MR. TAYLOR'S** biography and picture appeared in the April 1948 TECHNICAL REVIEW.

Telecommunications Literature

ULTRA-HIGH FREQUENCY ENGINEERING—THOMAS F. MARTIN, JR. — Prentice Hall, N. Y., 1950. 456 pp., $8.00. The trend of this book is towards radar engineering, with each section covering a particular phase of the radar problem. However, the sections on transmission lines have been expanded so as to create the transition from a mathematical analysis of transmission lines to the use of the Smith Chart for the solution of matching problems. This book is suitable for engineers.—E. N. WRIGHT, Ass't Radio Research Engineer.

ELECTRIC WAVE FILTERS—F. SCOWEN—Chapman and Hall, London, 1950. 188 pp., $5.50. The first edition of this book appeared in 1945 and this, the second edition five years later, can be taken as proof of its value. This concise treatment of wave filters was a welcome addition to the literature of its field, not only for its conciseness but also because of a good selection of subjects likely to be useful to a filter designer. The first 27 of the 188 pages are devoted to mathematical and electrical fundamentals of wide application, but the remainder applies directly to wave filters. It adequately covers such subjects as m-derivation, effect of dissipation, parallel or series connections and measurement with the emphasis on ladder rather than lattice sections. Another valuable chapter is entitled "Practical Considerations in Filter Construction" and includes discussion of balanced and unbalanced types, coil and capacitor components and adjustments. A feature of the second edition is 24 pages devoted to the Darlington method of filter design which takes into account the Q of the components as an integral part of the design procedure. However, the increased algebra required will discourage those not mathematically minded. —R. C. TAYLOR, Engineer, Transmission Research Division.

TELEVISION SIMPLIFIED — MILTON S. KIVER—D. Van Nostrand Co., N. Y., 1950. 608 pp., $6.50. An excellent fundamental treatment of the principles of television with particular stress on the home receiver. Little previous knowledge is presumed of the reader beyond an understanding of home radio broadcast receivers. The now popular intercarrier sound system is well covered, and the treatment of frequency modulation is sufficient in itself without previous knowledge of the subject. The latest edition explains the principal methods currently proposed for color television transmission and reception.—A. R. DAYES, Engineer, Telefax Research Division.

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