WESTERN UNION Technical Review

ATLANTIC CABLE ANNIVERSARY 1858-1958

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Telegraph Cable Centennial

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Developments in Printing Telegraphs

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Ferrite Cores for Communication Coils

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Lashing Tools for Aerial Cable

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Atlantic Telegraph Cable Centennial

Photo R-5610

Trinity Bay, Newfoundland, off Hearts Content, where U. S. steam frigate *Niagara* landed Cyrus Field's 1858 cable and steamship *Great Eastern*, shown here, then the world's largest, landed the 1865 and 1866 cables.

H. H. HAGLUND, Assistant Director of Applied Engineering

Laying of a continuous insulated electrical conductor across the Atlantic between America and England 100 years ago was a tremendous achievement, well documented. Development of efficient terminal and repeater apparatus for this and newer ocean cables has challenged the ingenuity of scientists and engineers continuously ever since—names such as Sir William Thompson, Michael Faraday and Charles Wheatstone are recognized immediately among those of the many savants who have contributed importantly to ocean cable technology. Since their time engineering developments for submarine telegraphy have been both numerous and notable.

THE FIRST transatlantic cable actually to carry messages between Europe and the New World was laid 100 years ago. Although its life span was very short—it remained in operation only from August 5 to October 20, 1858—this seems an opportune time to review the cable history over the past century. A great deal has been written about cables, their history, the history of the men who promoted them and who designed them, of their operation and of their import in world affairs.[1] In order not to make this recitation unduly long it will be limited principally to the North Atlantic cables which ultimately became part of Western Union's system, and Western Union's association with these cables.

Perhaps the genesis of submarine cables should be attributed to an invention and a discovery. The invention was, of course, the Morse telegraph. The discovery, gutta-percha.[2] This material is plastic at hot water temperature and in this state can be extruded around a copper conductor, then cooled to regain its solid state; it is in this condition an excellent insulator for the conductor, an insulator whose properties actually improve when it is immersed in cold sea water. A third factor played a supporting role. Rope manufacturers had machinery by means of which steel armor wires could be applied over the copper and gutta-percha core. A cable so made was first laid between Dover and Calais in 1851.[3]

From that date until the completion of the 1866 cable and the repair of the 1865 cable the story is mainly concerned with the faith, determination and resourcefulness of Cyrus W. Field and his associates who staked all the means at their disposal on the project of linking the Old and New Worlds by telegraph. This story has been fully told elsewhere and will be dealt with only briefly here.

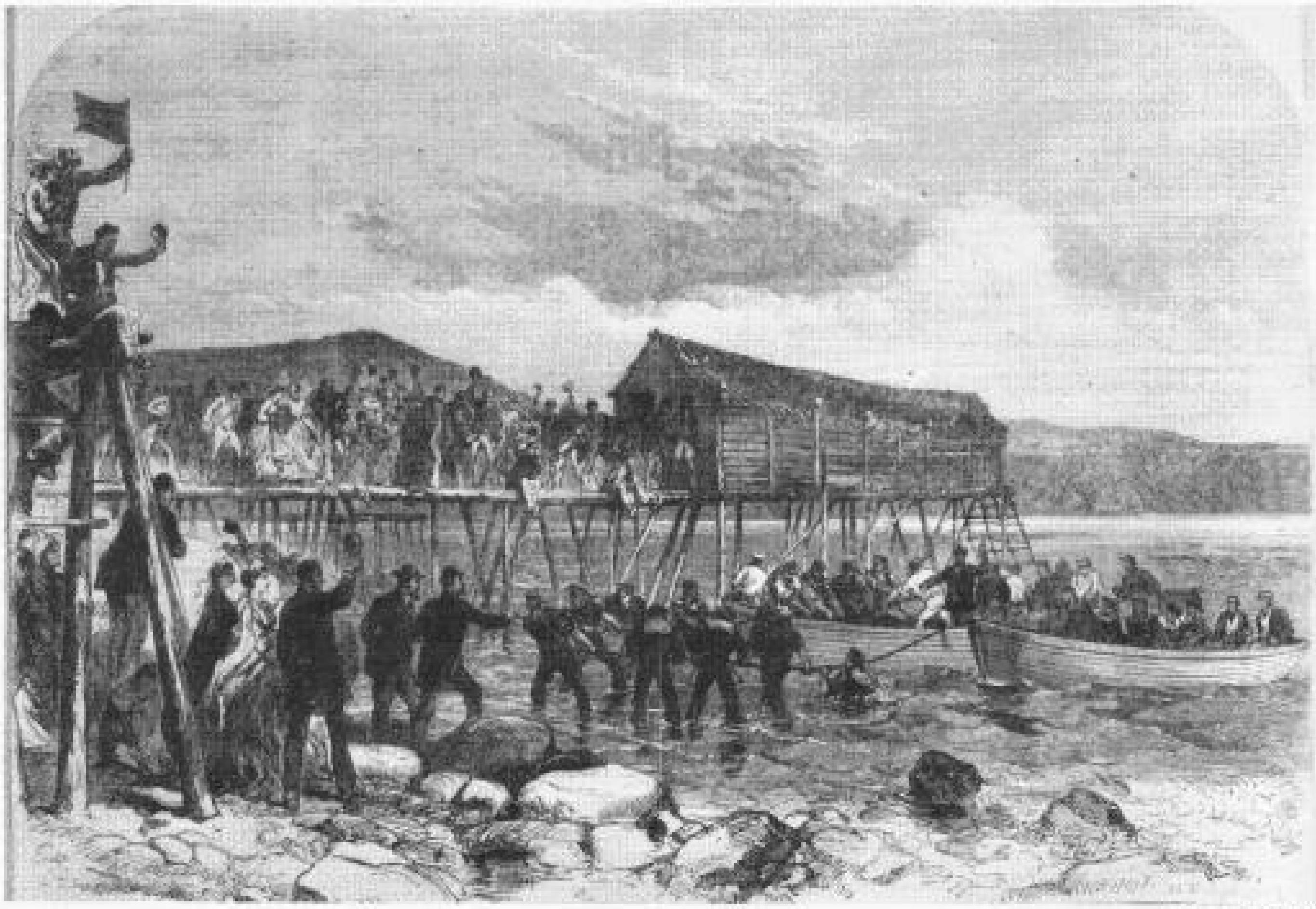

Photo R-2260

Landing of first Atlantic Cable at bay of Bull Arm, Trinity Bay, Nfld., August 5, 1858

The 1857 Expedition

The first attempt to lay the transatlantic cable was made in 1857. Two thousand five hundred nautical miles of cable was manufactured. The core was made by The Gutta-percha Company of London.[4] Seven strands of No. 22 (about 0.028-inch diameter) copper wire were covered by three coatings of gutta-percha to 3/8 inch-diameter, making 107 lbs. copper, 261 lbs. gutta-percha per nautical mile. One-half of this core was turned over to Messrs. Glass, Elliot and Company, of Greenwich, England, and one-half to R. S. Newall and Company, of Birkenhead, England, to be armored. These firms were wire rope manufacturers and the armored cable resembled a wire rope. The core was first served with hemp saturated with pitch, linseed oil and wax, and then sheathed with 18 strands each containing seven 22-gage iron wires. The final cable was coated with a further treatment of tar, pitch and linseed oil. Its weight was one ton per nautical mile. The shore ends—10 miles for Valentia and 15 miles for Trinity Bay—were sheathed with 12 No. 0 gage iron wires.

The cable was to be laid by two ships, the British battleship *Agamemnon* furnished by Great Britain, and the U. S. Frigate *Niagara* which was sent by the United States Government. Special paying-out gear was designed and installed on both ships. The original plan was that the ships would proceed to mid-ocean, wait for calm weather, splice together their cables and start paying out, one towards Newfoundland, the other towards Ireland. These plans were changed, however, and laying started from Valentia on the 6th of August 1857. Cable was being paid out by the *Niagara;* the *Agamemnon,* the British paddle frigate *Leopard,* and the sounding vessel *Cyclops* constituted an escort.

A mishap occurred before the shore end had been completely paid out. The cable parted and it was necessary to underrun it from the shore and again splice on. On Augst 7 the paying out began again. Early morning of the 10th, as the depth of water increased rapidly to 1750 fathoms, trouble began with the paying-out equipment due to the heavy load of the cable. Paying out continued, however, until daylight on the 11th when the brakes to the paying-out equipment were applied too suddenly and, with the added strain of a great deal of pitching in a heavy sea, the cable parted in 2050 fathoms of water.

So much cable had been paid out that only 916 miles remained on the *Niagara* and 1250 on the *Agamemnon* which was not considered enough with which to start over again. Hence the entire expedition returned to Plymouth.

The 1858 Cable

An additional 700 miles of cable was manufactured by Messrs. Glass, Elliot and Company, entirely new paying-out equipment was designed to give better control of the cable, and some paying-out trials in 1800 fathoms were made in the Bay of Biscay during the spring of 1858. Shortly thereafter the *Agamemnon* and the *Niagara* proceeded to mid-ocean and spliced together their respective lengths of cable using a special wood frame to take the strain off the splice. On June 16 the *Agamemnon* started for Valentia and the *Niagara* for Newfoundland in accordance with the original plans for laying the cable. The *Niagara* had favorable weather and landed its end in Trinity Bay, Newfoundland, at 5:15 a.m. on August 5 without incident.[5] The *Agamemnon* had a rougher time due to bad weather and a fault which was discovered in the cable, but in spite of these diffi-

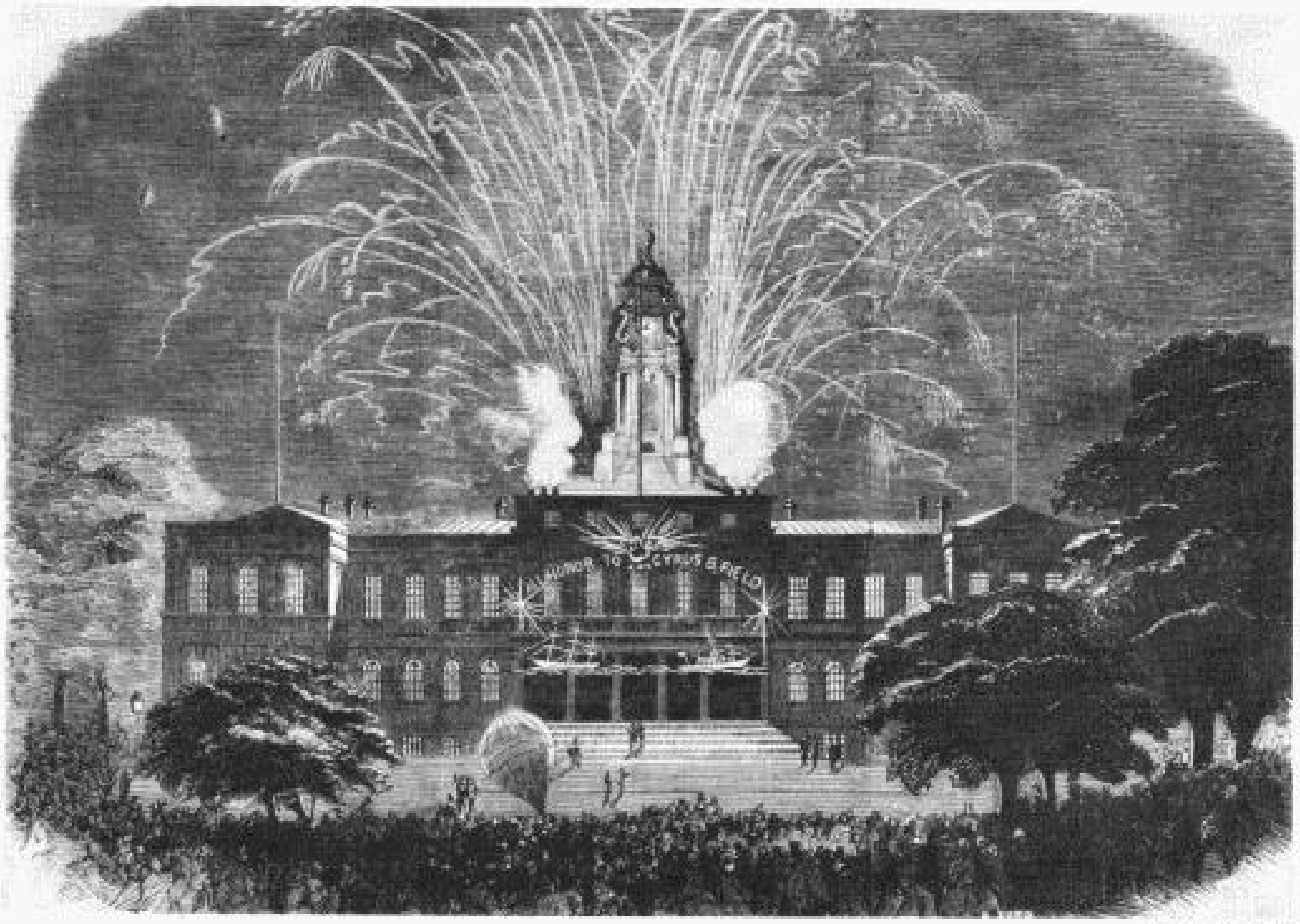

Photo R-2259

Celebration of the laying of Atlantic Telegraph Cable, Town Hall, New York

culties its cable was landed at Valentia on August 5. Total cable length was 2050 nautical miles. Signals were exchanged immediately and were said to be "strong."

The completion of the project set off a series of celebrations throughout both the United States and Great Britain. At New York a fireworks and torchlight display associated with these festivities ignited the cupola of City Hall and threatened to destroy the building. Messages of congratulation were exchanged between Her Majesty Queen Victoria and President Buchanan. Many of the backers and contributors to the enterprise were knighted or otherwise suitably rewarded.

But alas, the cable began to deteriorate rapidly almost the day it was landed. While it was being laid signals were sent through the cable from a bank of 70 Daniell cells[6] (about 1.1 volt per cell), but after the cable was landed Mr. Whitehouse, the Chief Electrician, introduced the use of huge induction coils with a 5-foot-long primary composed of 1-1/2 miles of No. 14 wire wound on the secondary consisting of many miles of No. 20 wire wound on an iron core. The peak output when powered from 10 cells of silver-zinc batteries was thought to be around 2500 volts, which high voltage probably punctured the insulation. As signals began to fail the induction coils were dispensed with but it was necessary to keep adding cells until as many as 480 had to be used to get signals through. By September 1 the cable was practically useless although some signals were received as late as October 20, 1858. A heavy lightning storm was also believed to have contributed to the final rupture.

The failure of the cable was a tremendous blow to Mr. Field and the other backers of the enterprise but the short operation had demonstrated certain important facts. *From an engineering viewpoint it had proved that a cable could be successfully laid at the depths encountered in an Atlantic crossing and that signals could be successfully transmitted and read over such a length of cable.* Both of these points had been held in doubt by some outstanding engineers. As a commercial venture it was also an indication of financial success. During its short life 732 messages, some of great length, were handled and one message alone—countermanding the departure of two regiments about to leave Canada for England—was said to have saved the British Government £50,000.[7]

The years immediately following the failure of the 1858 cable saw a great deal of cable laying activity in other than Atlantic waters. Cable design, transmission and operation was the outstanding electrical engineering problem of the time; the roster of men working on it included the great names in the new profession such as Professor Sir William Thompson (later Lord Kelvin), Michael Faraday, Professor Charles Wheatstone, Sir Charles Bright, Latimer Clark, William Whitehouse, Clerk Maxwell, C. W. Siemens, S. A. Varley, and others.

Some of these cable laying ventures were failures but others were successful. No cable was as long as the Atlantic span but some were in deep water. The successful cable between Barcelona and Port Mahon, in Spain, engineered by Charles Bright and manufactured by W. T. Henley, lay in a depth of 1400 fathoms. Valuable experience was being accumulated.

Cyrus Field and his associates had never for an instant relinquished hope of establishing a more permanent transatlantic cable. The Atlantic Cable Company, while busy endeavoring to raise fresh capital, prevailed on the British Government to dispatch two vessels to examine further the ocean floor 300 miles out from the coasts of Ireland and Newfoundland. Efforts to raise capital were continued; Mr. Field worked incessantly and is said to have made 64 crossings of the Atlantic in his efforts to carry out his project. The Atlantic Cable Company was responsible for the organization of a committee of engineers to advise them on the mechanical and electrical questions involved. A better understanding of the transmission problem had been developed by S. A. Varley, who showed that the signalling speed of a cable depended not only on its capacitance but also on its

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In remembrance of laying of the first Atlantic cable in August 1858, a commemorative stamp is scheduled for release at a ceremony to be held at the General Post Office, New York.

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resistance. This was eventually concretely developed by Lord Kelvin into the so-called KR law.

The committee finally adopted as the specifications for the proposed cable a strand of seven No. 18 BWG gage copper wires, weighing 300 lbs. per NM, coated with four layers of gutta-percha alternating with four of Chatterton compound weighing 400 lbs. per NM. This core was to be covered with jute and ten No. 13 BWG iron wires, each one covered with Manila hemp soaked in tar, India rubber and pitch. The shore ends were more heavily armored. The *Great Eastern*, the world's largest ship, was chartered to lay the cable.

The 1865 Expedition

Eventually capital was raised and the Telegraph Construction and Maintenance Company, successor to The Gutta-percha Company and Glass Elliot, undertook to make and lay the cable. Paying out was started on July 22, 1865, but a series of mishaps resulted first in several faults to the cable, which the ship succeeded in repairing, and eventually in the cable breaking on August 2 after 1186 miles had been paid out. Efforts to pick it up were unsuccessful and the work had to be given up on August 11, 1865.

Final Success

Although terribly discouraged the backers refused to give up. The Atlantic Telegraph Company was amalgamated with a new company called the Anglo-American Telegraph Company which had been formed with the object of raising fresh capital. Cable almost identical with the last was ordered and the new company proposed not only to lay a new cable but also to repair the one almost completed in 1865.

To get on with other parts of the cable story and Western Union's contributions to the art, let it be simply stated that the 1866 expedition was 100 percent successful. The new cable was completed July 21 and the 1865 cable was spliced onto and landed on September 18, 1866. The signalling speed of each cable was eight words per minute at the start but with practice and experience speeds of 15 to 17 words were attained.

Early Operating Equipment

Let us now leave the cable itself as a topic and look at the equipment with which it was worked. The use of induction coils and high voltage for transmission was abandoned. The pendulum swung the other way and as an experiment Mr. Latimer Clark is said to have shown that signals could be sent from Ireland to Newfoundland over one cable and back on the other which was joined to the first in Newfoundland, using as a source of power a battery consisting of a silver thimble filled with sulphuric acid and a grain or two of zinc.[8] For many years no one was allowed to apply more than a few volts to a submarine cable. As late as the 1930's, 50 volts was the normal limit.

Photo M-511

Cable key used to send polar signals

As early as 1858 Lord Kelvin had been convinced that cables over 700 miles in length could not be satisfactorily operated with the make-break system used in land line Morse code operation. To get better signals he developed the transmission of polar signals with one polarity standing for dots and the other for dashes. A special double type of Morse key was used for transmission and the receiving instrument was a "mirror speaker".[9] This was a reflecting galvanometer, originally employed in the Gauss and Weber Telegraph, improved by Helmholtz and developed in highly sensitive form by

Lord Kelvin. Light from a lamp was focused on a mirror mounted on the movable coil and reflected onto a screen. As the mirror was rotated by the signals a swing of the reflected light beam to the left indicated a dot and one to the right a dash. Since the dot and dash were not dependent on length this method of signalling resulted in a shorter code than the land line Morse because both dots and dashes were made just long enough to be readable on the mirror scale. Since an operator could not watch the transient signals and write at the same time, both a "reader" and a "writer" were required at the receiving end.

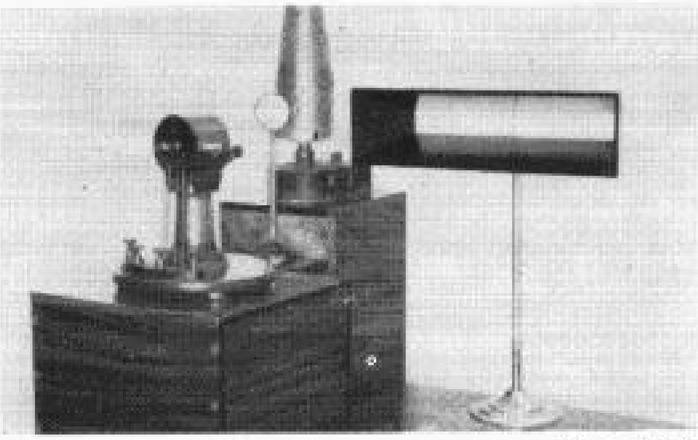


Photo R-1785

"Mirror Speaker" with lens, lamp and scale

The cable had a condenser inserted in each end. This eliminated the effects of earth currents on the galvanometer but imposed restrictions on the skill of the sender. The length of contact to produce a dot or dash had to be just right, since too short contact would not charge the cable and produce a signal at the far end, while too long contact would fully charge both cable and condenser with the result that upon opening contact the cable would discharge in a manner to produce counter signals difficult to distinguish from the real ones.

In 1867 Lord Kelvin invented the siphon recorder[10] which, after undergoing further development and improvements by several inventors, became the standard receiving equipment for all long cables. This instrument consisted essentially of a galvanometer the movement of which controlled the motion of a fine glass siphon through which ink flowed onto a paper tape. The paper was pulled under the siphon by means of a spring- or weight-actuated motor and later by a small electric motor of a type that became known as a "mouse mill." The mouse mill was credited with the generation of some static electricity which, when applied to the ink, helped to make it flow through the siphon onto the paper.

To lessen the friction of the glass siphon against the paper its end was vibrated by a small buzzer the clapper of which was attached to the siphon by means of a fine thread. This vibration assisted in expelling the ink from the siphon when it was barely touching the paper. The recorder had many advantages over the mirror speaker. One man could both read and transcribe the recorded signal and it could be read and reread if the operator was in doubt.

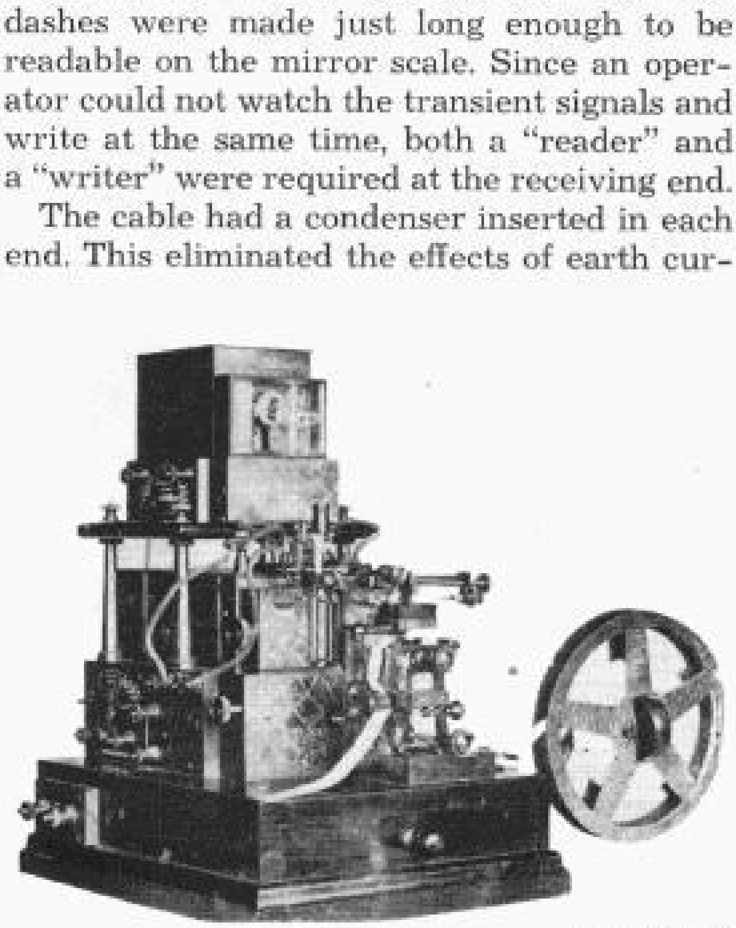


Photo M-522

Siphon recorder with "mouse mill" on top

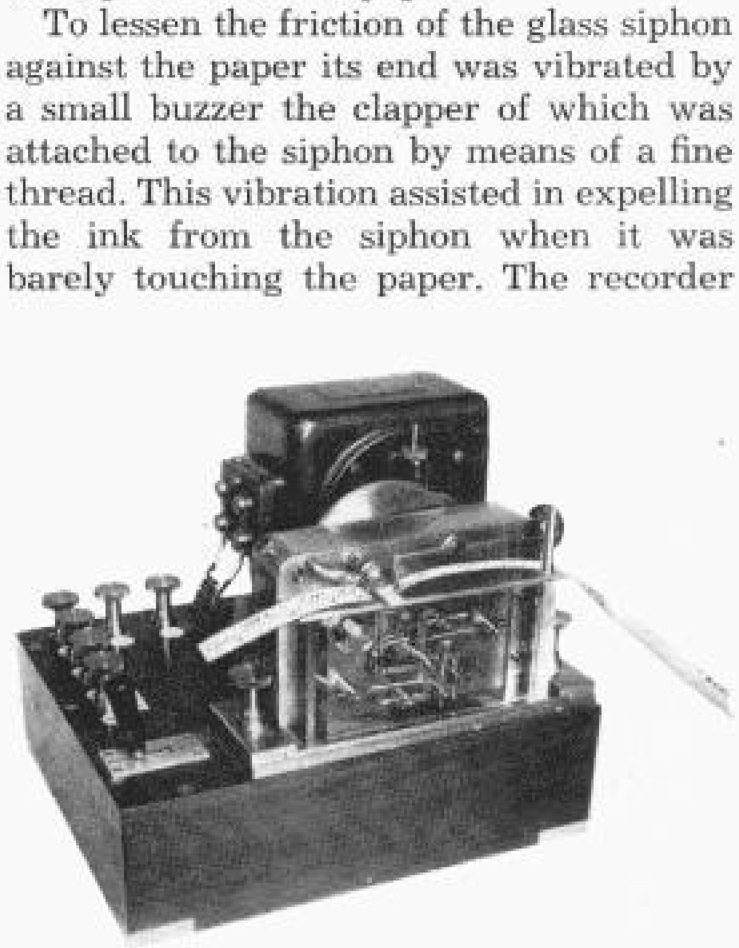


Photo M-535

Tape transmitter of Western Union design

Duplex Balance

The next great stride forward in cable operation was the application of the duplex balance to the system. A duplex system was first demonstrated by Dr. Ginth of Vienna in 1853,[11] and was applied generally to land lines by 1856 mainly through the work of the Siemens and Halske Company. Its application to cables was more difficult, however, and it was not until after the development of the Stearns artificial line in 1872 that much progress was made. The Stearns method involved the use of condensers to match the electrostatic capacity of the real line. In 1873 a short section of an Anglo cable was duplexed and in 1878 a long section was duplexed using the differential system. A siphon recorder with two windings on the coil was used. Dr. Alexander Muirhead, however, used the bridge duplex and that method eventually became the common system for long cables. Through the efforts of the company headed by Dr. Muirhead many improvements were made in the cable equipment; Muirhead also designed and built recorders, artificial lines, magnetic shunts, and all accessories.

Automatic Transmitters

About 1879 the idea of using a land line Wheatstone transmitter was evolved by Messrs. Belz and Brahic.[12] In 1888 Mr. Herbert Taylor designed and built for the Anglo-American Company a special cable code transmitter which soon became standard equipment. With this transmitter, which was operated from punched tape produced by means of so-called mallet perforators,[13] the signals were made of much more uniform length than could be produced by hand sending on a double-current cable key, with the result that the speed of transmission could be materially increased. The idea of "curbed" signals, that is, reversing the current or earthing the cable for a moment after each dot or dash, was later added with a still further increase in cable speed.[14]

Up to the beginning of the new century each section of cable was operated as a single unit. Messages from London to New York, for instance, were transcribed and retransmitted into the next section of the route at Penzance, at Valentia, at Hearts Content, and again at North Sydney.

Manual Relays

Since Morse and Wheatstone working were common on land line telegraphs the land line sections were worked by these methods and various ideas for speeding the rapid manual relay were developed. At Valentia and Penzance, for instance, Wheatstone signals from London were at one period received on a Creed reperforator[15] which duplicated the original tape used for transmission in London. This "slip" was then inserted in a Creed translator[16] which converted the Wheatstone signals into recorder code tape, and was fed into the recorder code cable transmitter. In order to insure correct retransmission the outgoing signals were usually checked by an operator who read them by ear from a pair of sounders called a "double herring," one sounder emitting a characteristic sound for a dot, the other for a dash. In the eastward direction the signals from the cables were manually perforated as Wheatstone for transmission to London where they were received on a Creed reperforator and this tape was used to operate a Creed tape printer.[17] At a later date and for a shorter time this system was used also between New York and North Sydney. As multiplex[18] equipment was developed by Western Union and introduced into the land line system, its use was extended into the cable system and multiplex equipment was installed and used between London and Penzance, London and Valentia, New York and North Sydney, and Hearts Content and North Sydney.

Automatic Relaying

To eliminate all this rehandling, a relay that would permit automatic retransmission from one cable section to another was obviously needed, and several such relays were developed. All used the conventional galvanometer movement and differed mainly in the manner that contact was made between the relay tongue and the relay contacts. The Brown drum relay[19] which became the Western Union

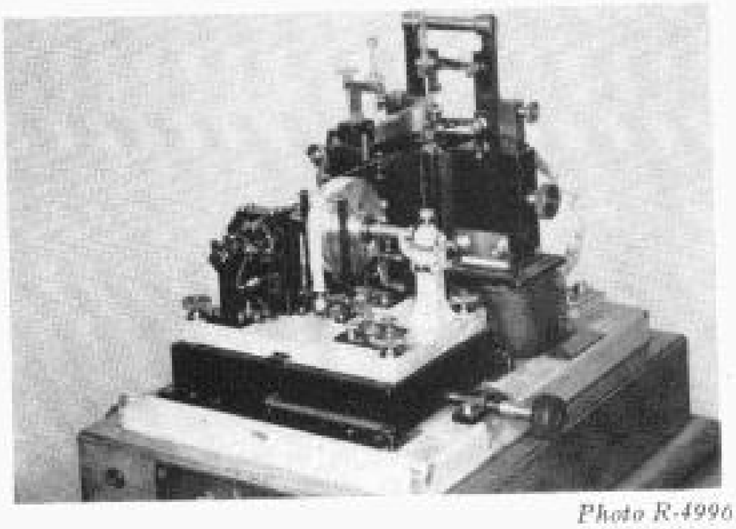


Photo R-4996

Brown drum relay with iridium contact point

standard has an iridium-pointed platinum wire tongue (enclosed in a fine glass tube for stiffness), the movement of which is controlled by the galvanometer coil. With very little pressure this iridium point makes good contact with the insulated silver rings of a rotating drum and the friction resisting lateral movement is small.

In the Muirhead gold wire relay, the coil controls the movement of a gold wire between two platinum contacts. The gold wire is maintained in rapid vibration by an electric buzzer arrangement for the purpose of securing better contact. In the Bruce relay[20] developed by an American engineer, the contact scheme consisted of a fine nickel wire controlled by the galvanometer coil which made contact in drops of mercury. The nickel wire was vibrated vertically with respect to the contact surfaces, thus reducing friction to its lateral motion. But even these sensitive relays would not operate well over long cables; the feeble signals were not sufficient to overcome their inertia and friction. Means were therefore sought to amplify the received signal.

Up to this point practically all ocean cable engineering had been done by European firms such as Clark, Ford and Taylor; Telegraph Construction and Maintenance Company; Muirhead & Company, and E. S. Heurtley. But American engineers were beginning to take an active part and Western Union and telephone company engineers became interested in the problems.

Magnifiers

Vacuum tubes were coming into use in the telephone plant and engineers from the telephone company in cooperation with Western Union engineers began experiments with tube amplifiers at Hammel, Long Island, N. Y. By 1918 sufficient progress had been made so that it was proposed to build an operating unit for trial. This was not done, however, because the engineers at that time, although able to get amplification, were not able to "shape" the signals with tube circuits as well as signals could be shaped with a galvanometer-type instrument. The mechanical resonance of the galvanometer coil and suspension had such an excellent shaping characteristic that more than a decade passed by before wholly electrical circuits were developed that could replace this simple instrument.

At least two inventors reverted to the idea of the mirror galvanometer and obtained magnification from the effect of the light beam on light sensitive cells.[21] The element selenium was known to change its resistance under the influence of light and grids of such resistance elements were used as the arms of a Wheatstone bridge. As the bridge became unbalanced the current in the cross circuit changed, thus producing amplification. Western Union engineers worked with both Mr. T. B. Dixon and Mr. K. C. Cox and results were sufficiently promising to warrant the installation of some Dixon magnifiers in the Company's Newfoundland stations.

In England, Mr. E. S. Heurtley had developed another type[22] which worked out so well that Western Union eventually adopted it as standard for all its long cables. The galvanometer coil of the Heurtley magnifier was connected to a pointer suspension by means of fine silk fibers. In the original model of the magnifier the pointer suspension carried only two fine wires which were suspended over a slit in two small tubes. The wires' positions were such that a slight movement of the suspension brought one wire closer to its slit while the second one moved away. The wires were slightly heated and a small stream of air was blown through the slits. As the heated wires moved into and out of the air stream the resistance of the wires changed and since they were connected as

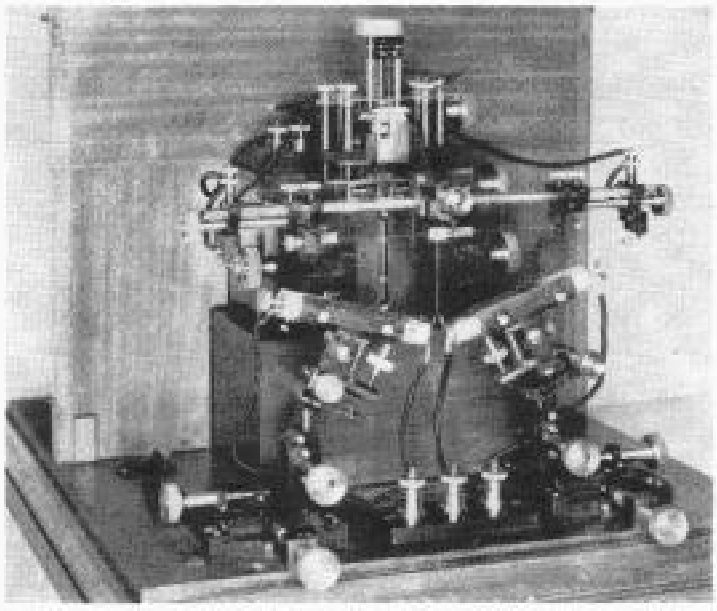


Photo R-2705

Heurtley magnifier has bridge circuit

two arms of a Wheatstone bridge this movement unbalanced the bridge. A siphon recorder or cable relay coil connected in the bridge circuit could be operated. This first model was superseded by one in which the slit cylinders were replaced with the same type of wire used for the cradle wires and these were heated. As the cradle wires approached or retreated from the stationary wires heat was transferred. All four wires were used in the Wheatstone bridge and with almost infinitesimal motion of the galvanometer coil about ten times as much current variation could be produced in the siphon or relay coils as that which passed through the coils of the magnifier. In other words, an amplification factor of about ten could be realized. The Heurtley suspension was well-made but delicate. The bridge arms were made of Wollaston wire which is drawn from an ingot having a platinum core surrounded by silver. When drawn down to 0.003-inch outside diameter the platinum core is 0.0003 inch in diameter. After "stringing" the cradle the silver is burned off by means of nitric acid thus leaving only the very fine platinum wires which are subject to a considerable change in resistance with change in temperature.

Although selenium magnifiers which had been furnished the cable stations remained in use for several years the new model Heurtley became the Western Union standard for all stations about 1918.

Auxiliary Apparatus

There were other needs to be supplied and other limitations to overcome before direct working could be established on a grand scale. Western Union engineers began to supply these needs with Western Union designed equipment. They developed specifications for siphon recorder paper, for tape reels, direct writers, tape pullers, and so forth. A superior type of magnetic shunt was developed and furnished for the long cables. Now that more power was available to operate recorders or relays, some power could be sacrificed for better signal shape. This problem was studied and improvements made.

Work on balancing and associated problems started a thorough study of ocean cable transmission which led to the publication in February 1922, by Mr. J. W. Milnor, of his AIEE paper on "Submarine Cable Telegraphy"[23] the appendix to which developed a method for signal analysis based on alternating-current theory. This method became the preferred theoretical approach to many cable transmission problems.

Regenerators

While this work was in progress engineers working on the land line system had introduced rotary repeaters into the land line plant.[24] These repeaters not only built the retransmitted signals up to full amplitude but also regenerated them with respect to time so that the retransmitted signal became a true duplicate of the signal transmitted from the originating transmitter. Ocean cable engineers picked up this development with a view to applying it to cable practice. This required not only the redesign of the rotary but also new transmitting equipment in order to obtain the speed stability necessary for synchronism between the originating point and the repeaters.

The phonic motor, which was used to drive distributors for multiplex terminals and rotary repeaters, and its associated driving fork were adapted to drive an improved type cable transmitter.[25, 26] This transmitter permitted the accurate transmission of 3-current (plus, minus and zero potential) signals and provided for transmitting automatic reversals to keep the rotaries from running out of synchronism when there is no slip in the

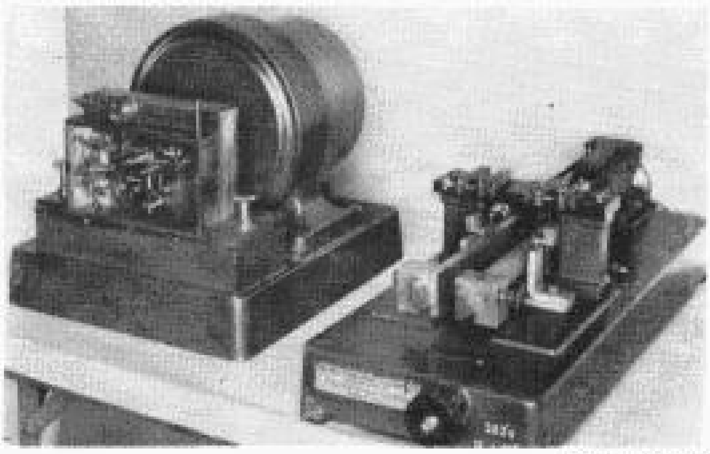


Photo R-2708

Phonic motor driven transmitter with fork

transmitter, and for varying the percent of "curbing." This latter feature permitted better shaping of the received signals.

The circuits of the land line rotary repeater were redesigned to provide for the reception, regeneration and retransmission of 3-current signals.[27] Since cable speeds were low compared with land line speeds, the "pickup" segment was made only one-tenth the length of the received dot or dash. Theoretically the received signal could be distorted as much as 45 percent plus or minus without failure of the rotary to retransmit a perfect signal.

The first regenerator went into service in the fall of 1921 and signals could now be repeated from one cable section to another without passing on distortion. The speed of service was materially improved and the eventual adoption of direct working between London and New York led to an annual saving estimated in 1925 at $375,000.

This development was copied by all telegraph administrations throughout the world. Regenerators of various types were produced but the basic plan was always the one originated by Western Union engineers. But the ability to pass 3-current signals through a rotary was not an unmixed blessing. Three-current signals work well on ocean cables but in transmission over land lines they are difficult to handle. Signals from two neutral relays or two biased polar relays are particularly subject to interference, such as line hits and induction during the zero or no-current intervals. Since most Western Union cables terminate in North Sydney and have to be connected to New York by means of land lines roughly 1600 miles long with several repeater points, the use of 3-current signals on these lines was a constant source of trouble which led not only to errors but also to delays caused by need for frequent line-ups and regulation.

This trouble was largely overcome by an invention which was developed independently by an American and a British inventor.[27, 28] It took advantage of the fact that the land lines were easily capable of twice the speed of the long cable. The regenerators at the long cable terminals were made to convert the plus, minus and zero signals to signals of only 2-current value. A dot was converted to one positive and one negative pulse, a dash to two positive pulses, and a space to two negative pulses. At a later date, this was changed to two plus pulses for a dot, two minus pulses for a dash, and a plus pulse followed by a minus pulse for a space.

At the terminal end a similar rotary repeater changed the 2-current signals back to the 3-current recorder code which was transmitted into a direct writer from which the operator transcribed the messages. In the opposite direction the terminal sent 2-current signals to the rotary at the cable station and this rotary converted the 2-current signals into 3-current signals for transmission into the cable.

On the American side this system was first tried out on cables from South America which terminated in Florida and used land lines to New York. After successful trial similar equipment was installed in Newfoundland and New York. Two-current signals were thus transmitted over the connecting cables to North Sydney and the land lines from there to New York. The system was also applied to Telegraph Company land lines in Great Britain.

With the adoption of rotary repeaters equipped to regenerate 3-current signals as they passed from one cable into another, and also to convert the 3-current signals into double-current signals and vice versa when it was desired to interconnect a land line and a cable, the operation of the cable plant became much more stable. Western Union adopted the new type Heurtley magnifiers and Brown drum relays as standard equipment throughout its system. The staffs at the cable repeater points gradually shifted from a cable operating force to a technically trained group capable of keeping the delicate magnifiers and relays in perfect operating condition and of maintaining rotary regenerators and associated equipment in working order.

Engineers continued work on balancing and interference problems. Artificial line rooms not only were built with insulated walls but thermostatic control was also placed on the heating facilities so that close temperature control could be effected. This contributed greatly to stability of cable duplex balances. By the middle 1920's cable operation was pretty well established. Kleinschmidt perforators had replaced the old mallet-type several years back, so the sending operator

Photo M-462

Kleinschmidt cable code perforator

prepared his tape on this keyboard machine and since the signals which passed over the "bridge" on the typewriter in front of the receiving operator had been regenerated before being fed to the direct writer, the uncertainty which often existed in the interpretation of signals coming from a siphon recorder was eliminated. With this favorable picture in mind this appears a good point at which to break the narrative on cable development to discuss an experiment which had not yet come to a successful conclusion.

Printer Experiments

Printing telegraphy was the aim of numerous inventors in the telegraph field. Western Union's earliest beginning was in fact founded on the House printing telegraph system.[29] But although the Hughes and Baudot printing systems[30] had found ready acceptance in Europe, the United States, except for stock tickers, did not go in for printing telegraphs on any large scale until the Barclay printing telegraph[31] became prominent around 1910. By 1914 about 20 percent of the Company's business was handled by printing systems and the trend to printing was greatly accelerated when multiplex was adopted as standard trunk line equipment in 1915. Single-channel start stop systems were employed subsequently. It seemed obvious that efforts should be made to apply printing techniques to the ocean cables.

The Baudot code, which was adopted for multiplex operation, is a 5-unit code whereas the 3-current cable recorder code works out to be a 3.7-unit code. Speed could not be sacrificed on the cable, hence it seemed necessary to adopt an alphabet at least as short as the recorder code.[32] A 3-unit code made up of plus, minus and zero intervals was developed for the cable code printer, such a code giving a maximum of 27 combinations. A combination in the lower case was assigned to each letter of the alphabet except J and V, plus combinations for a space, figure shift and letter shift. Upper case provided for the numerals, punctuation marks, and the letters J and V. Since some characters were in the upper case the actual average length of the code was something greater than three units. Specifications 728-A covering the system were issued in August 1918 but equipment had been built while the specifications were being written and dispatcher's logs for early 1919 have frequent references to one of the cables being worked printer experimentally quite successfully.

As compared with recorder code, printer operation before 1930 had several handicaps. Traffic was heavy and every means was employed to make transmission as short and fast as possible. With recorder operation on arbitrage (stock) traffic, a separate series of message numbers was used and in this series it was understood that the "office from" was London and "destination" New York and vice versa for eastward traffic. The office from and destination were therefore not transmitted but the receiving operator wrote them in. Since arbitrage messages are short, this was a great short cut. Other short cuts were also used, as for instance the substitution of "short numbers" for the long characters assigned the numerals in the continental Morse code. The letters a, u, e, d, n and t were used in place of 1, 2, 5, 8, 9 and 0, respectively. Another important advantage of recorder working was that when balances varied or the siphon recorder went out of adjustment, which was annoyingly frequent, the operator could tell that the signals were deteriorating and becoming more difficult to read. He could therefore stop the circuit for adjustment before errors were actually passed on to the customer. With printer operation, magnifier and cable relay adjustments as well as balance were still subject to change and the printer kept right on interpreting signals as they came to it without the ability to detect deterioration; hence errors were often passed into final copy before it was realized that reception was poor. In view of these handicaps the early printer experiments did not result in a permanent conversion to printer working at that time.

New Cables

In order to place the next major development in its right perspective, it is necessary to examine the cable business and plant as they were in 1918 at the end of World War I. Cable business had grown immensely since the newest of the cables owned or operated by Western Union was laid in 1910. All Western Union operated cables had reached an age at which faults could be expected at not infrequent intervals. During interruptions to one or more cables traffic suffered, sometimes severely. During the winter of 1918-19 messages accumulated due to loss of the Penzance-Valentia connections. It was inevitable that plans should be made for additional cable capacity. After the war the German cables were allocated to various of the allies and the Germans were anxious to rebuild their cable business. The Italians were also determined to connect with both North and South America. Discussions took place having in mind a Western Union cable to the Azores to connect there with a German and an Italian cable.

Perhaps even before these discussions had really taken form, a development by the Bell Telephone Laboratories interested them in cable development. Up to this time no significant change in the construction of the cable itself had been made and all telegraph cables laid up to and including 1923 were essentially the same as the 1858 cable. They had a copper conductor, usually wrapped with a copper tape as an insurance against fracture of the solid core, covered with gutta-percha, then jute, armor wires, and an outside jute or braid covering. The size of core, amount of gutta-percha and armoring had varied to meet the speed required and the condition of the ocean bottom where the cable was to be laid. The principle of improving transmission characteristics by adding inductance, either in the form of coils inserted in the circuit or by wrapping the conductor with a magnetic material, had been developed and was understood. Some comparatively short telephone cables had been continuously "loaded" by wrapping the core with fine iron wire but the permeability of iron is not high enough to make loading with iron wire

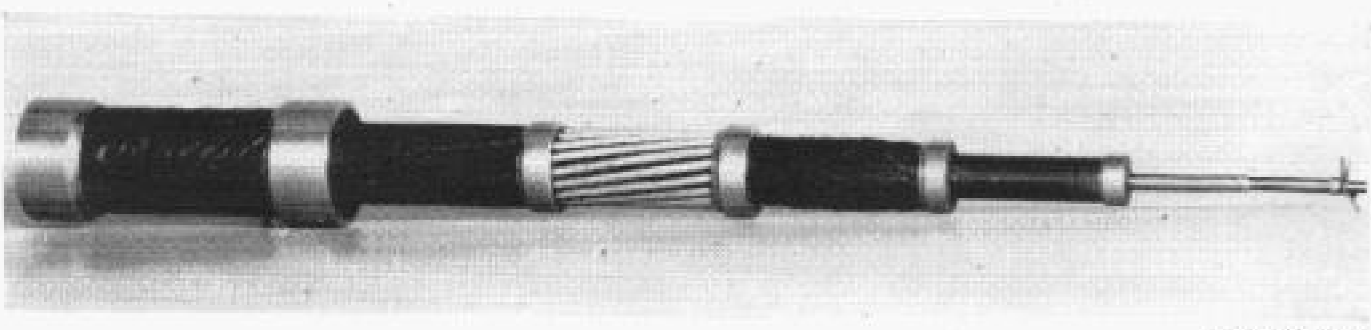


Photo R-2465

Permalloy loaded cable

effective at telegraph frequencies. The Bell Telephone Laboratories' development of Permalloy appeared to provide a material for continuous loading of telegraph cables.[33] Its possibilities were discussed with Western Union and a contract was entered into to test the proposed new type cable and, if tests were successful, to lay such a cable from New York to Horta in the Azores, there to connect with a similar German cable to Emden, and also to pick up traffic from a proposed Horta-Malaga-Rome Italian cable.

A 120-mile length of cable was manufactured by Telegraph Construction and Maintenance Company, and this length was laid by the Cable Ship *Lord Kelvin* in a loop in and out of Bermuda in 1923. Tests were conducted jointly by engineers from Bell Labs and Western Union to check attenuation and other parameters of the cable in order to determine that it could be laid in deep water without damage. These tests showed the cable design to be practical and manufacturing was started on the New York-Horta section. It was completed and laid in 1924 and its companion section Horta-Emden was laid in 1926.[34]

Loaded Cable Equipment

It was foreseen that the means for operating this cable must be very different from those for the old-style cables. Because of the difficulty of making an artificial line from relatively simple components that would match the cable in behavior, it was realized that it must be operated in but one direction at a time and that its operating speed would be in excess of the capabilities of conventional magnifiers and cable relays, and above the capability of one operator to send or receive. A new kind of magnifier and some type of channelizing were therefore considered essential.

Paralleling the early design and the work on the cable itself, Bell Labs engineers had developed a signal-shaping amplifier[35] to meet the problem of magnification and a co-operative effort between Bell Labs and Western Union was set up for designing other operating equipment. It was decided to make this of the 5-unit multiplex printing type

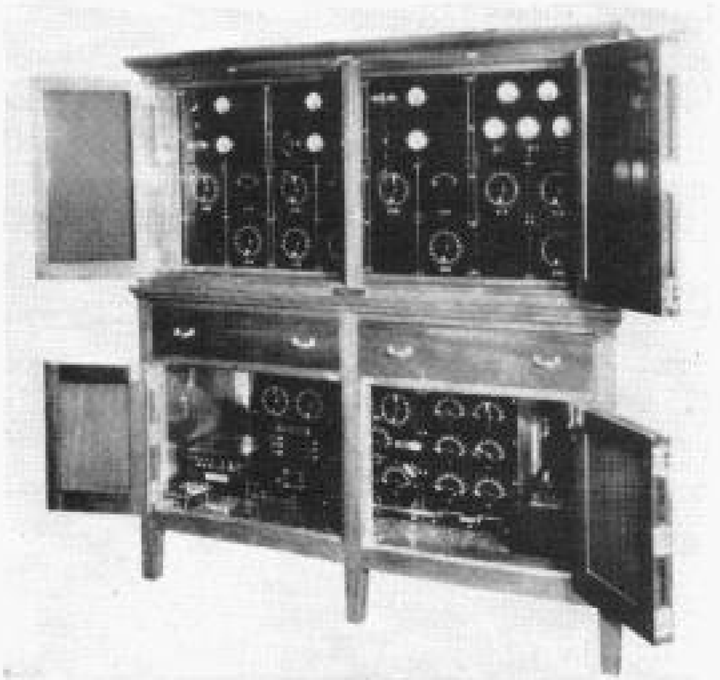


Photo R-11,212

Western Electric signal-shaping amplifier

and the resulting equipment was a simplex 5-channel printing system[36] operating at 315 letters per minute per channel using a synchronous fill-in system.[37] With such a system signals at a maximum speed of 65 cycles are transmitted into the cable. The attenuation of the cable is so great, however, that signals of less than two pulses in length do not arrive at the far end with enough amplitude to operate the receiving relays. Pulses are therefore supplied from the receiving distributor faceplate which anticipate the single pulses and fill them in. These anticipating signals are not strong enough, however, to take control away from the received signals when pulses of 2-unit length or longer are received.

Automatic reversing equipment[38] which can be set for varying time intervals depending on traffic load governs the transmission time for each direction. The turnaround may take place in the middle of transmission from any or all channels without loss of traffic or mutilation of text. Each turnaround requires six seconds.

During the second world war the German section of the cable was cut in the English channel but later was picked up and laid into Cherbourg, France, for the U. S. Army. Western Union supplied operating equipment, trained an army operating team and sent an engineer there to initiate through operation to New York in December 1944. Basically the equipment has not been changed, thus testifying to the soundness of the original design.

Additional Loaded Cables

Even before the New York-Horta-Emden cable had been fully equipped another loaded cable of similar design was laid in 1926 connecting Hammel-Bay Roberts-Penzance. This cable was

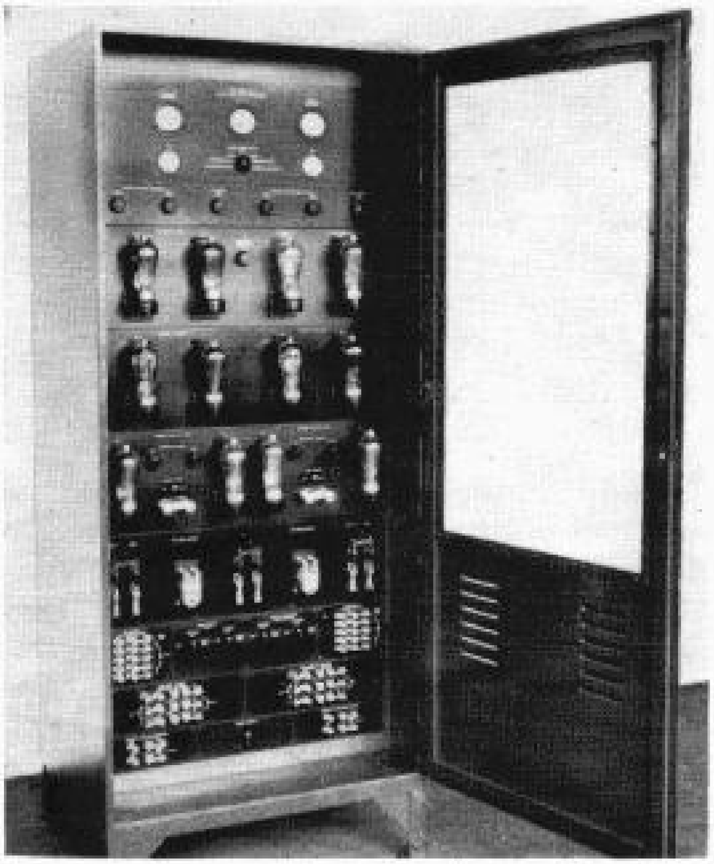


Photo R-1184

Thyratron tube unit for 1926 cable

equipped with Western Electric signal-shaping amplifiers similar to those furnished for New York-Horta-Emden, but the 8-channel equipment with which it was equipped was designed by Western Union without infringing valid patents held by others. To avoid the use of relays at 100-cycle speeds, the stations in Penzance and Bay Roberts used vacuum tube circuits employing thyratrons.[39] It is believed this was the first practical application of these tubes to signalling circuits.

Still another loaded cable was laid in 1928 from Bay Roberts to Horta. This one differed from previous ones in that it was a duplex cable. In order to permit duplexing the loading was "tapered," that is, beginning at the shore end the cable was unloaded, then inductance in the form of loading was started at a point 160 miles from each end and increased in several steps until maximum loading was attained in the center section of the cable. This permitted a close match with the shore section where it was most critical and a decreasing exactness as the distance from shore increased. Although this cable was manufactured and laid by Telegraph Construction and Maintenance Company the basic electrical design of both the cable and its associated artificial line was the product of Western Union engineers.[40]

Methods and equipment for using lump-loading technique in repairing the simplex cables were also developed.[41]

Advantages of Printer Operation

Let us return now to a further discussion of operating equipment from which we digressed to describe the loaded cables laid in 1924, 1926 and 1928. Printer operation of the New York-Horta-Emden cable soon became an assured success and printing systems were therefore installed

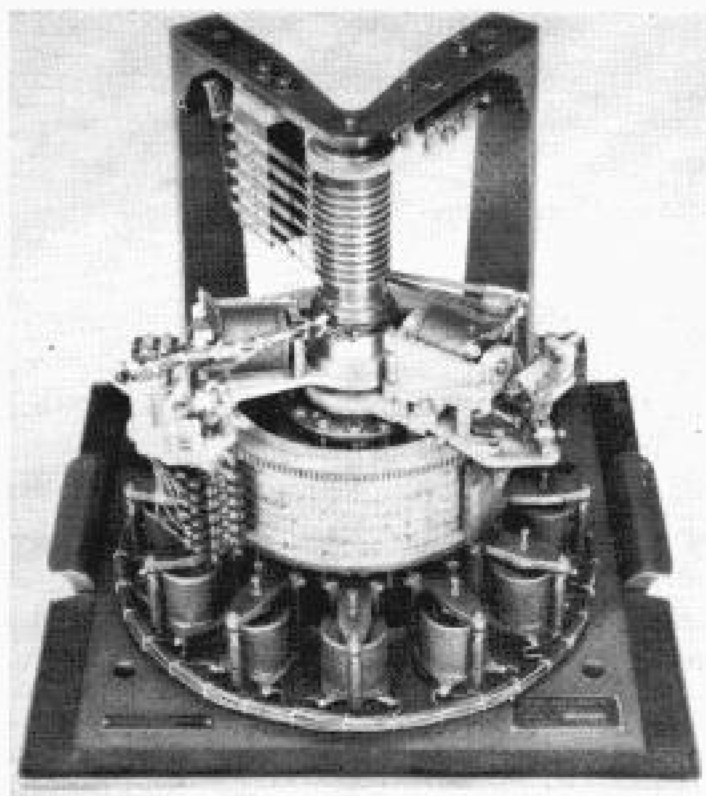


Photo R-555

Storing transmitter eliminated tape loop

on both the other loaded cables. The 1926 cable, since it was a simplex cable, was usually used in the eastward direction during the forenoon when the load was predominantly in that direction and turned only as the load demanded. It was soon found that printer channels into London provided certain advantages. By means of channel repeaters[12] a New York-London channel could be patched into a channel to Amsterdam over the London-Amsterdam 2-channel multiplex. Since Amsterdam handled a considerable amount of arbitrage traffic a storing transmitter[13] was installed on this channel at New York in November 1932, thus eliminating the delay due to the tape loop between the perforator and the transmitter.

When this transmitter was installed London soon discovered that arbitrage messages were reaching Amsterdam with less delay than similar messages to London which were handled over recorder operated cables. The solution was, of course, to provide London with arbitrage channels equipped with storing transmitters on the 8-channel printer operated cable. In order also to give Liverpool and the Shorters' Court (Stock Exchange) branch similar service, receiving channel assigners[14] and channel repeaters were installed in London so New York could select either London or Liverpool on one channel and London or Shorters' Court on another by a selecting signal in the tape. Similarly, when the cable was turned westward, Montreal and Toronto were connected through by means of channel assigners and channel repeaters, and by using a sending channel assigner[15] either London main or

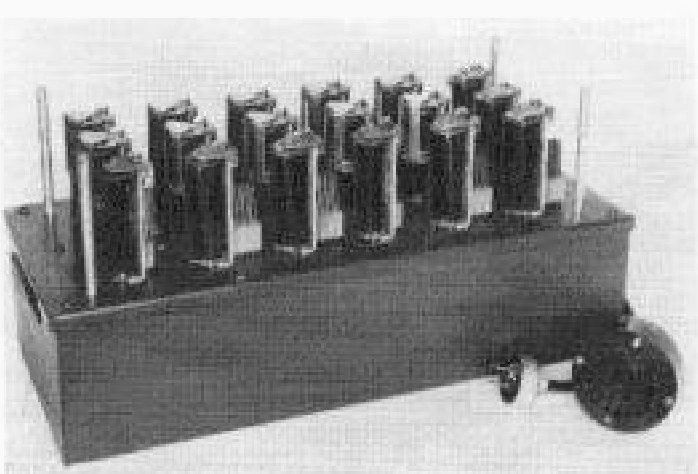


Photo R-2452

Channel repeater permitted interconnecting individual channels

Shorters' Court could select either New York, Montreal or Toronto on the same channel. This provided superior speed of service for this class of traffic. By means of MXPX repeaters[16] it was also possible to connect teleprinter signals from remote points into the cable and this was made use of for special events such as "Ginners' Reports" originating in Washington, and by press circuits for events which were of special interest in England and on the Continent.

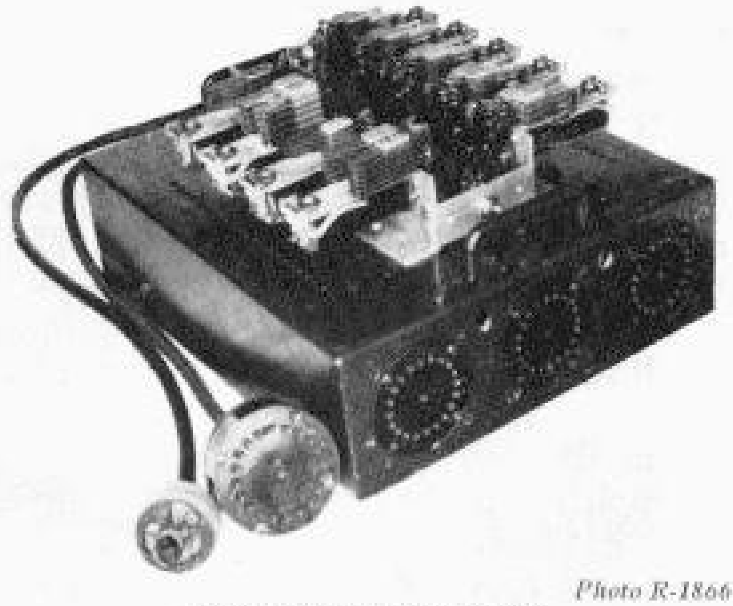


Photo R-1866

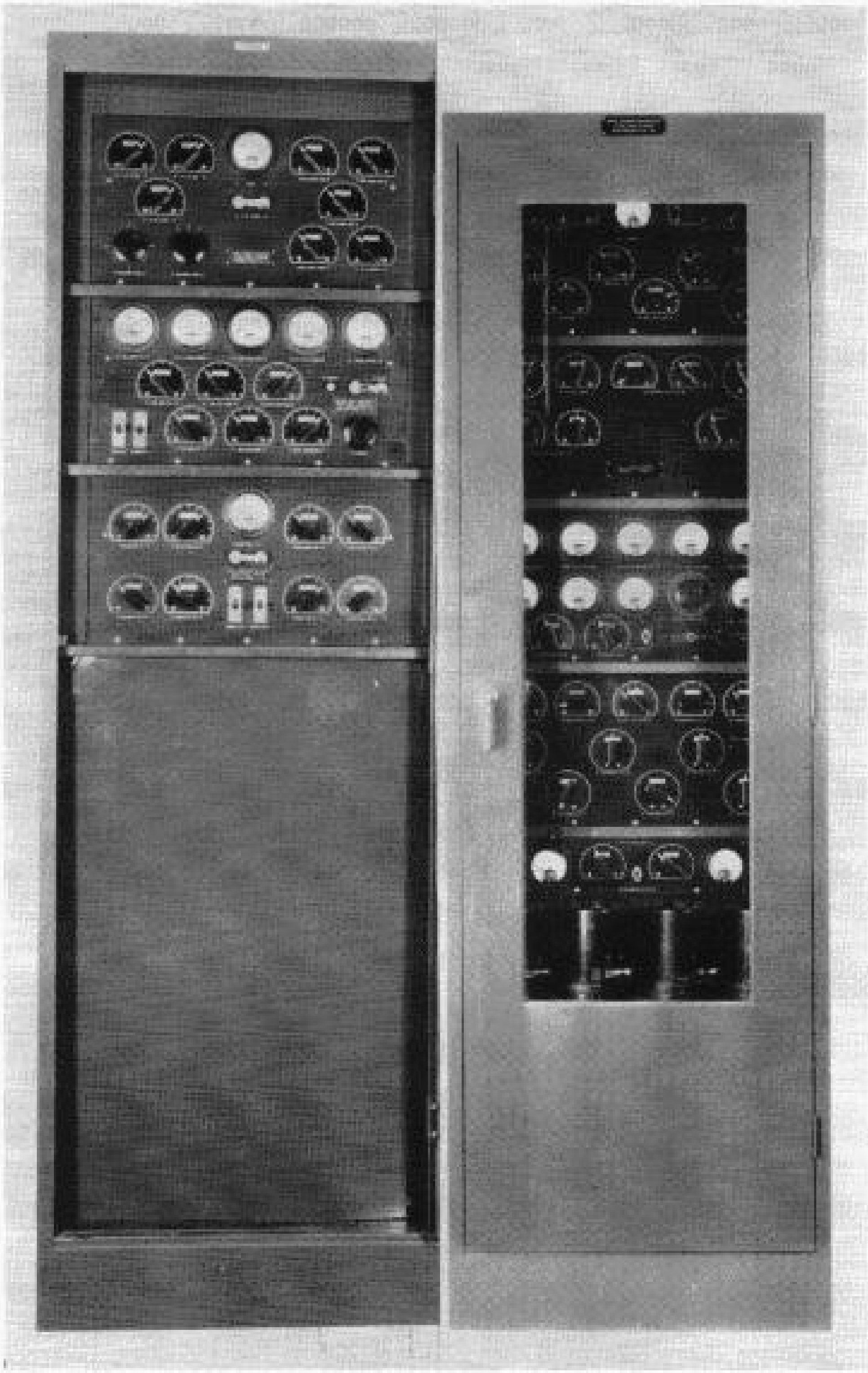
Receiving channel assigner

The flexibility of printer systems over recorders led to a reappraisal of printer versus recorder on old-style cables. It was no longer merely a race to see which system could handle the most business. The operating department became willing to forego some of the short cuts possible with recorder code, such as omission of office from and destination, in order to gain the greater flexibility and speed of service possible with printer operation. Printer experiments had in fact been carried on almost continuously since those mentioned earlier were discontinued, using at one time a single-channel system based on the Baudot code and synchronous fill-in circuits as already mentioned in connection with the high-speed cables. At a later date a system designed on the principle of a variable length code in which the shortest signal transmitted was equal to two units of the code was tested.[17] Single-channel conventional multiplex was also tried on the faster cables operating simplex at twice duplex speed. But at the required speed of 500 lpm the Heurtley magnifier and drum relay suspensions had to be strung up so tight that the output of the Heurtley was reduced and the power required to operate the drum relay increased to beyond the power output of the magnifier.

Vacuum Tube Amplifiers

It was then suggested that at this higher frequency a booster amplifier might be interposed between the Heurtley and the drum. Such a booster was built and tested in our laboratory and then taken to Hearts Content to try out. While this was going on, the engineers came to the conclusion that at the higher speed it appeared possible to shape the signals by electrical networks sufficiently to feed directly into an amplifier which would then feed into the drum relay where final shaping could be applied. Another amplifying stage was added to the booster and this combination of shaping, two-stage amplifier, Brown drum relay and local correction was tried out. It worked out so successfully that it was placed in traffic service on the 4VA cable, two channels simplex westward at 250 lpm per channel, on March 23, 1933. Amsterdam was connected through to New York on one channel, London on the other. By the following year an improved version had been constructed in a steel cabinet and a unit of this type was furnished for use on 2VA November 5, 1934. Tests proved that this amplifier could be used on recorder code at 240-lpm duplex as well as 500-lpm multiplex-simplex.

Pressure to produce vacuum tube amplifiers suitable for replacements for magnifiers and cable relays developed due to other reasons than the desire to employ printer operation. One compelling reason had to do with the problem of connecting cables. As originally provided, only three cables were laid (two single, one bicore) between Penzance and Valentia to feed four transatlantic cables, and six cables (five single, one tricore) connected Newfoundland with the mainland to feed eight transatlantic cables and provide a Halifax-St. John's local circuit and a talk wire. Whenever a connecting cable was interrupted a transatlantic facility became idle. When the Bay Roberts-Horta cable was laid no new connecting cable was provided but a Pernot carrier[48] was installed on the 3Z-HC cable from North Sydney to Hearts Content. In addition to paying for the cost of the equipment Western Union paid a yearly royalty for this facility.



Photos R-2347 & R-3023

First long nonloaded cable amplifier had drum relay in output (left). First long nonloaded cable amplifier with polar relay output (right)

To improve this situation the engineers proposed combining two transatlantic facilities into one connecting cable. These cables were all capable of the increased speed but the galvanometer-type instruments became more difficult to keep in adjustment as the frequency increased. Vacuum tube amplifiers were the obvious answer to the problem of high-speed connecting cables. Although certain desirable types of shaping networks were not available to Western Union's use because of patent restrictions, engineers concentrated on the problem and a model job for installation at North Sydney was made up for use on the St. Mary's Bay cable between Bay Roberts and North Sydney.[49] This was placed in service in December 1932. By 1934 amplifiers designed for use on low-KR cables had also been supplied to Penzance and Valentia so that double-current signals could be handled between London and Valentia at speeds up to 30 cycles without the use of cable-type relays.

Development of amplifiers for both long and short cable continued. Primary cable shaping networks suitable for use with vacuum tube amplifiers on long cables were engineered,[50] and means for applying local correction to the amplifier output were also developed.[51] These were incorporated in the Type 555 amplifier, which went into service in June 1936. The output was from two 17B Polar Relays which were operated by signals of sufficient power to require no special relay adjustment. Further improvements were made in shaping networks[52, 53] and the latest type amplifiers were put on the longest cables, the older types being used on the connecting cables to the mainland.

These signal-shaping amplifiers of Western Union design have been so successful that the Company has had to turn supplier for other cable companies. Amplifiers have been furnished to the U. S. Government for the Alaska cables, to Commercial Cable Company, Italcable, and the Canadian Overseas Telecommunications Corporation. Types suitable for high-speed cables also have been developed. These amplifiers are less vulnerable to interference than the original Western Electric amplifiers, some of which have been replaced with the newer Western Union types.

Plowing Operations

In order not to get our chronology too far out of line we must here describe another Western Union development which affected the cables themselves. For years fishing trawlers have been the cause of many cable failures in intermediate-depth waters. These ships drag behind them huge nets equipped with so-called otter boards which hold the net open and close to ocean bottom but which also unfortunately act as grapnels in that they often pass under the cables. As the trawler proceeds, either nets, towlines or cable must give and it is often the cable.

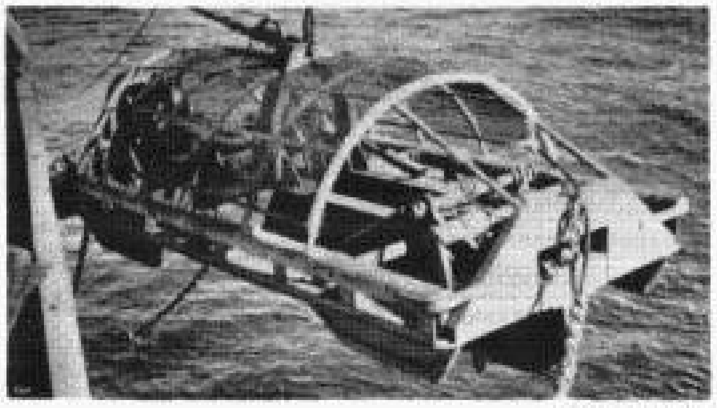


Photo M-2475

Cable plow put cable in ocean bed

To make Western Union less vulnerable to failures caused in this manner it was proposed to plow furrows on the ocean bottom and lay the cables in these furrows. A submarine cable plow,[54] and a depthometer[55] to determine the success

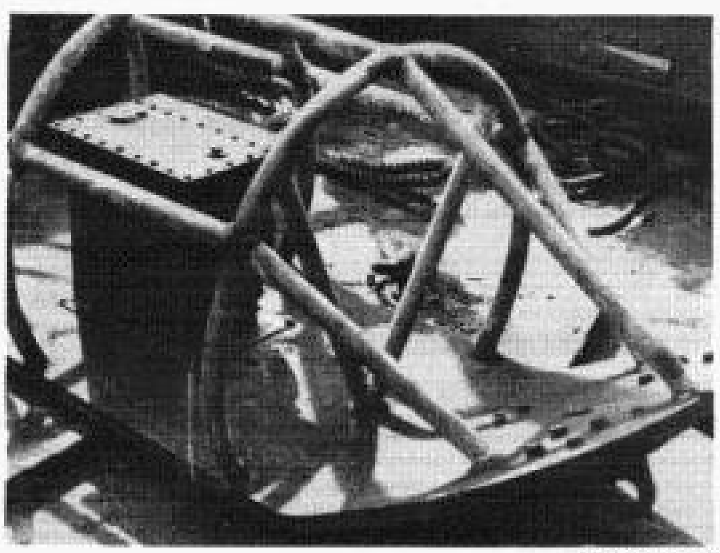


Photo H-480

Cable depthometer

of each plowing operation, were developed by Western Union engineers and built to their specifications. Plowing was started on the cables entering Penzance and three of them were successfully made invulnerable to trawlers in this area before World War II halted these activities.

Equipment for Miscellaneous Services

Another activity should also be mentioned at this juncture. The transmission of news pictures had become commonplace between cities connected with land lines and there was a demand for transatlantic pictures as well. Radio facilities were used to some extent but pictures were often distorted due to fading and other types of radio interference. It was thought that transmission via the loaded cable during off-peak hours might be profitable. A development was therefore started which resulted in a cable photo transmission system[56] which was placed in operation in April 1939. The quality of picture was considered a great improvement over that of the radio product then current. Since the off-peak time available for picture transmission was not great and due to the way news pictures "break" it was difficult to meet the demand. Continued improvement in radio pictures also made the competition keener and eventually the war made such a demand on cable facilities that the service was discontinued.

A shortage of staff at the Horta cable station, due in part at least to the war, brought a request for an automatic means for producing cable recorder code slip directly from signals received over multiplex printer channels from New York. Such a device would end the need for gumming up received printer tape from New York and perforating new slip manually for transmission over the Italian cable to Malaga and Rome. A multiplex to recorder code translator[57] was produced by adding multiplex selecting mechanism to a Creed perforator and parts for making this conversion were air mailed to Horta from New York in the winter of 1940 and immediately placed in service. Such units are still in use there. At a later date its counterpart—a recorder code to multiplex translator—was produced and placed in service at the cable office in New York to terminate one of our connections to Cable and Wireless' South American cables. The speed of this connection was increased eventually beyond the range of the translator and its use was discontinued.

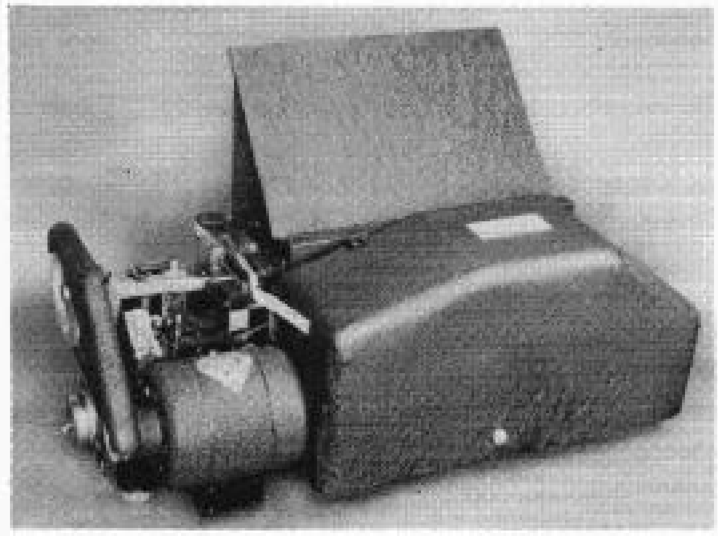


Photo R-6101

Multiplex to cable code translator

A different activity was directly due to the war. Western Union, having converted its cable operation to printer working, was in a position to provide direct teleprinter connections for government agencies such as the State Department with their counterparts in England and such facilities were set up on a leased wire basis. There were, however, requests for such leases for more direct connections than Western Union had cables. The combined loads from these agencies were not too great, and the demand for instant service was the governing factor. To meet this condition it was decided to install varioplex[58] equipment between New York and London. This equipment in its land line form is connected to a duplex facility direct, and serves to subdivide the total capacity of this facility between a number of customers each of whom obtains a direct connection to his distant counterpart merely by starting to transmit. When transmission stops, he is automatically disconnected from the facility. Unfortunately, the cables were not set up on a duplex basis with the proper capacity in each direction to handle a standard varioplex. The engineers met the situation, however, by superimposing varioplex equipment on a channel basis so it could be patched into either two or three available channels in each direction. Often the eastward and westward messages traveled over different routes; for example the eastward channels could be in the 8-channel cable via Hammel-

Bay Roberts-Penzance to London, while the westward routing was via Penzance-Valentia-Hearts Content-North Sydney to New York. As far as the customer was concerned it did not matter, to him it was a direct connection to his correspondent, available for traffic in one or both directions simultaneously as soon as either end started to transmit.

At the conclusion of the war, the various government agencies (with the exception of the State Department) no longer required these direct facilities. A means for switching customers into the available channels for short time durations was therefore added, thus providing a new service which became known as IMCO (International Metered Communication).

Another war-induced development resulted in the production of equipment for transmitting automatically enciphered traffic over the cable multiplex channels. Such traffic makes use of all 32 combinations possible with a 5-unit code. These 32 combinations are all usable with teleprinter signals which make use of a separate start pulse, hence the all-spacing character (blank) can be utilized as a signal. But on multiplex circuits the blank is the idle condition and blanks are therefore deleted at the receiving end. This resulted in development of translators in which tape containing blanks was reperforated into a tape wherein other characters were substituted for the blank. Three changes were necessary: a blank was converted to an X; an X in the original tape was converted to two letters, an M followed by an X; and an M in the original tape was converted into two letters, M and M. Another translator at the receiving end reversed the process thus finally delivering an exact duplicate of the original encoded teleprinter tape. During the war this translation was always done on an "off-line" basis. It was a separate conversion done on a local circuit. As the use of such encoding increased, "on-line" methods and equipment were developed.[59, 60]

Carrier Connecting Facilities

Perhaps the next major step in the development of the Western Union cable system was the conversion of the land line connecting facilities to carrier operation. As previously mentioned a large part of Western Union's transatlantic business must come down from Nova Scotia via land lines. Although 3-current signals passed out of the picture with the introduction of 3- to 2-current converters and the use of multiplex, land line hits and swings continued to give the land line transmission a poor reputation as against the transmission carried to New York over the Bay Roberts-Hammel cables.

This situation was greatly improved in the fall of 1952 when two 2-wire System E carriers[61] were installed on the North Sydney-Bangor land line with carrier repeaters at St. John and New Glasgow. At Bangor they are connected to a 4-wire voice-frequency band to New York. These systems were equipped with nine wide-band (300-cycle spacing) and one narrow-band (150-cycle spacing) channels. The wide-band channels carry four channel multiplex circuits with so little loss that in the eastward direction the signals are repeated directly into connecting cables to Newfoundland without the use of regenerators.

Since the circuits from Bangor to North Sydney are open wire and since either system will carry the total cable load, the circuits from Bangor to North Sydney are operated in parallel. This permits the repeater men at the receiving terminals to choose whichever system is in the best operating condition whenever line or equipment trouble appears and pass the best of the two outputs into the connecting circuits.

These facilities worked out so well that the engineering department requested permission from the British Post Office to lease voice-frequency bands between London and Penzance and equip them in the same manner. This was granted after the British Post Office had assured themselves that our operating levels were compatible with their facilities and duplicate voice bands were assigned as far as possible over diverse routes between London and Penzance in 1954. Each route provided more facilities than ever had been used before when leasing separate direct-current facilities and even with a complete fall-back system there was a saving in rental. Simplification of equipment at Penzance by omitting regenerators in the westward direction was also possible.

To insure against signal deterioration without repeater attendants being aware of it both the Bangor-North Sydney and the

London-Penzance systems were equipped with automatic level detectors which set off an alarm if the levels fall below a predetermined value.

The use of wide-band rather than narrow-band channels was decided upon due to the fact that all connecting cables could be made to carry a 50-wpm quad multiplex with satisfactory margin and when so equipped would have a greater total capacity than the capacity of the transatlantic system. The facilities between New York and Newfoundland, and between London and Penzance and Valentia, were then set up on a quad basis with channel repeaters at the long cable terminals. All cable channels are set to work at 50-wpm channel speeds and all sending distributors at New York are supplied power from a common frequency source. London has a similar common frequency supply. Western Electric vacuum tube forks are supplied as the primary source of driving frequency. At the repeater points the sending distributors are controlled from forks which in turn are driven from a frequency taken from the corrected receiving distributors. When the channels are tied together in this manner the auto-stop feature of the channel repeaters does not come into play but the advantage of using channel repeaters as against a straight relay bank lies in the fact that no phase relationship need be established when changing the routing of a cable channel at a repeater point. The channels can be interconnected almost as easily as separate circuits.

Submerged Repeaters

The late J. J. Gilbert of the Bell Telephone Laboratories, who had a great deal to do with the design of loaded cables, developed the theory of long sea earths based on the fact that in deep sea water the cable was well shielded from electromagnetic disturbances but such disturbances were encountered after the cable came into comparatively shallow water.[62, 63] By laying a sea earth which carries the ground connection out to deep water the same disturbance is picked up on this earth as on the cable but in opposite phase, thus neutralizing the disturbance.

As early as 1945 a Western Union engineer conceived the idea[64] that a submerged repeater, powered over the cable itself, if placed at the point where the cable emerges from deep water into the continental shelf could greatly increase the capacity of a cable through the repeater's ability to raise the signal level to a value which would override the disturbance.

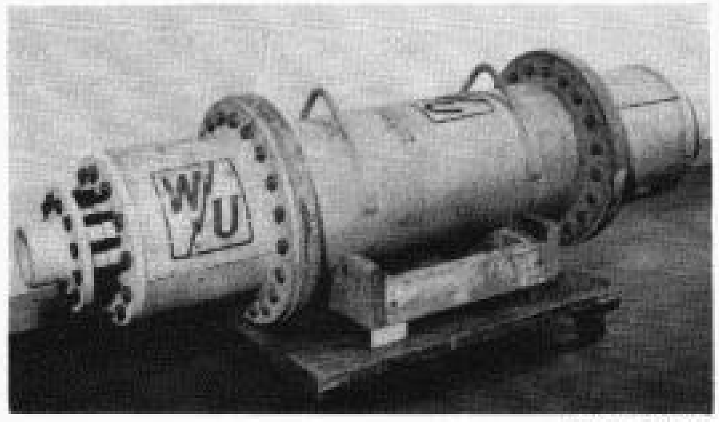


Photo R-9881

Submerged repeater

This idea was further developed by other Western Union engineers[65] and by 1950 a prototype was inserted in a slow-speed cable 170 miles from Newfoundland. This was successful in increasing the capacity about three times. Other repeaters were built for all of Western Union's long nonloaded cables[66] with a marked increase in the capacity of the ocean cable plant. Actually 19 additional 50-wpm channels were added through the insertion of repeaters. It was, of course, necessary to provide additional multiplex equipment to carry this load and the best cables were provided with 6-channel simplex equipment in place of the duplex equipment that had been used to carry a total of three channels before the advent of the submerged repeaters.

In passing it is interesting to note that with all this increase in transatlantic capacity the short cable connections and connecting carrier facilities as engineered are able to carry, with some margin, all of the added load.

Further study of the cable system has led to the belief that a still further increase can be obtained by adding a second repeater to each cable. Two such repeaters have been built but have not yet actually been placed in service. To achieve the hoped-for additional capacity two types of 12-channel equipment have been provided for test and service. One of these is of the conventional type with motor-driven brushes passing over suitable faceplates. The other is a completely electronic distributing system employing transistors in place of tubes. The 12-channel speed may establish a limit for the mechanical type distributors, in which case the electronic type should be able to carry on to even higher speeds.

This brings us up to date on Western Union's association with North Atlantic cables since the first was laid in 1858. In one hundred years Cyrus W. Field's dreamed-of facility that would carry intelligence between the Old World and the New at speeds of a few words per minute has evolved into a mighty artery of communication with thousands of words per minute successfully parading across the North Atlantic.

* * * * * * *

The author wishes to recognize the help of Mr. C. F. Nelson, formerly General Traffic Superintendent, Western Union International Communications, and several other co-workers in checking and revising the original draft.

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H. H. Haglund, Assistant Director of Applied Engineering, joined Western Union in 1911 as an installer. When Barclay automatic equipment was introduced into the Company's plant, he transferred to the operating department and worked as an automatic chief, progressively in charge of Barclay, Blue Code Morkrum, Green Code Morkrum and Multiplex equipment. During this period he also studied at the University of Utah where he obtained his engineering degree in 1921, and was subsequently transferred to the Engineer of Automatics' staff in New York. In 1925 he represented Western Union in cooperative work with Bell Telephone Laboratories on equipment for the first loaded cable, and supervised its installation and tests at Horta. Mr. Haglund in 1928 became head of the ocean cable equipment group which developed and supervised the installation and testing of new type automatic equipment for old style as well as new loaded cables and, during the war, for the Army's Alaskan and Aleutian Island cables, the Commercial Cable Company's and the Commercial Pacific Cable Company's cable. He is a Fellow of AIEE.

FRED W. SMITH, Assistant to Apparatus Engineer

Some Recent Western Union Developments In Printing Telegraph Apparatus

Four varied devices are among noteworthy mechanisms auxiliary to some modern printing telegraph systems. One such mechanism which has ingenious controls and alarms automatically separates telegrams received on pack folded blanks. . . . A tape transmitter device repositions and "resends" perforated tape automatically. . . . A new tape crimper helps relieve static and humidity troubles in tape accumulators. . . . And a new tape winder gives uniform roll tension.

THIS paper describes a number of recent developments in printing telegraph apparatus which, taken individually, are not of sufficient magnitude to warrant presentation in full length papers, but which are nevertheless considered noteworthy contributions to the printing telegraph art. The developments described include:

1. A message-separator page teleprinter mechanism which automatically separates messages received on pack fold paper and drops them into a conveyor belt for automatic distribution or into a storage bin where they are held for manual distribution.
2. A loop-gate tape transmitter which transmits part of the message perforated in a tape for the purpose of automatically switching the message, then retransmits this portion of the tape and transmits the remainder.
3. A tape crimper which crimps perforated tape in order to stiffen it and then pushes the tape into a tape accumulator even when atmospheric conditions are such that static electricity collects on the paper tape and tends to retard its motion. A tape-motion alarm is available as an optional feature to provide visual and aural alarms if defective perforating equipment fails to feed out the tape properly.
4. A tape winder embodying a new tape snubbing device which permits chadless perforated tape to be wound with uniform tension regardless of the diameter of the roll of tape.

A paper presented before the Winter General Meeting of the American Institute of Electrical Engineers in New York, N. Y., February 1958.

Message-Separator Teleprinter

The recently developed message-separator teleprinter permits unattended reception of messages on page teleprinters and provides automatic separation of each message. Incoming messages are ejected from the teleprinter onto a conveyor belt so that messages from all teleprinters in an office are automatically directed to a central editing and sorting position. The teleprinters and associated automatic control units require attention only in response to a trouble alarm.

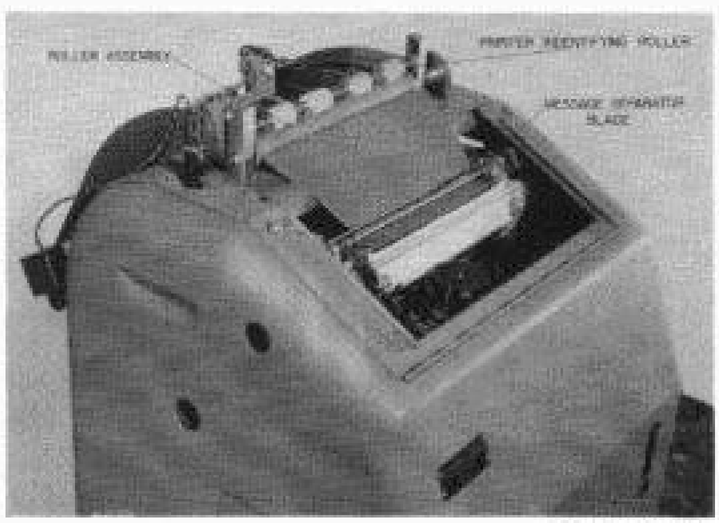

Photo R-10,856

Figure 1. Receiving-only teleprinter showing message separator

The essential parts of the message-separator mechanism are shown in Figure 1. The message separator blade mounted above the platen assembly provides a cutting edge which is aligned with the perforated line between adjacent telegram forms on the sprocket feed pack fold paper at the time that a message is to be separated. The blade is curved outward at the center so that separation of a message begins at the center of the form and progresses outward. Mounted on top of the teleprinter cover is a roller assembly consisting of a hard rubber roller and a shaft on which are mounted four metal rollers. These metal rollers are held against the hard rubber roller by means of compression springs. When a complete message form has been fed out far enough so that the dividing line between forms is directly opposite the separator blade, the hard rubber roller is rotated momentarily by a small motor. At this time the top of the blank is just touching the rollers. When the motor starts, the rollers rotate and pull the top message blank between them, causing the blade to separate this message along the perforated line, and then eject it from the rear of the rollers into a chute which guides it to the rear of the printer, as shown in Figure 2. The bottom of the chute is closed by a hinged gate which is opened by means of a solenoid. The gate normally opens after each single sheet message has been received and drops it onto a conveyor belt which carries it to a central editing position. Multiple sheet messages are held in the chute until all sheets have been received, when the gate opens and drops them onto the belt simultaneously. Under certain abnormal circumstances, to be described later, the gate will remain closed until released by a supervisor.

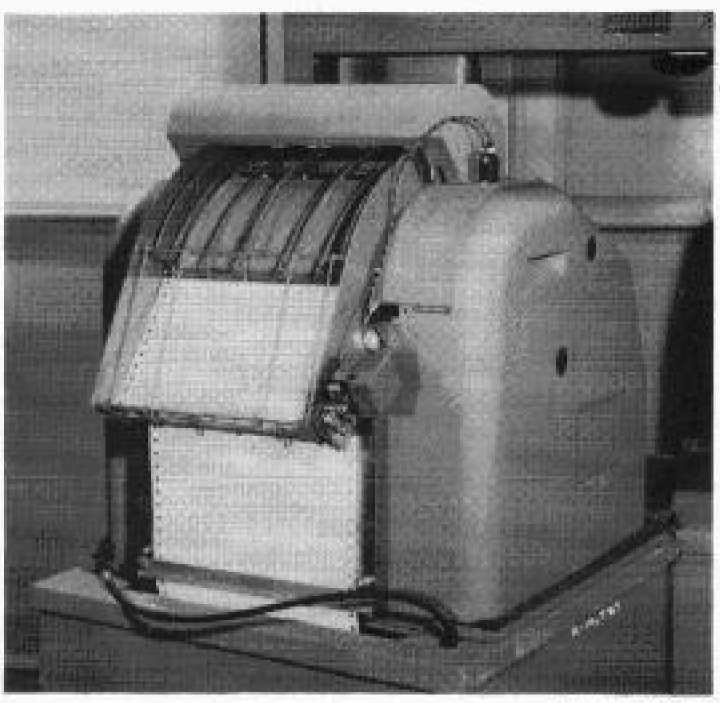

Photo R-10,789

Figure 2. Rear view of message-separator teleprinter showing message chute and solenoid-controlled gate

The circumference of the teleprinter platen is 5½ inches, which matches the vertical dimension of the standard telegram blank printed on the pack fold paper form. One revolution of the platen thus feeds out one message form. The platen feed mechanism has been modified to provide spacing of 4 lines per inch instead of the usual 3, so that one message blank is fed out for every 22 line feed operations of the teleprinter. The printed masthead across the top of each blank occupies 5 lines, leaving 17 lines to the end of the blank, 16 of which are usable for the message. The teleprinter is equipped with contacts which are closed at one point in each revolution of the platen. This point is called the "home" position. These platen contacts cause the message-separator motor to run for approximately two seconds each time the platen returns to its home position. When the platen is in this position, the top of a message blank is against the rollers, the perforated line between two blanks is opposite the separator blade, and the next blank is in a position for printing to occur on the first line below the printed heading.

The message-separator teleprinter is equipped with a set of contacts which read the code combination set up on the vanes of the teleprinter for each character received. These contacts are used in conjunction with an associated automatic control unit to perform various functions and provide a number of safeguards. Telegrams transmitted from the distant end are numbered sequentially to guard against lost messages. The number of each telegram received is read by the code reading contacts and compared with a number set up on a sequence number indicator located in the automatic control unit. If the number of the incoming message is the same as the number set up on the sequence number indicator, the operation of the teleprinter message separator at the end of the message proceeds in a normal manner and the sequence number indicator is advanced one step to prepare it for checking the number of the next message. If the two numbers fail to agree, the message is separated as usual, but the solenoid-operated gate on the message chute fails to open and the message is held in the chute. An alarm signal is then operated to call a supervisor to the position for the purpose of determining the cause of the error and correcting the trouble. Two message-separator teleprinters with associated control apparatus are shown in Figure 3. The sequence number indicators associated with the teleprinters are located near the top of each rack.

but since no end-of-message signal was received, the solenoid-controlled gate does not open and this sheet is held in the chute until all sheets of the message have been received. When the end-of-message signal is received, the last sheet is separated from the pack fold and all sheets of the message are dumped onto the conveyor belt simultaneously.

In any unattended message handling device, safeguards must be provided to protect against lost or mutilated messages. The message-separator teleprinter and its associated control apparatus provide the following protective features, in addition

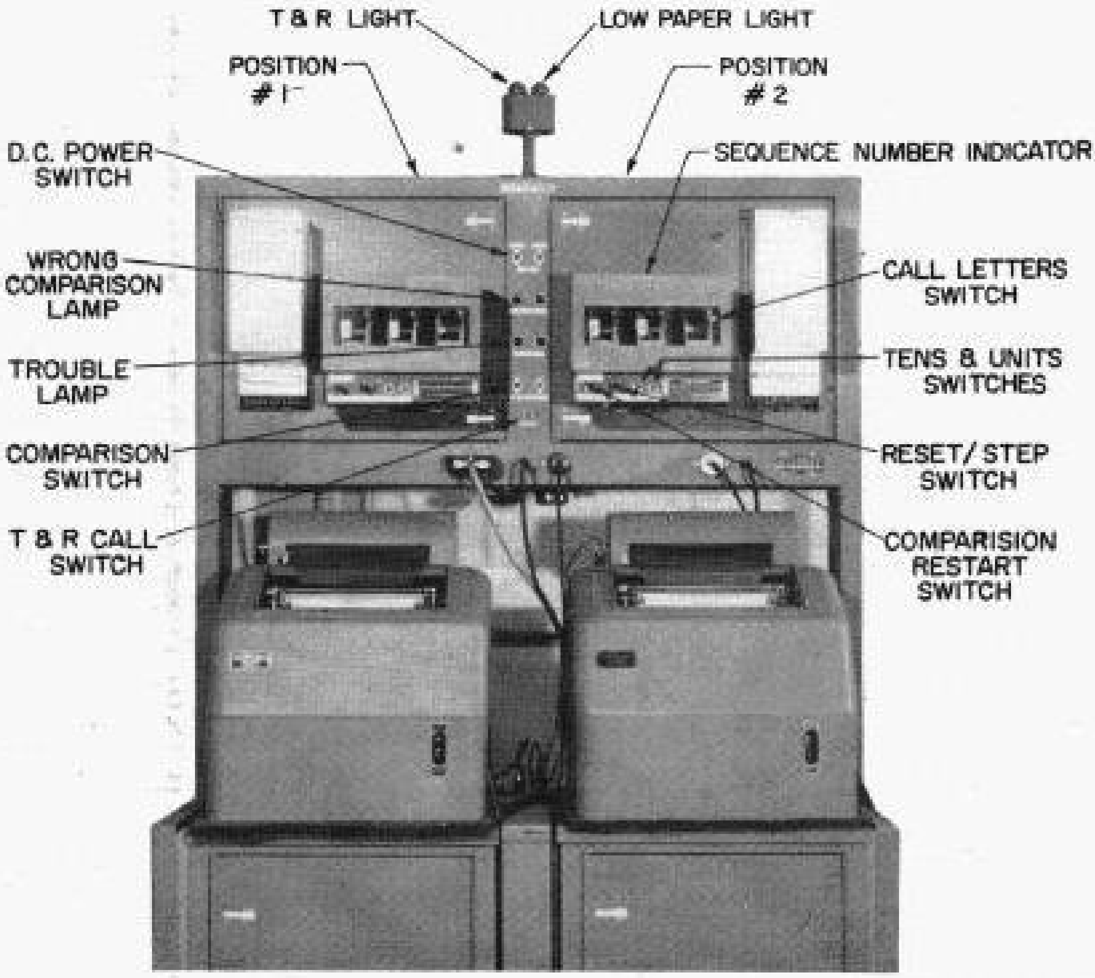

Photo R-10,788

Figure 3. Two message-separator teleprinters with associated control apparatus

At the end of any message, when the end-of-message signal (carriage return, carriage return) is received, the control equipment inserts enough line feeds to bring the total to 22. The message-separator mechanism is then actuated. On multiple sheet messages, after 16 lines have been received, transmission of the message is automatically stopped and sufficient line feeds inserted to bring the next message blank into proper position for printing. The first sheet of the message is separated in the normal manner,

to the sequence number check previously mentioned:

1. An alarm is sounded if a message form is not ejected from the teleprinter for each message number compared by the sequence number indicator. This function is controlled by a microswitch which is operated each time a message passes between the rollers on the message separator.
2. A pattern of needle holes is pierced in the right margin of each blank which passes between the rollers. Each teleprinter in an

office pierces a different pattern of holes, so that the pattern identifies the teleprinter from which each message blank was ejected, even though there may be no printing on the blank, due to ribbon breakage or to a type bar pile-up. When a printing failure occurs, appearance of a blank message form at the editing position calls attention to the trouble and identifies the teleprinter which failed to print. The trouble can then be corrected and all lost messages rerun.

3. If the teleprinter is not in its normal position so that ejected messages will fall on the conveyor belt, the chute gate will not open. Reception of messages can continue and the sequence numbers will be checked in the normal manner, but all messages will be held in the chute until the trouble is corrected.

4. In the event that a wrong comparison occurs, the sequence number indicator stops advancing, an alarm is sounded, and all messages are held in the chute until the trouble is corrected and the sequence number indicator reset to the proper number.

5. If the teleprinter platen and the line feed counter are out of step when the platen reaches its home position, a trouble lamp will light.

6. A low-paper lamp and buzzer are provided. If the paper supply becomes completely exhausted, the trouble alarm will operate.

7. Each stack of pack fold forms has a number printed on the back of each form. The numbers are sequential so that an editing operator can associate the forms making up a multiple sheet message. This prevents sheets from two such messages from becoming intermixed.

Loop-Gate Transmitter

The loop-gate transmitter is a magnet-operated tape transmitter intended for use in switching systems where it is necessary to transmit part of a message through the transmitter and then, by means of external control circuits, automatically reposition the perforated tape so that this part of it will be retransmitted before the remainder of the message is transmitted. This is accomplished by means of two feeding mechanisms and a loop-gate shuttle mechanism. The shuttle mechanism is merely a sliding tape latch with a rectangular opening in it. In Figure 4 (left), the shuttle is shown in its right-hand or normal position and at the right in its left-hand position. When the shuttle is in its normal position, tape is fed through the transmitter from right to left by means of the left-hand feed wheel.

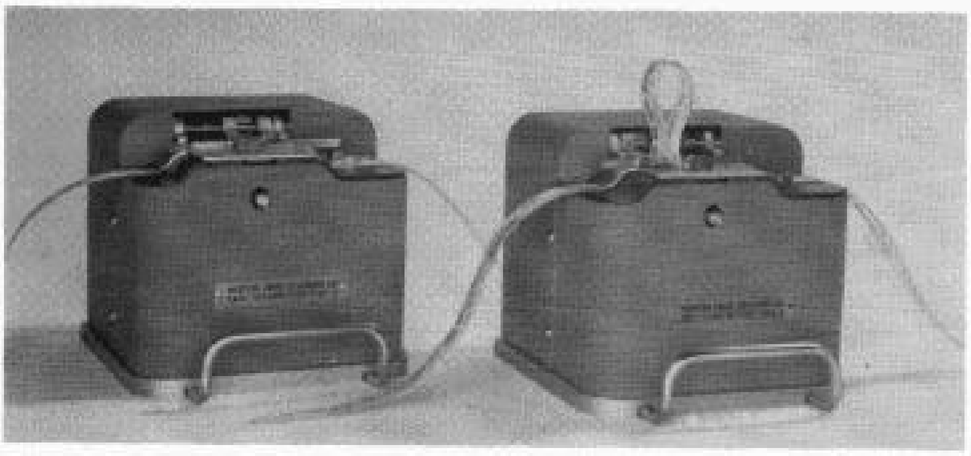

Photo R-11,099

Figure 4. Loop-Gate Tape Transmitter 7595-B. Left: Transmitter operating normally. Right: Transmitter forming loop for retransmission

The right-hand feed wheel then idles; that is, the tape being fed through the transmitter causes this feed wheel to rotate, but it does not contribute to feeding of the tape. When the shuttle is moved to the left, the left feed wheel is held stationary so that it cannot rotate and the tape is then fed by the right-hand feed wheel. As the tape feeds past the sensing pins which read the code combinations perforated in the tape, a loop of tape is formed and rises through the rectangular opening in the shuttle. When the shuttle is in this position, the loop opening is to the left of the sensing pins, so that the pins read the code combinations before the loop is formed.

When the shuttle moves back to its normal position, the left end of the tape is held stationary by the left feed wheel. The shuttle carries the loop of tape with it, so that the first character in the loop is again over the sensing pins and the remainder of the loop is to the right of the pins, ready to be retransmitted.

The mechanism for operating the shuttle is shown at the right in Figure 5. When the solenoid mounted on the rear of the base is energized, a shuttle arm fastened to the solenoid plunger rotates about its pivot and moves the shuttle to the left, as viewed from the front of the machine. When the shuttle is in this position a feed deleting stud, which is part of the shuttle mechanism, disengages the left feed pawl from its ratchet so that the left feed wheel is not rotated as the transmitter steps. Feeding of the tape is then done by the right feed pawl and ratchet. When the shuttle is moved back to its normal position, the right feed pawl is disengaged from its ratchet and feeding is done by the left feed pawl and ratchet. The two feed pawls are mounted on each end of a feed pawl link which is pivoted at its center and is operated by the step magnet armature. The left feed pawl is a push-type which feeds on its upward stroke and the right feed pawl is a pull-type which feeds on its downward stroke.

The left and right detent arms are connected by means of a link. When the shuttle is in its normal position and the left feed wheel is feeding, the detent link causes the two detents to rise and fall together. However, a swing plate operated by the shuttle mechanism moves the right detent slightly away from its star wheel in order to reduce the pull on the tape required to rotate the right feed wheel, yet still provide proper indexing of this feed wheel. When the shuttle is moved to the left, the right detent fully engages its star wheel and feeding is done by the right-hand feed pawl. The right detent is fastened to the detent link by means of a shoulder screw and an elongated hole, so that the right detent rises and falls without moving the left detent out of engagement with its star wheel. The left feed wheel is thus locked while the right feed wheel is feeding.

A loop former, part of which can be seen protruding through the top of the guide plate in Figure 5 (left), prevents the tape from buckling when the loop begins to form and while the shuttle is moving back to its normal position. This is simply a spring-loaded arm which presses against the under side of the tape directly below the rectangular opening in the shuttle when it is in its left-hand position. When the shuttle returns to its normal position and the loop of tape is diminished, the loop former is pulled downward and latched to prevent further pressure against the tape.

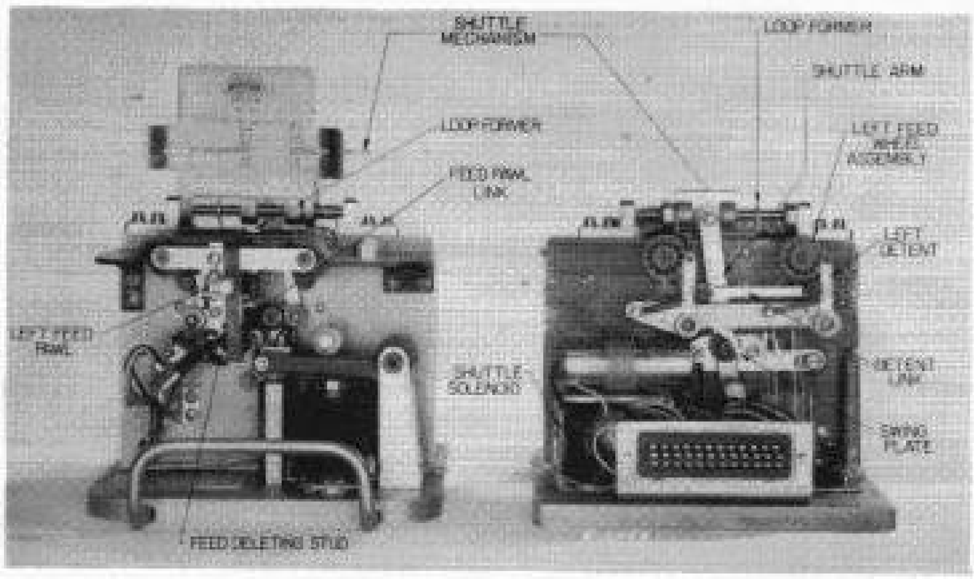

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Figure 5. Loop-Gate Tape Transmitter 7595-B with covers removed. Left: Front view with latch and shuttle raised. Right: Rear view showing shuttle control mechanism and dual detent

Tape Crimper

When paper tape is fed through a reperforator or a printer-perforator, rubbing of the tape against the metal surfaces of the reperforating device causes an electrostatic charge to accumulate on the tape, particularly under conditions of low humidity. If the tape emerging from the reperforator is then directed down a long narrow tape neck into an accumulator (tape storage bin) as is usually done in reperforator switching systems, the tape tends to cling to the surfaces of the tape neck and adjacent lengths of tape sometimes cling together. This impedes the motion of the tape in the neck and frequently results in a pile-up within the neck, even though the accumulator may contain little or no tape. In automatic switching systems which normally operate unattended, this can result in interruption in automatic message relaying. Crimping devices, which crease the tape in two places along its length, were tried out several years ago in an effort to overcome this problem. These crimpers stiffened the tape and greatly reduced the tendency of the tape to buckle in the neck, but the original crimpers[1] were an integral part of the reperforating apparatus and the power for crimping the tape was obtained from the reperforator feed mechanism. The added load on the feed mechanism made it difficult to maintain the required 10-holes-per-inch gauge of the tape, and these crimpers were finally abandoned.

Recently a requirement developed for a tape-motion alarm which would be operated when tape failed to feed out of a reperforator while it was receiving signals. It was decided to meet this requirement by passing the tape between a motor-driven roller and an idler roller held against the rotating roller by spring tension. Rotation of the roller would then be used alternately to open and close electrical contacts. Failure of the tape to feed out of the reperforator would cause a friction clutch on the driven roller shaft to slip and prevent the roller from turning. The contacts were then used, in conjunction with a receiving relay in series with the reperforator and an associated electronic timer, to actuate an alarm after a predetermined interval in the event that the relay operated in response to incoming signals and the roller-operated contacts failed to open and close.

Since the tape-motion alarm had to be located so that the motion of the tape was detected after it emerged from the reperforator, it was decided to mount the crimper at the top of the tape neck and to crimp the tape as it passed between the rollers. This served to stiffen the tape and then push it directly down the tape neck.

Figure 6 shows the tape crimper and tape-motion alarm mounted in position on a tape neck. The tape entering the rollers is flat, but as it is pulled between the rollers two flanges on the idler roller and two corresponding undercut sections on the driven roller crimp the tape longitudinally between the first and second

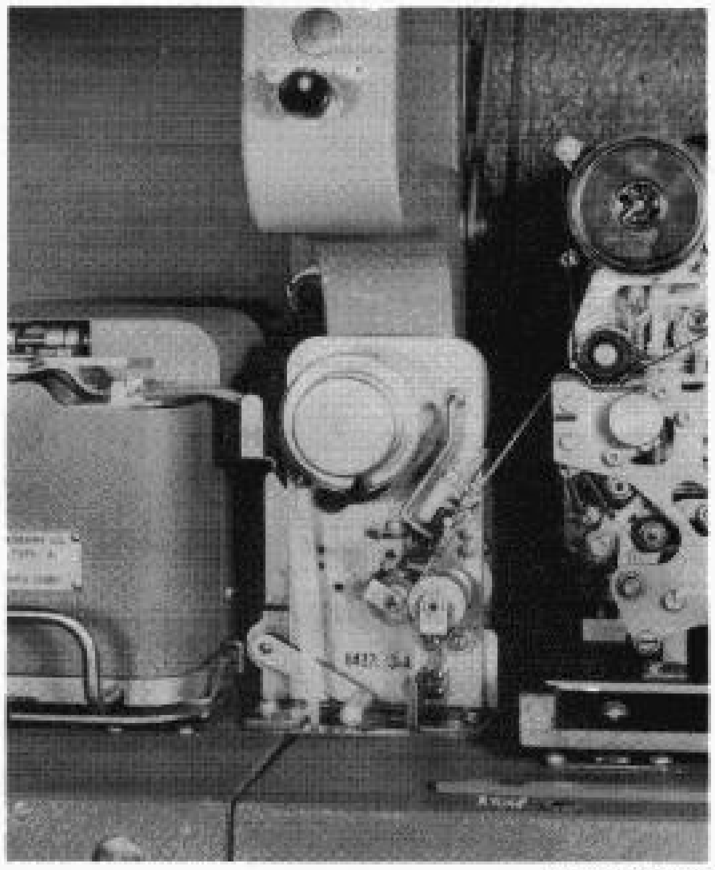

Photo R-11,165

Figure 6. Tape Crimper 8432-A mounted on a tape neck

code holes and also between the fourth and fifth code holes. This serves to stiffen the tape and force it down the neck even under conditions conducive to electrostatic accumulation or when the tape is unduly limp because of excessive absorption of moisture under conditions of high humidity.

Construction of the tape crimper is shown in Figure 7. At the left of the figure is shown a front view of the crimper with the crimping rollers and the timing motor used to drive the unit. The arm shown at the lower left in this view is a tight-tape arm which operates a microswitch when all of the tape has been pulled out of the accumulator by the associated transmitter. The microswitch then turns off the transmitter until another message has been received by the reperforator. The arm at the top right of the crimper operates a microswitch when the tape is torn and the end of the torn tape passes under the arm. This turns off the crimper motor and holds the end of the tape between the rollers to prevent it from dropping into the accumulator.

A rear view of the crimper is shown at the right in Figure 7. The commutator-type contacts operated by the driven roller are located near the bottom of the crimper. The large disc on the driven shaft just in front of the sprocket and chain drive is the disc used to adjust the torque of the friction clutch.

The combination crimper and tape-motion alarm proved to be very successful in reducing the problem of feeding tape into an accumulator through a long tape neck. It also considerably increased the amount of tape which could be stored in the accumulator. Because of this, a simplified version of the tape crimper has been developed for use where a tape-motion alarm is not required. This unit eliminates the contacts and the clutch, resulting in a smaller and less expensive crimper. These new units are now being tested.

Tape Winder

In conventional tape winders perforated tape which has been transmitted is wound on a reel which is driven by a motor through the medium of a friction clutch. The friction clutch slips when tape is not being stepped out of the transmitter and the reel stops rotating. In order to wind the tape reasonably tight so that it does not take up too much space in storage, and at the same time avoid excessive pull on the tape being fed through the transmitter, it is necessary to use a snubbing device between the tape winder reel and the transmitter. In conventional snubbers the tape is passed over a number of rollers placed between the winder and the transmitter so that friction between the tape and the rollers progressively decreases the pull on the tape from the winder reel to the transmitter. This allows the clutch torque to be set fairly high without exerting excessive pull on the tape at the transmitter.

In a tape winder employing a friction clutch, the amount of pull on the tape required to cause the clutch to slip decreases as the diameter of the wound tape roll increases. As a result, the tape is wound tightly at the center of the roll and becomes progressively more loosely wound towards the outside. The difference is barely noticeable when completely perforated tape is used, since adjacent layers of tape are free to slide against each other, but when chadless tape is used the difference is much more pronounced. A tape reel 12 inches in diameter is usually required to hold a roll of chadless tape which measures only eight inches before being perforated. In addition to the space required for such large reels, the size of the roll of perforated tape and the fact that it is loosely wound make it difficult to remove from the reel for storage purposes.

A tape winder has been developed which incorporates a new snubbing device that provides a constant pull on the tape as it enters the reel, regardless of the size of the wound roll. The new tape

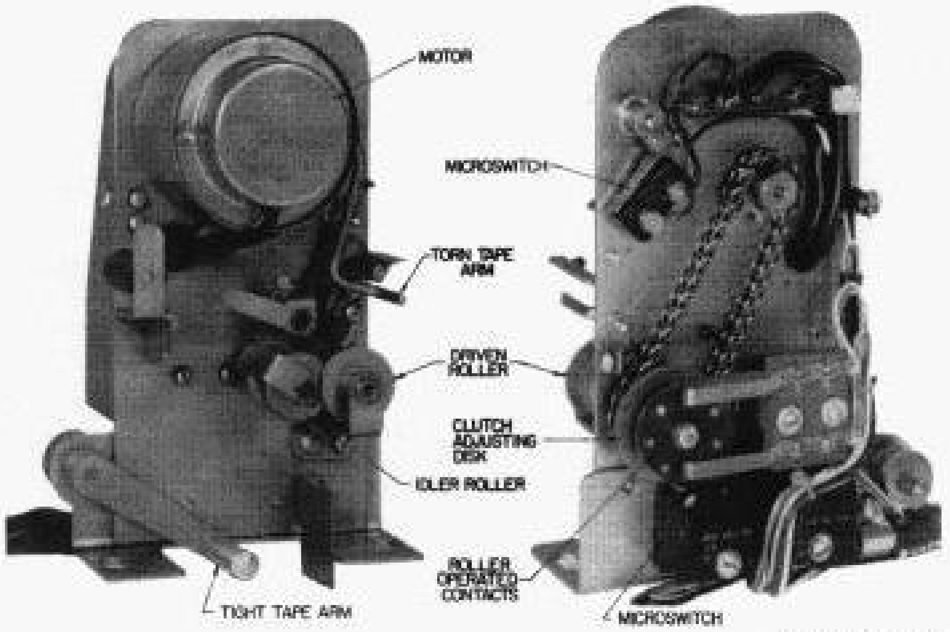

Photo R-11,054

Figure 7. Tape Crimper 8432-A, with tape-motion alarm. Left: Front view showing crimping rollers and tape control arms. Right: Rear view showing tape-motion alarm contacts

winder is shown in Figure 8. Tape entering the winder passes over a tape guide rod, then down beneath a roller on a motor control arm, and back up through the tape snubber. This device is a tape latch equipped with a spring-loaded snubber which presses against the tape in

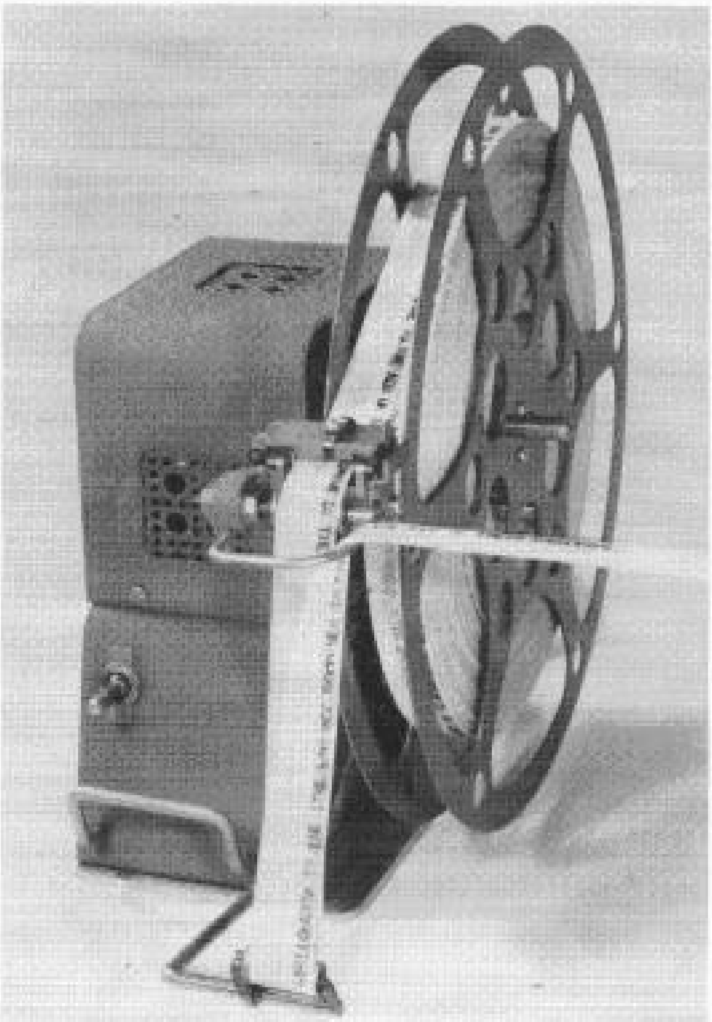

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Figure 8. Tape Winder 9385-A winding chadless tape

the area between the second and third code holes. This exerts a uniform load on the tape regardless of the code combinations punched in it. When chadless tape having pierced feed holes is used, the snubber also compresses the raised feed hole projections slightly and thus reduces the over-all thickness of the perforated tape. The tape winder with the reel removed and the snubber latch open is shown in Figure 9.

The speed of rotation of the reel is such that tape is wound faster than it is fed out of the associated transmitter. As the tape winder operates, the loop of tape between the guide rod and the snubber slowly diminishes and the motor control arm is raised. When the roller on the control arm reaches a point about 1.5 inches below the guide rod, the rotation of the control arm about its pivot operates a single-pole double-throw microswitch. This switch opens the a-c circuit to the motor and at the same time causes a 50-microfarad capacitor to discharge through

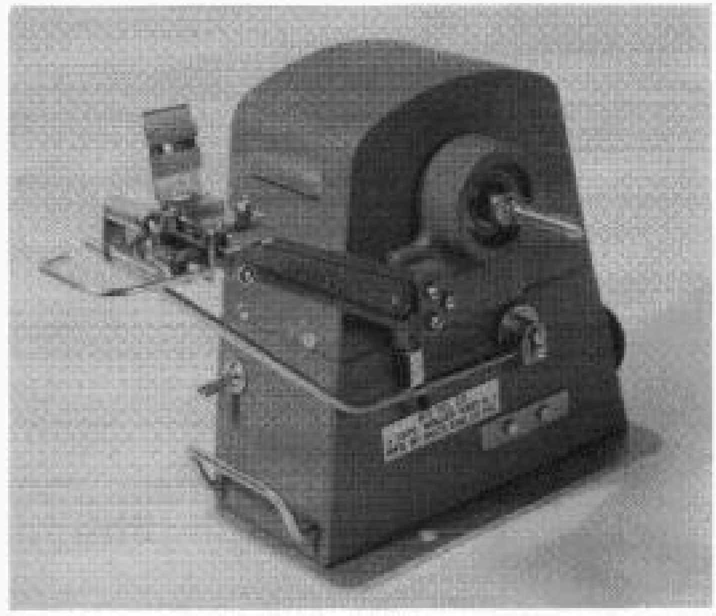

Photo R-11,069

Figure 9. Tape Winder 9385-A with reel removed and tape snubber latch raised

the field winding of the motor, thus dynamically braking it. As tape continues to feed out of the transmitter, the loop of tape lengthens and allows the motor control arm to move downward. When the arm moves to within about one inch of the base it releases the microswitch, which turns on the motor and connects the 50-mf capacitor to the a-c supply voltage and in series with a rectifier and resistor, so that the condenser is again charged. This method of electrodynamically braking a motor has been tried on tape winders in the past, but it was never used in a standard Western Union tape winder until the new tape snubber was developed.

The new tape winder is inexpensive to manufacture and to maintain. It can wind a standard 1000-ft. roll of chadless perforated tape on a 10.5-inch reel.

Acknowledgment

So many people contributed to the developments covered in this paper that

it would not be practicable to acknowledge the contributions of each of them. A considerable number of engineers in both the Development and Research Department and the Plant and Engineering Department contributed to the design and development of the new apparatus described here.

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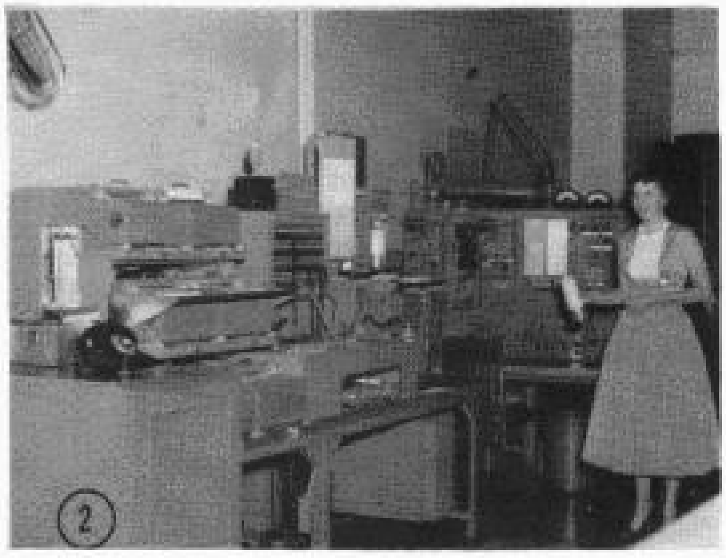
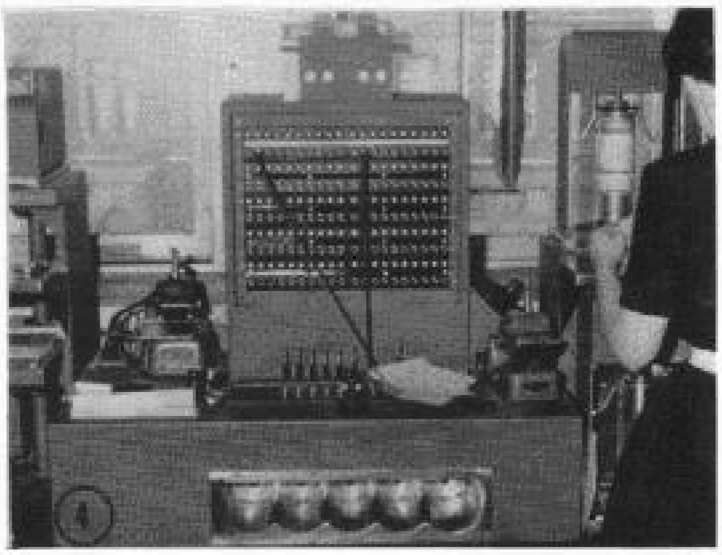
Fred W. Smith joined the Applied Engineering Division of Western Union in 1946, after having served four years as a radar maintenance and repair officer in the U. S. Army Signal Corps. He has worked on the design and field application of mechanical equipment used in start-stop printing telegraphy and in reperforator switching, and is now in charge of the Mechanical Equipment Group in the Apparatus Engineer's office. Mr. Smith graduated from the Georgia Institute of Technology in 1938, with the degree of Bachelor of Science in Electrical Engineering. He is an Associate Member of the American Institute of Electrical Engineers and Chairman of the AIEE Committee on Telegraph Systems.

Cablegrams, Telegrams by Desk-Fax in Canada





1. Montreal financial house, L. G. Beaubien, has Desk-Fax directly to Anglo-American Telegraph Co. (right).

2. Montreal office of Anglo-American Telegraph Co., a Western Union associate, serves Desk-Fax customers.

3. At Vancouver office of Canadian National Telegraphs operator attends 100-line Desk-Fax unit.

4. Canadian National Telegraphs, Montreal, employs Desk-Fax concentrator to speed pickup and delivery.

ROLAND C. TAYLOR, Senior Project Engineer, Radio-Wire Transmission

Ferrite Cores for Communication Coils

fer'rite (fĕr'īt), *n.* [L. *ferrum* iron + *-ite.*] 1. *Petrog. & Metal.* a In rocks, any yellowish, reddish, or brownish amorphous substance apparently of iron compounds, but not certainly a particular mineral. b In iron and steel, pure metallic iron. 2. *Chem.* Any of several compounds which may be regarded as metallic derivatives of the ferric hydroxide $Fe_2O_2(OH)_2$; as, franklinite is zinc *ferrite.*

ce·ram'ic (sē·răm'ĭk), *adj.* [Gr. *keramikos,* fr. *keramos* earthenware.] Of or pertaining to pottery or earthenware.

—*Webster's Dictionary.*

THE modern magnetic materials called ferrites are examples of man's ability to improve on nature. The black oxide of iron is important as an iron ore, magnetite, and was in use as the needle of the magnetic compass at least as early as 1200 A. D. It found limited use in radio sets as intermediate-frequency transformer cores and shields in the nineteen thirties. However, man's improvement on nature came during the second world war when J. L. Snoek in the Netherlands discovered how to make synthetic ferrites with superior magnetic properties.[1] In the succeeding decade applications mushroomed. The television receiver with its 15.75-kc saw-tooth sweep frequency accounted for the bulk of the production but a great variety of other important applications were developed such as antenna rods, telephone loading coils, tape recorder heads, pulse transformers, microwave isolators and network elements of high quality and stability. They range in size from tiny one-sixteenth-inch diameter toroidal memory units to a cosmotron transformer core built up of "bricks," the resulting structure nearly four feet in its longest dimension.

Until recently tests of cores made in both the Netherlands and the United States showed that they were usually too small for audio-frequency applications and also showed a large increase in resistance as current level increased. Now that the ferrite industry has come of age, cores of sizes, shapes and compositions suitable for telegraph use are becoming more and more available, and since they are likely to become more important in the telegraph company plant it may be well to review some of their salient properties and some of the types that may appear in plant equipment in the near future.

Composition and Characteristics

Ferrites are very specialized ceramics made by chemically combining certain metal oxides at high temperature. A symbolic formula is $MOFe_2O_3$ where M stands for one or more of a group of metals having about the same atomic size. Magnesium, manganese, iron, cobalt, nickel, copper and zinc are named in reference 1. Common ferrites for audio-frequency application have M partly manganese and partly zinc. For radio-frequency applications M may be part nickel and part zinc. For square hysteresis loop applications M may be part magnesium and part manganese. The exact composition and processing are frequently trade secrets, being varied to produce highest permeability, lowest temperature coefficient or other property of interest. A full complement of oxygen atoms is considered essential so the firing atmosphere contains oxygen and the resulting cores are in no danger of rusting since they are completely oxidized.

Mechanically, ferrites are like ceramics. They are brittle, machinable only by grinding (usually wet grinding to avoid thermal stress), and they shrink during firing. Since this shrinkage is rather large, dimensions are uncertain by several percent. Since shrinkage varies with composition, different materials must be formed in different size dies if it is desired to produce the same size product. Densities are moderate, ranging from 3.5 to 5.0 grams per cc depending on composition. The temperature coefficient of expansion is sometimes given as 10×10^{-6} per degree centigrade. For comparison, the density of aluminum is 2.7 and of iron is 7.9 while the expansion coefficient for iron is about 12×10^{-6} per degree C.

The combination of high magnetic permeability and high electrical resistivity possessed by ferrites is outstanding and makes unnecessary the insulation between laminations or between core particles that was required by the thin laminations or compressed powdered core materials of the prior art. Electrical resistivities range from one million to one hundred million times that of iron, which allows latitude for large increases of both dimension and frequency. Even this large resistivity is not enough to make a good insulator and resistances of the order of 10,000 ohms may appear in the circuit if contact is made to cores of certain compositions. High resistivity increases the importance of displacement currents and makes it necessary to consider the dielectric constant, something almost unheard of with metals. Dielectric constants as high as 100,000 have been reported, and the combination of high dielectric constant and high permeability may result in an electromagnetically induced mechanically resonant vibration with associated dissipation of energy. Such resonances depend on core dimensions and will rarely be important below 100 kc.

For ferrites the *raison d'être* is, of course, the magnetic quality of the materials and while it is ample to support their wide use, when any one property is singled out for attention, it will usually be found inferior to a conventional magnetic material. For example, the Curie point may be as low as 100 degrees C and as a result the temperature coefficient of permeability at room temperature may be almost plus one percent per degree C. Much higher Curie points and smaller temperature coefficients can be had in conventional materials. Saturation flux density may be as little as one-tenth that of iron but that is a point of no consequence if operating flux densities never exceed one-thousandth of saturation as is common in communication equipment. The coercive force of the square-loop ferrites is much greater than that of some soft nickel-irons but where this is a disadvantage it should be remembered that eddy currents tend seriously to widen hysteresis loops in conducting magnetic materials.

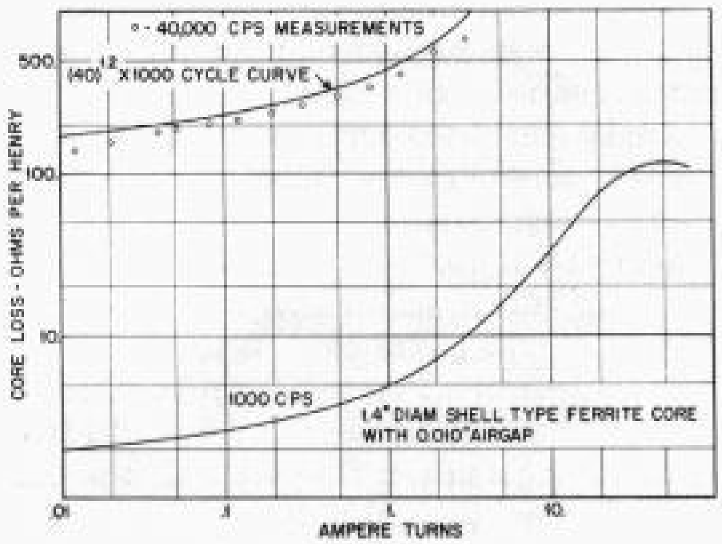


Figure 1. Core loss characteristic at 1000 cps and 40,000 cps

The coil designer often measures core loss in ohms per henry. Such core loss in magnetic materials has traditionally been considered as the sum of two terms, one proportional to the first power of the frequency and one to the square of the frequency. The latter term can be shown to be eddy current loss as long as skin effect is absent. The first power term has been associated with the area of the hysteresis loop and is sometimes separated into two parts; one, a function of flux density and the other, called residual loss, independent of flux density. This scheme is not so useful for ferrites since eddy current loss is rarely large enough to be significant yet the core loss is found to vary appreciably faster than the first power of the frequency. An average 1000-cycle characteristic of a good grade of ferrite core with air gap is shown in Figure 1 as a function of total magnetizing force. The core loss is seen to be proportional to less than the first power of magnetizing force except for a region approaching saturation where the performance is poorest. If the ordinates of this curve are increased by the factor $(40{,}000/1000)^{1.2}$ a good approximation to the losses at 40,000 cps is obtained as shown in the figure. These core losses are considerably less than are obtained from conventional compressed powder cores.

"Core" and "Shell" Types

Magnetic materials are used in two basic coil geometries. At one extreme the winding completely surrounds the core as in the familiar toroid construction. This has been called core-type construction. At the other extreme the core completely surrounds the winding as in the ironclad coil, pot-core, cup-core, or hedgehog constructions. Core-type or toroidal construction is used if air gaps must be minimized as, for example, to develop the best square-loop properties. They also excel where minimum leakage inductance is required but suffer from excessive distributed and interwinding capacitances, high winding costs, unprotected windings and difficulty in making complicated or shielded windings. Shell-type construction is used where air-gap control is important, winding capacitances must be minimized, or unusual or complicated winding constructions must be made. It is the more versatile construction of the two. Constructions intermediate between core and shell types are frequently used. Since it is feasible to manufacture ferrites in the shell-type configuration and since an air gap is usually desired it is likely that this construction will become increasingly important. Typical examples of both constructions are shown in Figure 2.

For temperature and current stability at audio frequencies an air gap is essential but is the site of fringing or stray magnetic fields which introduce undesirable couplings to adjacent coils, to poor quality magnetic materials such as coil cases or rack panels, and even to eddy current paths in the coil's own winding conductors. Fortunately these defects can be remedied. The external couplings can be adequately controlled by keeping the external or rim gap small. About two-thousandths of an inch is small enough. The internal or winding eddy current couplings are controllable by using stranded wires or sacrificing the winding space directly adjacent to the gap where the stray field is greatest. When the rim gap is small the center post must be ground shorter to realize the optimum air gap for the intended use which increases eddy currents in the winding conductor. In most cases, however, winding eddy currents will not be bad enough to require control measures.

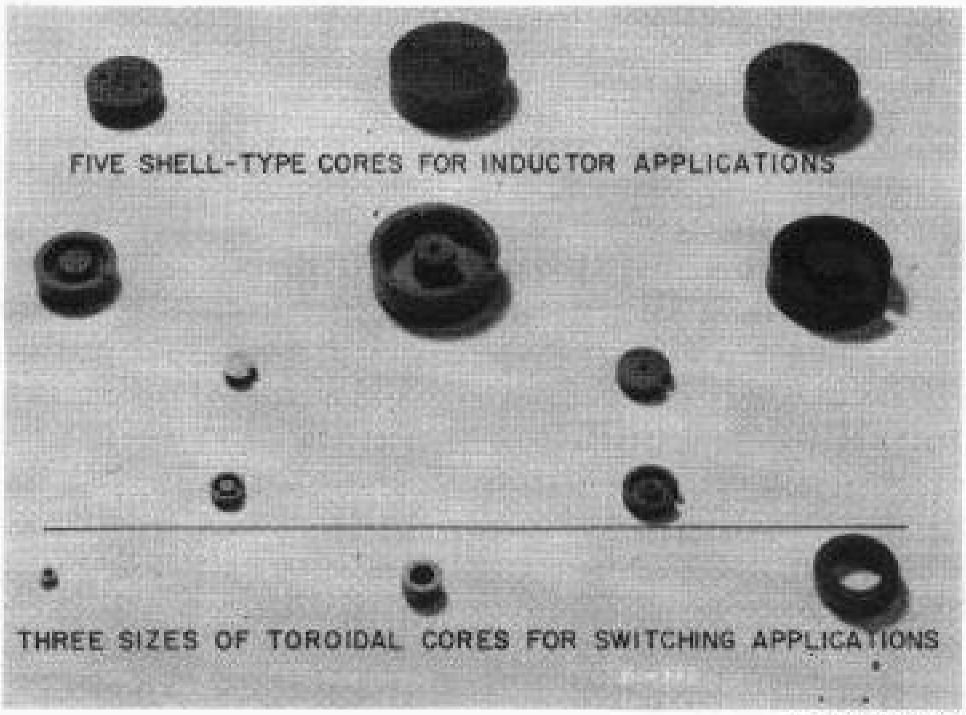


Photo R-10,983

Figure 2. Typical ferrite cores

An air gap offers an excellent opportunity to reduce the temperature coefficient of inductance. Since the permeability of the core increases with temperature, an increase in air gap with temperature is in the right direction for compensation. As a practical matter the thermal expansion of an epoxy resin filled with aluminum oxide has been found to provide excellent compensation when used in an air gap that is sufficient for current stability and optimum for audio-frequency use. The curve of Figure 3 shows a typical temperature characteristic. At high temperatures the negative characteristic of a ferrite approaching its Curie point dominates, while at usual operating temperatures the negative coefficient contributed by the air-gap material almost cancels the normal positive coefficient of the ferrite. If temperature compensation for smaller air gaps is required, an air-gap material such as nylon which has a larger expansion coefficient may be used. For larger air gaps a larger proportion of filler such as aluminum oxide of smaller expansion coefficient is suitable. Since the air gap is of the order of one-hundredth of an inch, one ten-thousandth of an inch corresponds to one percent in inductance. The contact between air-gap spacers and core is important as it can easily be unreliable by some millionths of an inch due to surface roughness. A desirable method of assembly is to polymerize an adhesive resin in place in the air gap thus eliminating any unreliability of contacting surfaces. Epoxy resins are notable for good adherence to glass and ceramics.

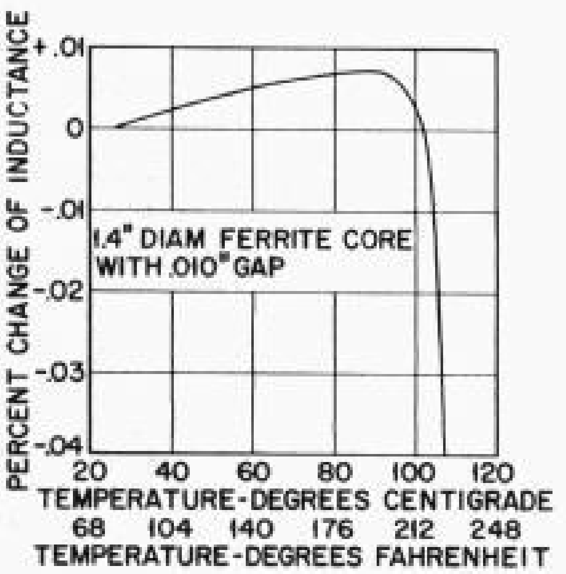


Figure 3. Inductance versus temperature using compensating air-gap spacer

The word epoxy may be unfamiliar to some readers of this article. It comes from the structural formula of the chemist as illustrated in Figure 4. The two valence bonds of the oxygen atom are each attached to a different atom or group of atoms and both of these are attached to each other. The Greek prefix *epi* means above, in some circumstances, so epoxy means oxygen above. To the user of the material it means a strong, heat-resistant, low-shrinkage, thermosetting resin with good adherence to glass.

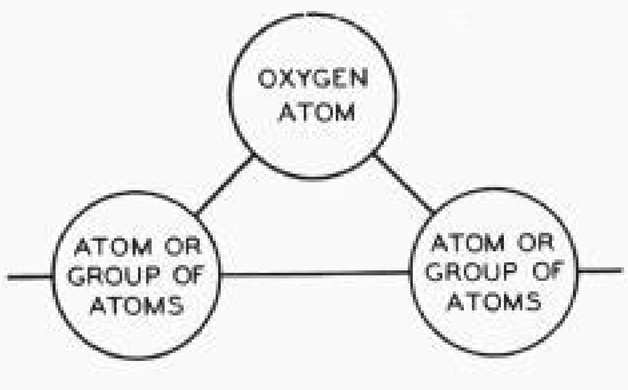


Figure 4. Part of a chain of molecules illustrating "epoxy" structure

Core Assembly

If the core has no movable pieces and the winding is inaccessible the exact value of the inductance is determined at the time of cementing the core pieces together. Therefore, if a close inductance tolerance is essential a fixture capable of determining the position of the cores very precisely is required, and if the cement requires heat for curing, thermal coefficients of expansion of the fixture are important. A fixture capable of producing coils of plus or minus 1-percent inductance tolerance is shown in Figure 5. In use the lower core piece is clamped by three pointed set screws. To secure a firm grip without chipping of the ferrite a relatively soft material such as phosphor bronze is used between point and core. The core faces abutting the gap are coated with the viscous epoxy cement and the winding and both core pieces assembled. The winding is then connected to an inductance measuring device such as an impedance bridge and the two core pieces pressed together, squeezing out the cement until an approximate balance is obtained. The upper half core is then clamped in the same way as the lower half and an exact balance obtained by the vernier screw. The coil and fixture may then be placed in an oven to polymerize or cure the cement. If the thermal expansion coefficient of the fixture is correct, the oven temperature will change the air gap just enough to compensate for the shrinkage of the cement and the completed coil will have the inductance to which it was adjusted. For a certain combination of ferrite core and low-shrinkage epoxy resin a brass fixture has been found suitable. An aluminum fixture of the same construction was found to have too much thermal expansion for this core and cement.

It has been found possible to approximate these results without any fixture if a proper allowance is made for cement shrinkage. When the rim gap is small enough and the cement viscous enough so it will not be squeezed out by the weight of the upper core during the curing cycle, inductance adjustment by hand pressure can be successfully accomplished. Care must be taken not to overshoot because, if the air gap is later increased to correct the overshoot, it is apt to tend to return to the previous smaller gap. An epoxy cement with aluminum oxide filler has been found practicable in a gap not exceeding two-thousandths of an inch. Any gap from the minimum possible, which may be two ten-thousandths inch up to about two-thousandths inch, will remain substantially unchanged during the curing period. Any shrinkage of the cement during cure must be allowed for by setting the inductance low by the same percentage that the cement shrinks. Obviously a low shrinkage is desirable and this is a property of epoxy resins. It may be still further reduced by incorporating additional filler material into the cement.

Various levels of inductance tolerance are practicable. Cores can be bolted together without adjustment and variations due to air-gap dimension, turn count, core material and temperature coefficients may amount to ten percent or more. As the various refinements described in this article are added tolerances can be progressively reduced to one percent. For still closer accuracy an adjustment after

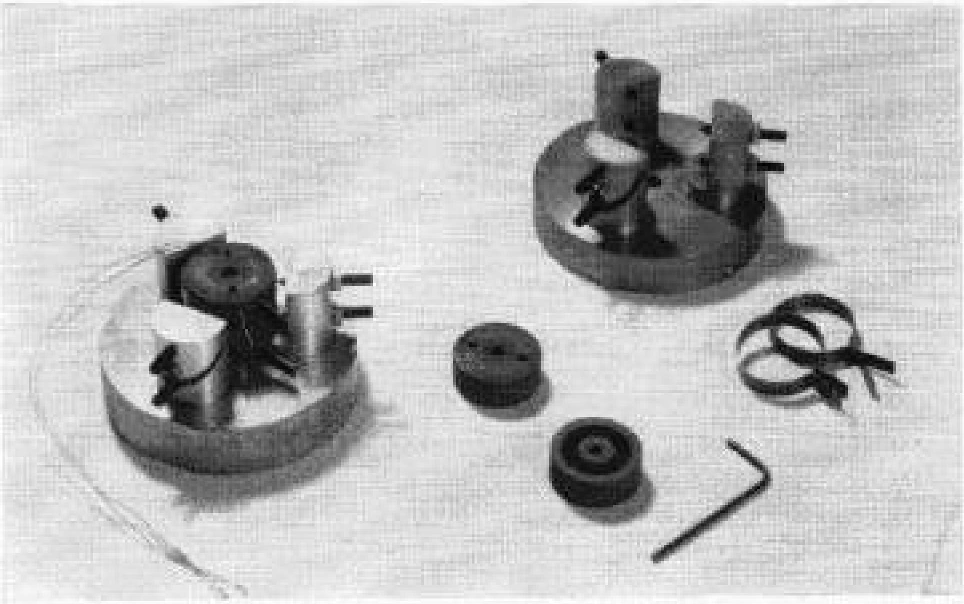


Photo R-10,984

Figure 5. Cementing fixture with vernier air-gap adjustment

cementing such as grinding away small parts of the core or positioning a small movable core piece can be used. A cement such as the epoxy resin used in the air gap can be filled with a finely divided mag-

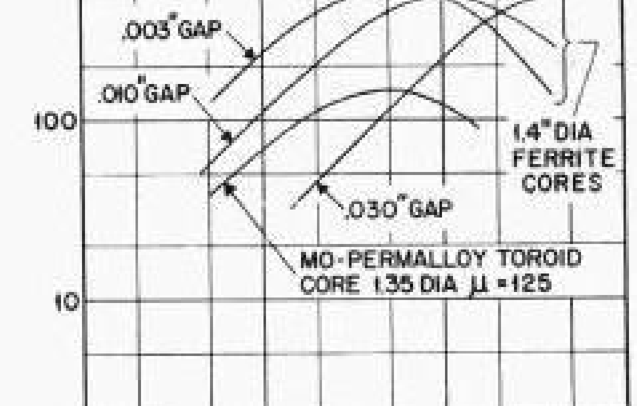


Figure 6. Performance of ferrite-cored coils as a function of frequency and air gap

netic material such as carbonyl iron powder and used to bridge the air gap for final adjustment. This will always increase inductance while grinding away always reduces inductance thus permitting salvage of coils that have inadvertently been moved beyond the desired inductance.

Some of the properties that can be realized with ferrite-cored coils are shown in Figures 6, 7 and 8. Figure 6 shows three curves of Q versus frequency, one for each of three air gaps. The one at the left is taken at a small current to reduce core loss while the one at the right was wound with stranded wire to minimize eddy currents in the winding. Figure 7 shows how inductance changes with magnetizing force. Figure 8 shows temperature coefficient for four different epoxy resin gaps. There is little or no hysteresis in these curves and they recycle well. In each figure a curve for a 1.35-inch powdered permalloy toroid with permeability 125 and without temperature compensation is shown for reference.

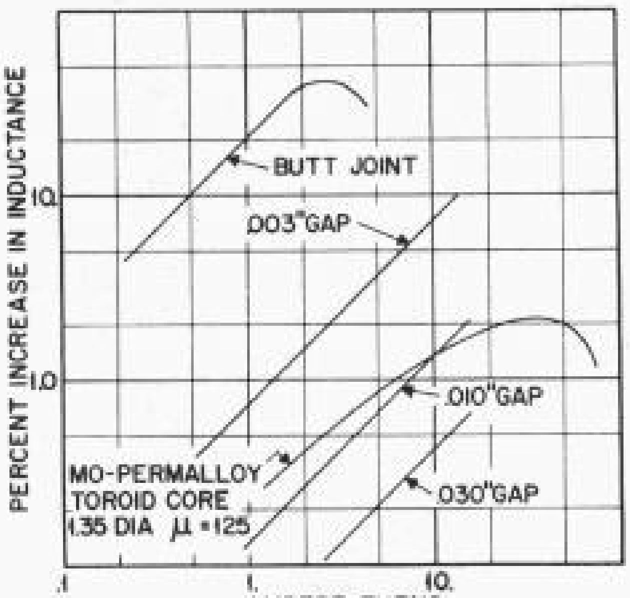


Figure 7. Inductance stability as a function of magnetizing force and air gap

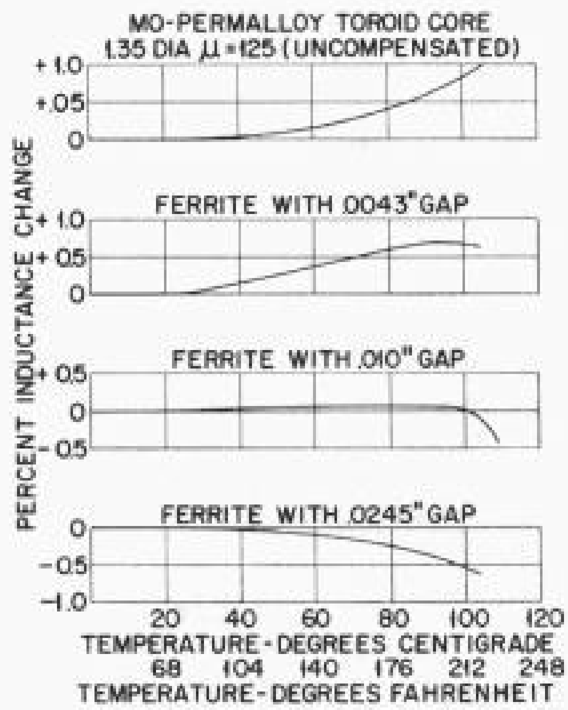


Figure 8. Inductance stability as a function of temperature and air gap

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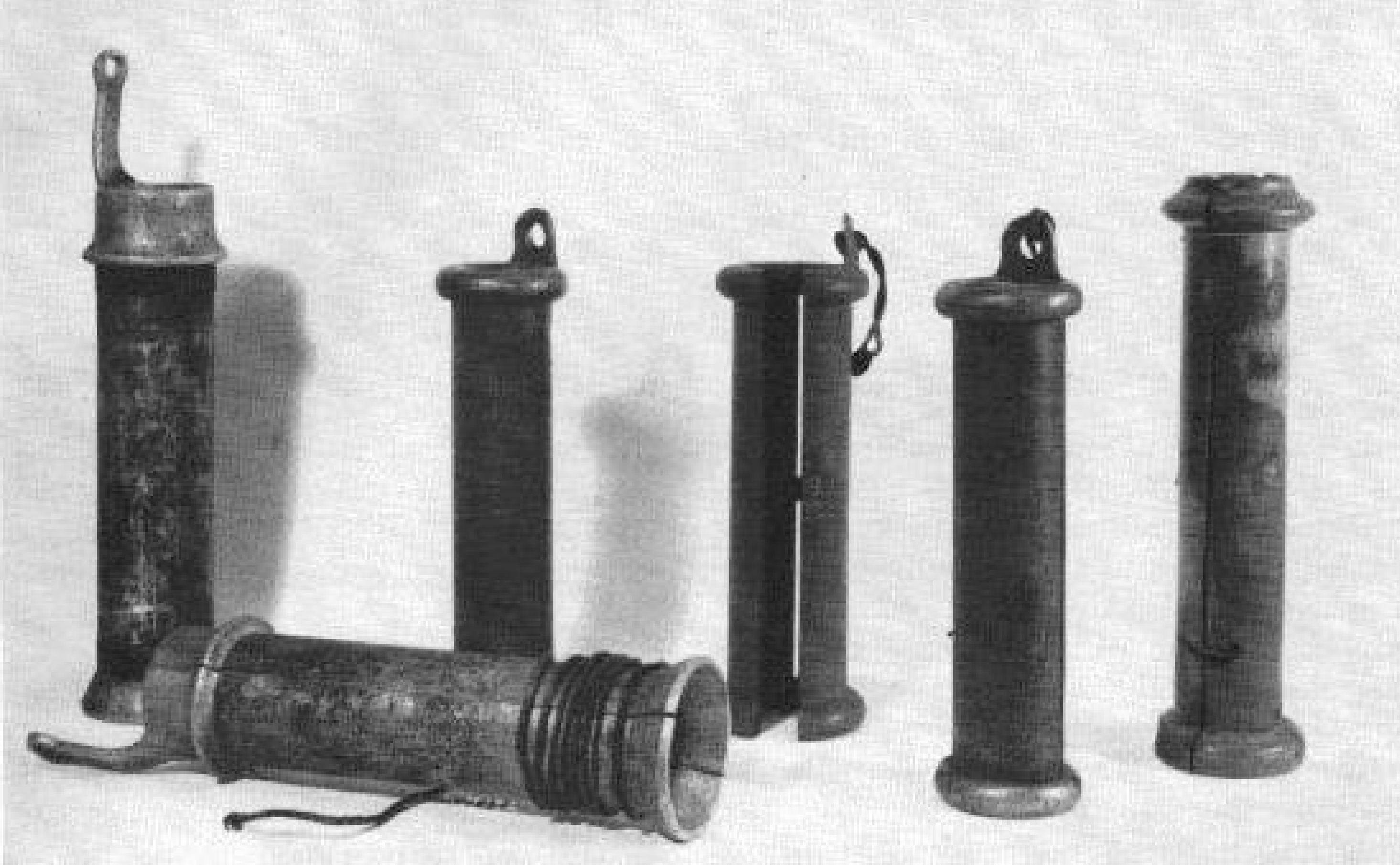
Much credit is due to H. C. Perkins for fixture design and many variations of the epoxy cement formulations; to G. C. Ratledge for grinding of ferrite materials; to P. R. Herbst and V. J. Lawler for careful bridge measurements, and to Mrs. C. U. Depperman for constructive criticism of the manuscript.

Reference

1. New Developments in Ferromagnetic Materials, J. L. Snoek, Elsevier Publishing Co., Amsterdam, 1947.

Roland C. Taylor is a graduate of Case Institute of Technology, class of '28. He has been concerned largely with coil and filter design in his association with Western Union and the results of his work are found throughout the carrier, cable and land line plant in amplifiers, modulators, filters, test equipment and many other devices. The system of modulation on which the WN-2 carrier is built is his invention, and he is also responsible for the shell-type powdered iron core so widely used in carrier equipment. He is an associate of AIEE.

Lashing Tools for Aerial Cable



Western Union Museum Photo R-11,182

Figure 1. Among earliest aerial cable lashing tools was the Chinnock cable winder or spinning jenny. At left, aluminum; center, brass; right, lignum vitae. When placed around cable and strand, then wound with layers of strong marline the end of which was made fast at a telegraph pole, as the spinning jenny was pulled along the strand the marline unwound into helical lashing.

GROSVENOR HOTCHKISS, Coordinating Engineer

Placement of aerial cables on pole lines has been a continuing activity in the telecommunications industry but methods have changed infrequently. A noticeable technical advance in procedure was made possible by the development of efficient hand and machine tools for attachment of cables to messenger strand.

Most aerial cable comprised of copper wires, insulation and a lead or plastic sheath, has insufficient tensile strength to be installed without support for any considerable distance. It is customary, therefore, to attach aerial cable to a stranded steel carrier wire or "messenger."

Attachment of cable to a messenger strand has been accomplished by various methods. "Ideally," says C. A. Mitchell writing succinctly in the *Post Office Electrical Engineers' Journal*, "the (attachment) device should be as durable as the cables and suspension wires themselves. The device should not, however, be so hard and unyielding, or the method of using it such that the cable sheath is damaged as a result of movement and vibration. Moreover, the suspension device should permit the cable to expand uniformly throughout its length and so avoid the accumulation of slack at a few isolated points. Finally, installation cost should not be so high as to be out of proportion to any advantages conferred."

It is of interest today that newer

materials and machines have led to reintroduction and widespread current use of an earlier method of aerial cable suspension abandoned many years ago—namely, continuous spinning or lashing of open lay helical windings around both cable and suspension strand. Now, with heavy-duty lashing machines as well as simple tools specially designed for cable suspension work, either communication or power cables can be positioned rapidly, firmly and permanently in a trim and efficient manner.

Early "Spinners" Employed Marline

Aerial cable was in use on some telegraph lines around 1880. For its support, attachment to a messenger strand with individual loops of marline or rawhide was one method first employed. Before long there was evolved a simplified procedure in which a continuous helix of marline rope was wrapped around both cable and messenger strand by utilizing Chinnock's cable "winder" or "spinning jenny" (a term borrowed from the textile industry).[1] These winders were two-piece split bobbins about 14 inches long and four inches in diameter, fashioned at first from wood such as lignum vitae and later made of brass or steel tubing or cast aluminum (Figure 1).

Or Goose Grease?

Postal Telegraph Cable Company's 1906 rule book reads, "For hanging cable with a spinning jenny the best quality of 3-ply marline or hambroline should be used and should be greased before being wound on the jenny. A piece of raw tallow thoroughly rubbed over the marline is very satisfactory and enables it to pay out freely and smoothly when the jenny is being drawn over the messenger wire and cable."

In use, these split bobbins or spinning jennies were placed over the messenger and cable, then wound with layers of strong marline as shown in Figure 2. With an end of the marline tied to one pole, the bobbin was pulled along the messenger to the next pole trailed by turn after turn of marline spun continuously around the cable and its supporting strand.

Because the marline lashing deteriorated, however, employment of this ingenious spinning jenny generally was superseded around 1910 by use of uniformly spaced iron cable rings or straps almost exclusively until about 1940 when spinning machines employing soft steel lashing wires instead of marline became available.[2,3] These new machines were very welcome inasmuch as iron cable rings rust in time and both galvanized and steel rings sometimes cut into lead cable sheath owing to either vibration or continuing expansion and contraction movements caused by temperature changes.

U. S. Sig. C. Manual (1905)

Figure 2. Cable spinning with marline and jenny

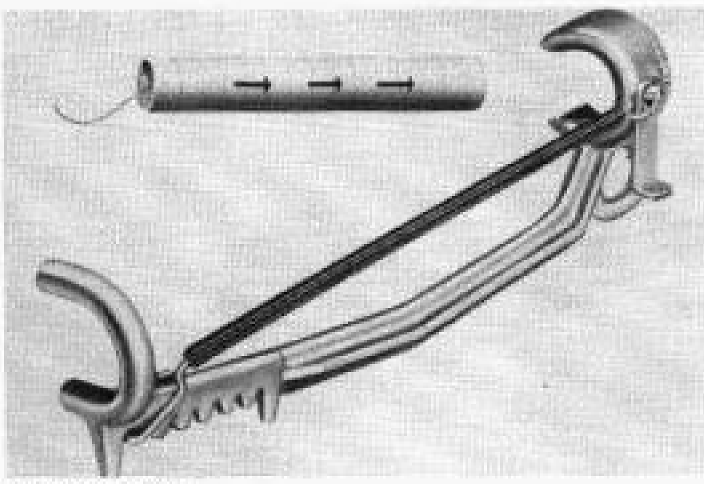
Vibration of a messenger strand as a result of wind sway or heavy vehicular traffic is transmitted to the points of contact beween rings and cable and may cause serious cuts, especially when messenger tension is high.

With cable rings, sheath cracks owing to thermal changes also are reported as more serious if strand tension is raised, because the relative motion between strand and cable is greater at higher strand tensions than at lower tensions.[4] Studies show thermal expansion occurring daily results in small bends or bows in cable sheath which are more pronounced although less numerous with rings than with continuous lashing. The latter, assuming moderate tension is applied during lashing, distributes expansion of the cable in a large number of comparatively minute bows instead of allowing movement to accumulate in a marked bend at any one place. By making certain the lay of the lashing wire is the same as that of the strand, good load distribution at the strand and tight lashing is obtained.

Inasmuch as modern spinning holds the cable closely against the messenger strand with load well distributed over, say, a 13- or 14-inch lay for single wire or half that when spinning with two wires simultaneously, any tendency for lashing wire to cut the sheath is minimized. Although use of cable rings is, of course, a standard procedure that undoubtedly will continue to have wide acceptance, nevertheless cable spinning or lashing with stainless and galvanized steel wire as well as with copperweld and aluminum wire is accepted practice today for both communications and power cables whether lead sheathed or plastic sheathed.[5,6]

Modern Lightweight Lasher

A lightweight, simple and effective spinning tool for cable up to 1-1/4 inches diameter with a 5/16-inch messenger strand is available for lashing jobs which do not require either a machine with lineman's seat or the somewhat more complicated, and of course more expensive, heavy-duty equipment. This tool, shown in Figure 3, is a cast aluminum bracket 16 inches long which is hung over the messenger strand and cable by means of integral, hook-like parts formed into the tool at each end. It is fastened in position on the strand by means of a coiled spring which is passed twice around the strand and cable to an attachment hook. The spring's tension is adjustable readily at its notched fastening for tight lashing of small or large cable. A ring or loop is formed into the tool at one end for towing rope attachment.



Hubbard and Co.

Figure 3. A modern cable lashing tool and (above) waxed container of precoiled lashing wire

This spinning tool employs 0.045-inch lashing wire which instead of being furnished on reels comes uniquely coiled *inside* waxed cardboard cylinders 2 inches in diameter and approximately 13 inches long. The 2-inch cylinders contain 150 feet of wire and for convenience in estimating wire footages these tubes are marked into 15 sections each containing about 10 feet of wire. For spans requiring more than 150 feet but less than 300 feet of lashing wire, additional coils or parts of coils may be spliced together before use and placed on the messenger *in advance* to meet varying span-length requirements. Enough wire must be provided before starting a spinning operation because after the messenger has been made fast coils cannot be added if the wire is exhausted in mid-span. The tool itself weighs approximately 1.2 pounds and the wire containers weigh approximately 1 pound for each 150 feet of 0.045 wire. The amounts of lashing wire required for spans of various lengths and cables of different sizes are given in Table I prepared by the manufacturer.†

TABLE I

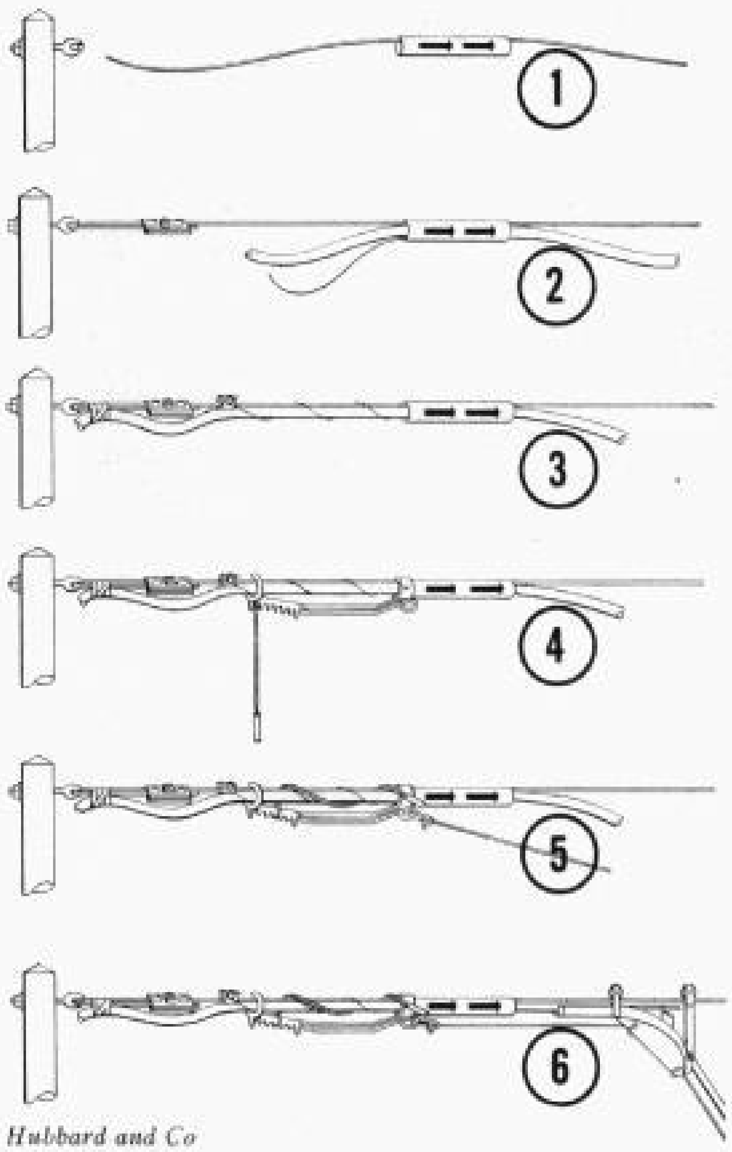
Length of lashing wire required when .109 inch steel line wire is used as messenger			Length of lashing wire required when 5/16" (6M) strand is used as messenger		
Cable—Size (In.)	*Span Length in Feet		Cable—Size (In.)	*Span Length in Feet	
	25	100		25	100
1¼	30	120	1¼	33	130
1	28	111	1	30	117
¾	27	107	¾	28	111
½	26	104	½	27	107

*For span lengths not given, interpolate in direct proportion. (Example: for cable size 1¼" with .109 line wire, a 50 ft. span would use 60 ft. of lashing wire or a 75 ft. span would use 90 ft. of lashing wire.)

In using this lasher the first step as indicated in Figure 4 is to slide the lashing wire container over a loose end of the messenger strand which then is drawn up to correct tension and clamped tightly. Next, the end of the lashing wire is drawn back through the wire container and clamped to the messenger, and the cable end also is inserted through the wire tube and fastened.

Now, with the lashing tool secured in place behind and with its cupped end fitting snugly

† Hubbard and Company, Pittsburgh, Pa.



Hubbard and Co

Figure 4. Strand is run through tube of wire (1) then made fast. Cable and wire are drawn through tube (2) and secured (3). Tool is placed on strand (4) and fastened (5). A cable guide is helpful (6).

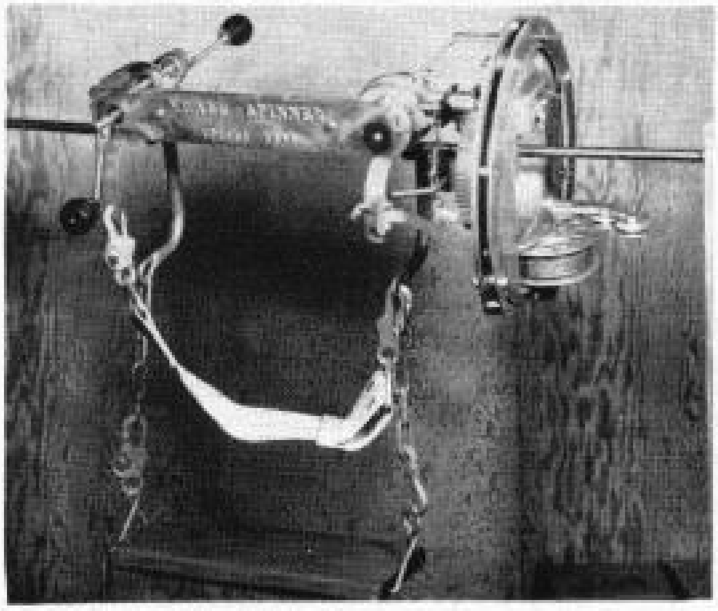
over the end of the wire container, as the tool is drawn forward the lashing wire will unroll around both strand and cable. A cable guide or shoe is available to aid in lifting cable into lashing position against the strand.

This lasher is a simple device for many smaller installations, and especially for new cable suspension work when the messenger strand still is unfastened to allow its insertion through the wire container tube. A light tool such as this is particularly well suited for new work between poles and buildings or in other locations in which short spans hardly warrant the time and effort required to set up a heavier lashing machine.

Cable Car Spinner

Another type of lashing machine well suited for work on either existing cable or new installations is designed so that a line worker may ride on a seat with the machine. Thus in one trip over an existing span the operator may remove old rings, examine the cable for possible damage and, at the same time, provide new lashing. As shown in Figure 5, the seat assembly with its belt hangs suspended by chains just below a two-wheel welded steel one-man cable car having a hand operated drive wheel and mechanism at one end and a machined aluminum spinner head at the other.

A removable latched gate permits the spinner to be placed over the messenger strand and secured; thereafter a coil of lashing wire on its spool spindle is set into place in spinning position in an opening in the spinner head (here a hole in the head is quite convenient). This machine will use all lashing wire sizes and materials to spin cable from 1/4-inch diameter to 5-inch diameter.



Cable Spinning Equipment Co.

Figure 5. Spinner with seat allows inspection

After the car is in place on the strand, as the car is rolled along on its two traction wheels by the operator, the spinner head rotates to unwind its coil of lashing wire around strand and cable. If desired, of course, the car may be pulled with a rope from the ground. Also, for upgrades, the drive mechanism has a gear reduction which may be employed with two cranks to be worked by the operator with both hands to propel the car. A ratchet and pawl associated with one of the traction wheels prevents the machine from rolling backwards and relaxing the lashing wire tension. (As a point of interest, however, with the cable secured under moderate tension, the soft wire spun under tension does not have as much tendency to unwind, even when breaks occur, as perhaps might be expected.)

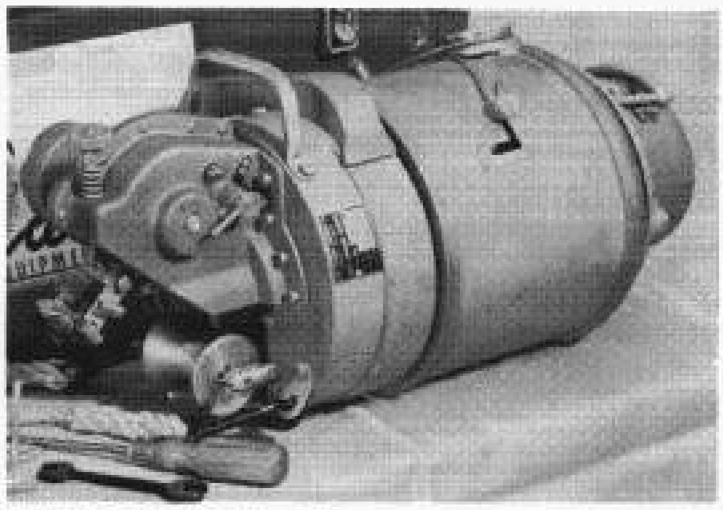
The cable car steel frame, which is cadmium plated, is approximately 24 inches long and 16 inches high, and weighs about 30 pounds. The complete machine* with spinner head is approximately 35 inches long and 19 inches high, and weighs 53 pounds without wire. Steel wire weighs about 8 pounds per coil.

Heavy-Duty Lashers

The modern heavy-duty cable spinner designated as a "pull type" is contained in a housing within which are mounted small trolley wheels to carry the spinner as it travels along a messenger strand, and a drive mechanism which produces spinning motion to rotate one or two reels of lashing wire and their tension pulleys spirally around both strand and cable as the machine is pulled along on its overhead path, usually from pole to pole.[7]

The housing of the lashing machine has an open slot parallel to its axis to admit the strand and cable so they will be about centered within the device when it is in use. Horizontal rollers over which the cable will enter the machine at the front end may be swung into place and adjusted to position the cable so that it is close beneath the messenger strand ready for lashing. A pulling plate or pulling rings are provided at the front of the machine housing.

Since it is important that the lashing wire is spun with constant tension throughout an entire span and that lashing spirals are evenly spaced and of uniform length, modern machine spinners are equipped with tension controls and holding ratchets. Lashing wire tensions vary from around 18 pounds up to 40 pounds per square inch according to cable size and lashing conditions. For lashing small cables, drop wire and twisted pair, tension of 18 to 25 pounds is adequate but for 51-pair 22-gauge or larger cables, tension of 35 to 40 pounds is recommended.

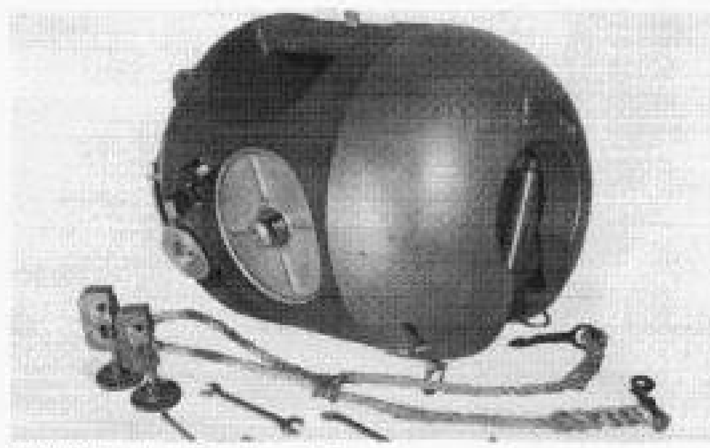


Cable Spinning Equipment Co.

Figure 6. Spinner for 2¼-inch or smaller cable

"Pull Type" Machines

So-called pull type lashing machines or spinners, one of which, shown in Figure 6, is designed primarily for work on new cable up to 2-1/4 inches in diameter, also are made by the manufacturers of the cable car spinner. This lasher in Figure 6 employs two driving mechanisms for its "spinning" drum; the first is a rubber-cored friction wheel which travels on the messenger strand and is connected under controlled tension to the spinning drum through gears, chain and sprocket. The second drive is from the lashing wire as it passes around a tension wheel which also carries a rubber friction tire that drives against the spinning drum. This arrangement provides a 13-inch lashing at each



Cable Spinning Equipment Co.

Figure 7. Compact two-coil pull type spinner

*Made by Cable Spinning Equipment Co., Topeka, Kans. and Pirelli General Cable Works, Ltd., Southampton, Eng.

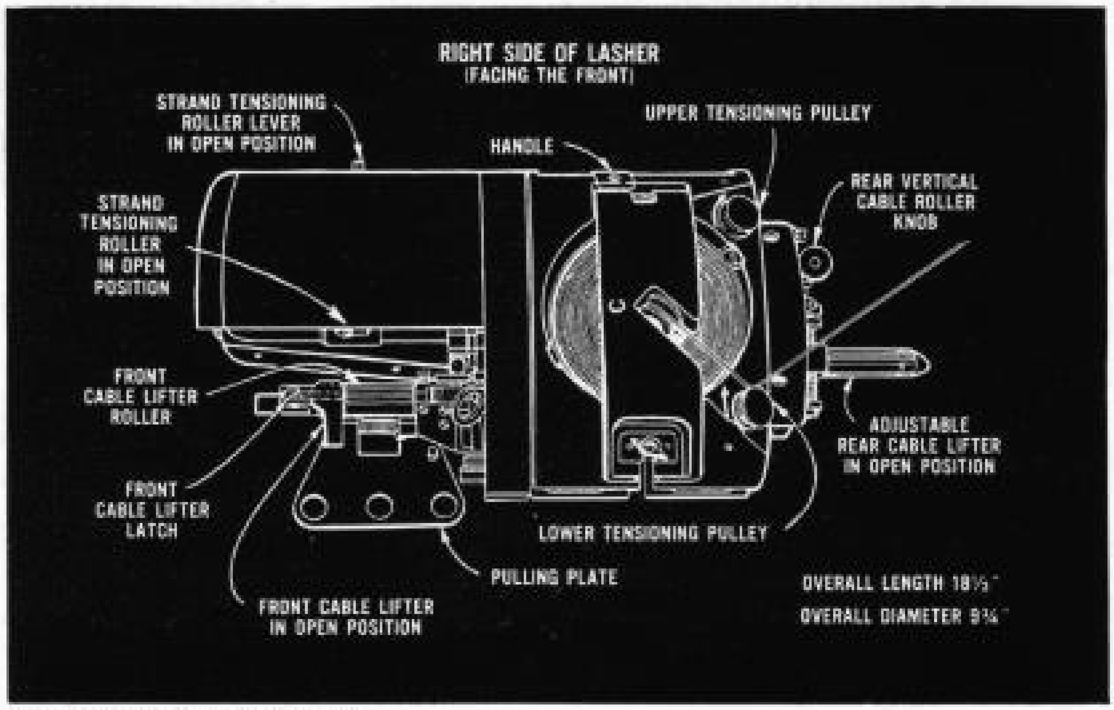
revolution of the spinning drum. Either drive will operate the spinner which will accommodate lashing wire of all types and sizes. This machine measures 22 inches long, 10 inches wide and 10 inches high, approximately, and without wire weighs 43 pounds.

Another heavy-duty pull type machine made by the same company and shown in Figures 7 and 8 is designed especially for lashing together a messenger strand and up to three individual cables compactly and without twisting as, for example, to suspend overhead conductors for a 3-wire single-phase secondary power line. Two or three telecommunications cables, of course, may be suspended in the same manner, or single cables from 5/8-inch to 3-1/2-inch outside diameter can be handled. The machine will accommodate at maximum three cables each two inches O.D.

Cable Spinning Equipment Co.

Figure 8. Lashing three cables with double lay

A feature of this machine is a spinning drum which provides for lashing with two coils of wire simultaneously. Since the two wire spools are located 180 degrees apart on the rotating drum, and the drum makes one revolution for 17 inches of forward motion, the machine will produce two lashing spirals in each 17 inches of travel if used with two wire coils. Of course, if it is used with only one coil of wire there will be only one lashing in each 17 inches of forward motion. Rotation of the spinning drum is effected by rubber friction drive wheels actuated by movement around tension pulleys of the lashing wire as it is pulled off the wire spools. This machine is 19 inches long and 12 inches in diameter, and without wire weighs 36 pounds.



General Machine Products Co.

Figure 9. For 1⅝-inch cable, holds two wire coils

A different pull type lasher shown in Figure 9, for aerial cables up to 1-5/8 inches in diameter with strand wire diameter from 5/16 to 7/16 inch is made by another manufacturer.* This machine, which also will hold two 1200-foot coils of 0.045-inch lashing wire, is about 20 inches long and 11 inches in diameter and without wire weighs 33 pounds. A heavier model of the same type is made for cables up to 3-1/4 inches in diameter with strand wire from 1/4- to 1/2-inch diameter. It will secure two or more cables simultaneously if the diameter of cables and strand is not over 3 inches; it also takes two 1200-foot coils of 0.045 wire; it measures 20 inches long and 14 inches in diameter and without wire weighs 43 pounds.

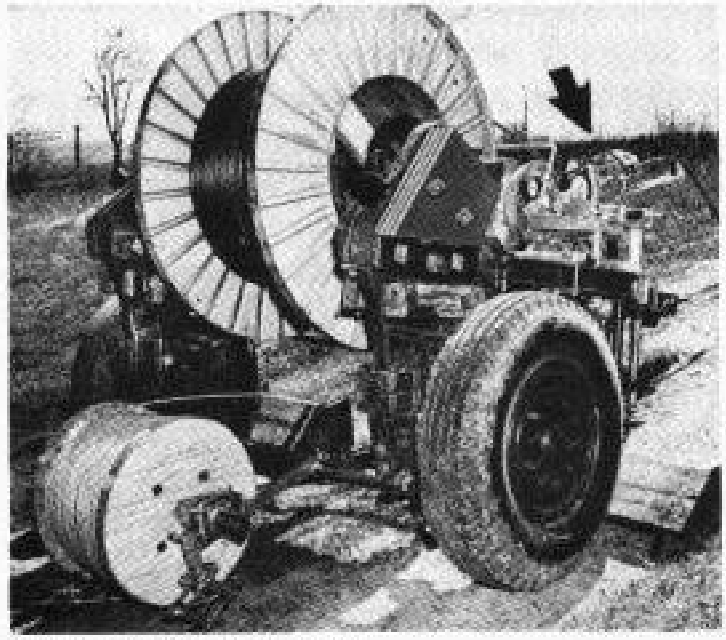
In both of these lashers the rotating drums which carry the wire coils are geared directly to two rubber drive wheels that ride on the strand. Various necessary rollers and automatic ratchet type brakes are mounted on and in the lasher housings

*General Machine Products Co., Inc., Trevose, Pa.

which are equipped with sealed ball bearings and Oilite bushings for their moving parts. Aluminum, bronze and cadmium plated steel are used in manufacture.

An even heavier machine in the same series is built "king size" for lashing 2½-inch to 5-inch diameter cable and 11/32-inch to ⅝-inch diameter strand. It is designed to spin one or two lashings of 0.045 stainless steel wire with a lead of from 15½ to 17½ inches per turn depending upon the diameter of the messenger strand. An interesting feature of design is the arrangement by which the pulling mechanism pivots around the axis of the rear drive wheel so as to apply a hold-down force at the strand roller which the manufacturer says is "approximately 2.2 times the forward component of the towing force." This lasher is 26 inches long, 18 inches in diameter and weighs about 75 pounds.

A fourth model by this manufacturer is adjustable for aerial cables from ½-inch to 2½-inch diameter and may be modified to use 0.045 s.s. wire but normally holds one 650-foot coil of 0.065 stainless steel wire or a 325-foot coil of 0.091 galvanized wire, measures 19½ inches long and 12¼ inches in diameter, and weighs 43 pounds not including wire.



General Machine Products Co.

Figure 10. Prelashing rig reduces pole climbing. Arrow points to lasher mounted on front of trailer

Prelashing on Location

When a new cable is hung in place temporarily in rings or blocks before lashing is undertaken, it is evident that this temporary suspension means some extra work despite the fact that special cable placing rings, some with spacing rope attached, and special easily assembled blocks may be had to facilitate this operation, and the fact that machine spinners may be set up to push along these temporary rings or blocks to the next pole as lashing progresses. Then, too, moving the machine around a pole from one span to the next may prove awkward and in any event involves terminating the lashing wire at each pole and unlatching spinner rollers, spinning head gate, pulling line, and so forth which, of course, makes cable lashing from span to span something less than as straightforward and convenient as might be desired.

To avoid such inconveniences, particularly on a big job, as well as to reduce pole climbing and keep both men and equipment on the ground more and thus improve safety and efficiency in general, there have been developed equipment and procedures for prelashing aerial cable on location.[8] Here, the cable lasher or spinner is mounted on a motor vehicle trailer such as made for cable reel transport, along with a reel of cable, a reel of strand wire and necessary reel brakes and tension controls as illustrated in Figure 10. After temporary cable blocks (Figure 11) have been attached to the poles, it is

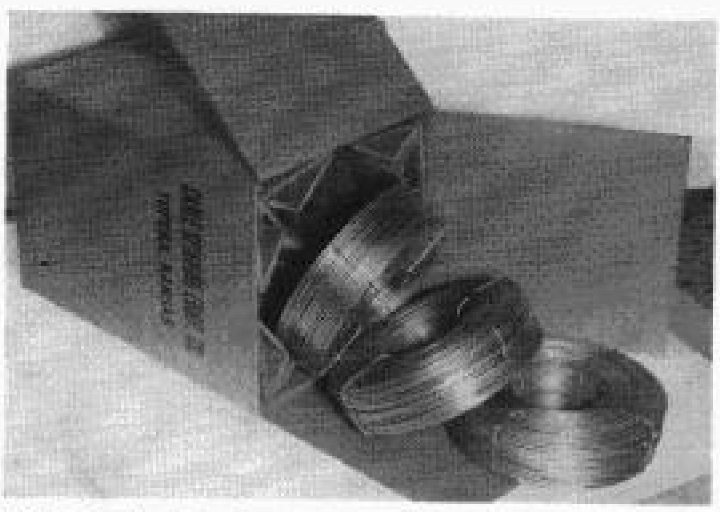
Figure 11. Temporary cable block on messenger strand

entirely practical continuously to lash and haul the lashed cable into position overhead. Cable and strand drawn by a traction line from their separate reels pass together through the spinner which remains stationary on the trailer at ground level. As spinning proceeds, the lashed cable and strand follow the tow line through the temporary pole blocks; thereafter the strand tension is adjusted for correct sag and the lashed cable and strand are removed from the blocks to permanent pole suspension clamps, releasing the blocks for reuse.

It is reported that an experienced five-man team working with a trailer mounted lasher and associated equipment can install as much as ten miles of lashed cable in a day.

Wire and Accessories

Lashing wires of various materials for use under appropriate conditions, and of different diameters as shown in Table II, are available in suitable coils from spinner makers and from wire manufacturers. Regular round wire is standard; ribbon type flat wire such as has been employed on factory prelashed cable is not used with spinners.



Cable Spinning Equipment Co.

Figure 12. Coils of 0.091 aluminum spinning wire

Stainless steel wire (A.S.T.M. type 302-18Cr8Ni) of 0.045-inch diameter is preferred by the Telegraph Company but 17-percent chrome steel wire (A.S.T.M. type 430) of this size also is satisfactory although it may stain and rust slightly in corrosive atmosphere. Because the 0.045-inch diameter is small, it can cut into cable sheath more readily, of course, in case the line is badly damaged by falling trees or vehicle impact. Commonly used sizes are the larger 0.061- and 0.091-inch diameter wires which may be had in soft annealed galvanized steel, soft copperweld, and aluminum alloy (Figure 12) as well as stainless steel. An 0.090-inch soft drawn copper wire also is furnished as is the copperweld for use in locations where there are corrosive fumes. Copper and copperweld spinning wire are to be used only with copper or copperweld strand.

It is reported reliably that galvanized lashing wire proves entirely satisfactory in uncontaminated atmosphere with a low humidity range, as in plains states and some mountain areas of the U. S. A. It should be remembered, however, that corrosive, humid atmosphere will engender some galvanic action as between dissimilar metals of lashing wire, lead sheath cable and messenger strand. Moreover, when galvanized (zinc) coating eventually begins to deteriorate the corrosion factor for base iron in contact with lead is much higher than for the original zinc coating. Plastic sheath may prove advantageous in this respect.

Table II

Spinning or Lashing Wire

	Stock Sizes (X)				
	0.045″	0.061″	0.080″	0.090″	0.091″
Stainless steel, type 302*	X	—	—	—	—
Stainless steel, type 316*	—	X	—	—	—
Chrome steel, type 430*	X	X	—	—	—
Galvanized	—	X	—	—	X
Aluminum	—	—	X	—	X
Copperweld	—	—	X	—	X
Copper	—	—	—	X	—

*American Society for Testing Materials

Aluminum alloy wire not only is reported to give general satisfaction in resisting corrosion when in contact with lead sheath and galvanized or uncoated areas of iron strand but also has the decided advantage of light weight.

Accessories specially designed for the

purpose facilitate proper lashing under various conditions which are found along aerial cable lines. Adjacent to splices, loading pots, and pole suspension clamps, lead or polyethylene spacers are used in combination with stainless or chrome steel straps to position the cable firmly and give needed separation between cable and strand. Contoured spacers are available in 1/4-, 1/2-, 3/4- and (in lead) 1-inch sizes; the latter will usually accommodate large diameter splices. Straps 3/4-inch wide come finished in lengths from 16 to 78 inches to provide three turns around cable and strand. Where lashing wires are terminated on messenger strand as is customary, both temporary and permanent special lashing wire clamps are used. The latter are of galvanized malleable iron with a spacer bar of stainless steel which prevents the small lashing wire from resting between strands of the messenger inadequately clamped. Other accessories include previously mentioned cable guides or shoes used ahead of cable spinners to help place cables smoothly into position for lashing, and cable placing rings, rollers and blocks. In addition, there are, of course, numerous other cable handling devices which are used with or without the lashing tools which have been described.

* * * * * *

In concluding this summarization of information about various lashing tools which are employed in construction and reconstruction work on aerial cable lines it may be noted that today much cable is being installed underground. Incidentally, it may be noted, too, that some enthusiastic space-age scientists have visions of conducting all telecommunications without wires—perhaps by telepathy? Nevertheless, space age or not, economic factors apparently will dictate continuation of aerial cable installations for both telecommunications and power in many areas for some years to come. Meanwhile, therefore, it would be well to continue assiduously to improve the component elements of existing practices in this field.

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Grosvenor Hotchkiss, E. E., Polytechnic Institute of Brooklyn, joined Western Union's Traffic Department in 1918 after an enlistment in the Signal Corps. As Engineering Assistant he organized the traffic routing bureau and handled circuit layout before accepting an assignment in 1930 as Executive Assistant in the office of the President of Teleregister Corporation, then a subsidiary of Western Union. Later he was Assistant to the Development Engineer until appointed to his present position as Coordinating Engineer, Development and Research Department. Mr. Hotchkiss is a former member of the Division of Engineering and Industrial Research, National Research Council, a Professional Engineer, and a member of AIEE.

Patents Recently Issued to Western Union

Facsimile Telegraph Apparatus for Variable Blanking and Carriage Return

L. G. Pollard, C. R. Deibert, F. T. Turner, R. H. Snider

2,824,902—February 25, 1958

In a high-speed facsimile transmitter, as the longitudinal gap between edges of the copy sheet inside a transparent drum passes before a fixed scanner during the first few revolutions, pulses are produced which release phasing pulses from a phasing modulator. After phasing, a travelling scanner produces facsimile signals and, to prevent spurious marking at the receiver, the signal modulator is blanked for periods which overlap the gap periods, whatever their width. Closure of the drum end door after insertion of the copy sheet energizes the driving motor, removes stand-by tone from the line and initiates the phasing and transmission cycle. At message completion, a short end-of-message tone is sent to line, the motor disconnects, the message scanner returns to starting position, and either a readied alternate transmitter is started or a stand-by tone is sent to line.

●

Facsimile Stylus Holder

E. E. Bedell

2,829,942—April 8, 1958

A simple, inexpensive, self-aligning stylus holder combination for small facsimile recorders designed to permit rapid replacement. The stylus is permanently fixed to one tine of a disposable fork-shaped spring metal holder which is insertable into a mating fork-shaped mounting member on the recorder stylus carriage. Projections and complemental apertures on the mount and holder, respectively, serve to lock and align the stylus in proper position. In a modification of the holder, the stylus itself is readily replaceable.

●

Aqueous Graphite-Polyvinyl Alcohol Ink Composition

H. W. Glaser

2,833,736—May 6, 1958

A nonsmudging, readily erasable drafting ink comprising graphite particles within the size range of 2 to 5 microns in an aqueous solution of polyvinyl alcohol or other suitable binder. The size and flake structure of the graphite prevents its penetration into the paper, hence permitting ready erasure.