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AMERICAN TELEGRAPH ENGINEERING—NOTES ON HISTORY AND PRACTICE

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Although there may not be any startling technical announcements to make relative to recent progress in American telegraph engineering practice, yet within the twenty-five years past, in common with the progress in other lines of engineering, substantial developments have been also made in the telegraphic art along numerous lines, such as the standardization of equipment, and the adoption of improved apparatus and methods of operation which have generally resulted in increased efficiency of the plant, greater reliability of operation, a more rapid handling of the traffic, and consequent improvement in the service rendered the public; and which developments have, in fact, been adequate to meet the demands made upon the telegraph.

The time has been deemed opportune to record some of the salient features of present telegraph engineering practice in this country, but first in order more clearly to illustrate the differences between past and modern practice a resumé of the early history of telegraph practice in this country will be essayed in which resumé certain more or less interesting items of information relating to that history perhaps not hitherto published, or in any event not readily available, may be recounted.

The first electric telegraph line in this country was constructed by Morse in 1844 between Washington and Baltimore. The progress of this art into public favor was slow; due mainly to the high rates for service and to more or less imperfect service, the latter due mainly to poorly constructed lines and the former largely to heavy legal expense incurred in the effort to maintain for the Morse interests a monopoly of the telegraphic art. Morse endeavored to obtain a British patent for his electro-magnetic telegraph, but failed on the score of previous publication. Bain of Edinburgh came to the United States in 1848 to obtain a patent covering his chemical telegraph which was refused on the allegation that his device infringed the patents of Morse. Bain's telegraph consisted of a device for perforating long and short holes in a strip of paper, which were used to transmit long and short impulses of current over a wire. At the receiving end he used a sheet or strip of paper saturated with a chemical solution consisting of nitric acid 2 parts, prussiate of potash 20 parts and pure liquid ammonia 2 parts, which solution was decomposed by an electric current from the sending station thereby leaving long and short marks on the receiving paper sheet or strip. Bain pressed his claims in the United States Supreme Court and in the year 1849 a patent was finally allowed. A British patent to Morse would have been of doubtful value at that time, as during the life of the United States patent the Morse telegraph was but sparingly used in Great Britain, various needle and dial telegraph systems having obtained a strong foot-hold in that country.

The maximum speed claimed for the Bain system was about 1000 words per minute, but as a writer of that day remarked:[1] " The process of preparing the message to be transmitted, took quite as long as to transmit it " by the Morse method, and while " Mr. Bain's plan was entirely successful as far as it went it was found that after the quick receipt of a long dispatch, it would take about as long to copy it into manuscript as it would have taken to transmit it in the ordinary manner in the first place." Following the granting of the U. S. patent to Bain, numerous telegraph companies were organized and lines built on which the Bain automatic chemical system was employed, in opposition to the Morse Companies, but in 1850 an injunction was obtained, based on the charge that Bain's apparatus infringed the Morse telegraph patent of 1840. A consolidation of many of the chemical automatic companies with the existing Morse lines soon followed, and subsequently the Morse manual system (in which the Morse stylus recorder, or register was used) went into almost general use.[2] The Morse register was

1. "Electric Telegraph," (1852) Jones, pp. 110-150.

2. In a personal letter to Mr. Maver dated August 22, 1890, Mr. D. H. Craig who was a prominent figure in the early annals of American telegraphy, writes: " I used Bain's system on lines between New York,

gradually displaced by the reading sounder, but not without opposition on the part of the superintendents of telegraph who were apprehensive, needlessly as experience proved, of the introduction of errors thereby. The first printing telegraph was that due to Royal E. House[3] the use of which was begun in 1847–1848 and continued for many years in this country. This system employed a key-board the depression of a key of which resulted in the printing of a given letter on a strip of paper at the receiving station. The speed of transmission by this system was about 50 words per minute. It was operated on lines 1000 miles in length. The Morse interests endeavored to bring this telegraph printer within the scope of the Morse patents but were overruled by the courts.

In the early days of the electric telegraph the methods of line construction were naturally crude, but every year saw improvements in the direction of workmanship and materials used. Wooden poles were used from the first in this country, but the forms of insulators and the materials used in their construction were multitudinous, and it was not until much bitter experience was had with various "improvements" in insulators that practice converged on the glass petticoat form now universally employed in overhead electric telegraph work in this country. One of the so-called improvements termed the "brimstone" insulator was especially defective and nearly ruined several of the competing companies that employed it. This insulator consisted of an iron arm which screwed into an augur hole in the pole, the outer end of the arm carried a hollow pendant filled with sulphur into which an iron hook that upheld the line wire was inserted.

Boston and Portland between 1850 and 1853 and was able often in stormy weather to send to the Boston press columns of news when the Morse lines would not telegraph a word. We frequently, however, had trouble with "tailings" when the dots and dashes all ran together and made the record partially or wholly unreliable, so that in a message or series of messages of 500 or 1000 words there would be yards of record that would have to be discarded and the messages repeated. The later use of artificial resistances or magnets largely eliminated this trouble. Bain used on his early lines (for his chemical solution) nitrate of ammonia, 2 pounds to a gallon of water, and muriate of ammonia one pound to a gallon of water, and one-half ounce of yellow prussiate of potassia. This makes a fair solution, but we discarded it, (date not given) and substituted one half ounce red prussiate of ammonia and one pound of muriate of ammonia dissolved in one gallon of pure rain, or distilled water—iron pins were used with this."

3. Described in "Manual of the Telegraph," Shaffner, p. 391.

The civil war in this country, 1861–1865, again directed the attention of the world to the great utility of the electric telegraph in war and while its use at this time did not perhaps materially aid in the advancement of telegraph engineering it emphasized the value of the Morse telegraph system for this purpose because of its simplicity and reliability in operation.

The source of electromotive force for telegraph purposes in the United States up to the year 1855 was the Grove cell, which was displaced by a modification of the Smee cell known as the Chester battery, and this battery in turn gave way to the Callaud or gravity battery, of which up to the introduction of the dynamo machine in the year 1882, many thousands were in use. In some of the main telegraph offices 5,000 to 15,000 such cells were employed; entire floors of large office buildings being set aside for their occupation.

To meet the increasing demand for additional telegraph facilities in the decade 1870–1880, without resorting to the continual construction of additional line wires, the thoughts of inventors were directed to means for increasing the capacity of existing wires. To this end the chemical automatic telegraph, and the duplex and quadruplex systems of telegraphy were called into service. Thus in 1870 a compound wire of steel core and copper was erected between New York and Washington a distance of 275 miles on which a chemical automatic system due to Mr. George Little was employed. This system was a modification of the Bain chemical telegraph previously mentioned herein. Originally, adequate means were not provided in the Little system for diminishing the "tailings," or prolonged currents, due to the static capacity of the line, at the receiving instrument, in consequence of which the speed of signaling was low. Subsequently Little introduced a plain resistance in shunt around the receiver with beneficial results.

The Varley devices consisting of electro magnets in shunt with the receiver, and of condensers in series with the receiver[4] for the purpose of eliminating the tailings were subsequently employed, (the electro-magnets probably first by H. Grace,) to great advantage in this and certain other later automatic chemical systems in which a single row of holes in the perforated paper (and a uni-directional current) was employed; the condenser as thus employed virtually giving the equivalent of the double current method. Still later the speed of

4. British patent No. 3543, 1862. U. S. Patent 78495, 1868.

transmission on this New York–Washington line was increased to 900 words per minute by the substitution of an iodine solution and by using a platinum needle in place of a nitric acid solution and iron needle.

An important contribution to the art of chemical automatic telegraphy at this stage was the Edison key-board perforator, which by the depression of a key perforated in a moving paper tape the characters necessary for any given letter. By the Little method of preparing the perforated tape not more than 7 or 8 words per minute was feasible, while with the Edison key-board perforator the tape could be prepared at a maximum rate of 40 words per minute, the average being about 25 words per minute. This key-board perforator while highly ingenious from a mechanical point of view was somewhat cumbersome in operation. The key board was about 18 inches in length, and the keys had a drop of about 2 inches requiring strong pressure to carry them down. As a writer of the period remarked " An hours work on one of these punches is a severe strain on the muscles of a strong man."[5] An important test of this system was made between Washington and New York, January 27, 1874 when the President's message on the Spanish " Protocol " consisting of 11,130 words was transmitted. This matter was prepared for transmission by ten perforators in 45½ minutes. The message was transmitted in 59 minutes. Time from the beginning of perforation until message received at distant end of the wire, 53 minutes. The time consumed in translating the characters by ten operators in New York was about 45 minutes, or roughly it required 72 minutes for the entire operation. Four Morse operators on 4 single wires, it may be remarked, are capable of transmitting a message of this length in 55 minutes. In the practical operation of this system by the Automatic Telegraph Company on its single wire from New York to Washington, D. C., during 1873–1874 business was frequently badly delayed by the breaking of the wire, there being no emergency wire, or alternate route. This fact undoubtedly detrimentally affected the commercial success of this system, a result that must obviously follow in all cases where but one route or only a limited number of wires between the important business centers are available. This automatic system[6] was subsequently employed, more or less in combination with the Morse

6. (Described in " The Electric Telegraph ", Prescott, Vol. 11, p. 727.)
5. " The Telegrapher," 1875, p. 109.

manual system, on the lines of the Atlantic and Pacific Telegraph Company until the year 1876, when it was gradually displaced by the Morse manual method of transmission.[7]

From about 1880 to 1884 the American Rapid Telegraph Company and its successors the Banker's and Merchants, and United Lines Telegraph Companies, operated a chemical automatic system known as the Foote & Randall system. These companies lines (compound copper coated wires) extended from Boston and New York to Washington, Pittsburgh, Buffalo, Cleveland and intermediate points. In this systemt he double-current method was employed. The prepared paper was perforated in two rows as indicated in Fig. 1.

Dots were represented by one hole on either side of the strip, the dashes by two holes. Consecutive dots, and dashes, were perforated diagonally on alternate sides of the paper strip as shown in the figure. Two metal drums *d*, *d′* connected with the positive and negative poles, respectively, of the battery were placed side by side in such a manner that one drum came under the holes on one side of the paper, the other under the holes on the other side. Transmitting needles or brushes *n*, *n′* connected jointly to the line wire were arranged so that each was in line with one row of holes on the paper. By the arrangement of the holes as shown each consecutive character of a letter, and the first character of a following letter were made by a different polarity to that making the preceding character and consequently all letters containing more than one character were represented by dots and dashes on alternate sides of the received paper strip.

7. About the years 1875-77, the widely advertised claims of the Atlantic and Pacific Telegraph Company relative to the advantages of the chemical automatic and Wheatstone automatic telegraph systems controlled by that company were having a depressing effect on the stock of the Western Union Telegraph Company. Presumably to offset this effect President Orton of the last named company contracted with Messrs. Craig, Randall and Foote to pay $500,000 for a chemical automatic telegraph system that would be superior in every respect to that operated by the rival company. Tests were made of the new automatic system and the experts reported that all the technical conditions of the contract were fully met. Upon the sudden death of President Orton shortly thereafter however complications arose, a compromise offer of $250,000 being declined, whereupon the contract was abrogated and the inventors' interests in this system were turned over to the American Rapid Telegraph Company. It may be added on the authority of Mr. C. A. Randall that the inventors finally received about $15,000 as their portion of the amount received for the patents covering the automatic system bearing their name (W. M. Jr.)

At the receiving station needles n, n' were arranged in series in the line circuit as outlined, and rested on the sensitized receiving paper p. As the chemical solution is decomposed only by a current of positive direction, marks were made by the needle n with currents from battery E, and by needle n' with currents due to battery E'. In this system advantage was taken of the retardation of current due to the static capacity of the line in forming the dashes; the short perforations, all of uniform length, also limiting the time of contact of battery with the line, and thereby limiting the charge imparted to the line at each contact. The records thus produced were easily read by copyists. This system was capable of transmitting clear, legible characters between New York and Boston at the rate of 1000 words per minute, and 500 words per minute were ordinarily so transmitted. Messages were prepared by operators using the Anderson keyboard by means of which 30 to 50 words per minute could be

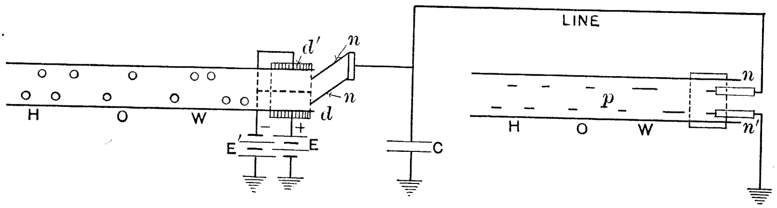

FIG. 1.—Foote and Randall chemical automatic telegraph

perforated, the machine operating with the ease of an ordinary typewriter. In June 1883, the American Rapid Company had in operation over 2,400 miles of pole line and 14,000 miles of wire. As already intimated this company began operations with the use of compound wires (6 ohms per mile) consisting of a steel core covered with a copper strip each weighing 200 lb. to the mile. This compound wire proved unsatisfactory, owing it was claimed to imperfections in manufacture which led to breaks or openings in the copper strips admitting moisture and ultimately causing the copper to peel off in long lengths. Subsequently No. 6 iron wire was employed as line wires by this company. The rates charged by this company in 1881 for transmitting messages was \$1.00 for 195 words between New York and Boston, but experience showed this rate to be unprofitable and it was increased to 15 cents for 20 words. The Foote and Randall automatic system was set aside in 1884 upon the financial failure of the company.

In 1881 the "Leggo" chemical automatic system was installed by the Postal Telegraph Company between New York and Chicago (1,000 miles) on its two 1.7-ohm-per-mile wires (compound steel and copper) on which by the Leggo system 1000 words per minute were commonly transmitted. Taylor found by experiments on these wires that up to 400 miles, a speed of 400 words per minute was possible by the old Bain method; that is without compensating for line static,[8] but at a distance of 700 miles the signals arrived in a continuous black line. To remedy this defect Taylor introduced an extra battery E', Fig. 2 at the receiver R in opposition to the transmitting battery E. The e.m.f. of battery E' was one third of that of E. r, r' were adjustable resistances. With this arrangement a speed of 1200 words per minute was possible on this New York-Chicago circuit.

The method of preparing the messages for transmission by the

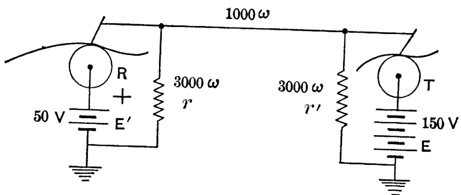

FIG. 2.—Taylor arrangement of Leggo's automatic telegraph

Leggo automatic system consisted in depositing an insulating ink spirally on a revolving metallic cylinder by means of a spout attached to the armature of an electro magnet operated by a relay or Morse key in a main or local circuit. The dots and dashes thus recorded were transmitted from the metallic cylinder at high rates of speed over the line circuit. An advantage claimed for this method of recording signals for re-transmission by Morse telegraphy was that the business originating at branch offices and way offices could be transmitted over through wires automatically without further preparation. The extra battery E' was kept constantly to the line during operation and at the instant when the transmitter needle or brush passed onto the insulated ink on the drum this negative polarity cut short the tailings.[9] The Leggo automatic

8. See article of Theodore F. Taylor, *Electrical World*, May 24, 1884.
9. This arrangement of batteries for this purpose is perhaps suggested in Prescott's "Electric Telegraph," 1866, p. 137.

system was abandoned for lack of patronage after a comparatively short period of operation.[10]

Since the discontinuance of the American Rapid and the Leggo systems there has been no extensive employment of automatic chemical telegraphs in this country or elsewhere although workers in this field like Anderson and Delany have devised certain features designed to be conducive to greater reliability of operation and speed of translation of the received characters, notably perhaps the Anderson page method of recording the message which enables the attendant to observe the condition of the incoming signals as they arrive, and simplifies the reading of the characters by the copyist[11]. It also lends itself readily to means for drying the paper speedily as received, thus obviating, or minimizing an objection to "wet" strip, namely the tearing of the strip.

The well known Wheatstone system of automatic telegraphy was introduced on certain circuits of the Western Union Telegraph Company in 1883, and its use was continued thereon up to a comparatively recent period when it was[12] to a considerable extent displaced by the Buckingham-Barclay printer. Further reference will subsequently be made to this subject.

As previously stated the employment of duplex telegraphy began about the year 1868, and on short lines was practiced with a certain degree of success without any device to compensate for the static discharge from the main line. Stearns, however, applied the condenser to the artificial line for this purpose in 1872, whereupon the general use of the duplex ensued. Subsequently in 1873–74 the Edison quadruplex was placed in operation on the Western Union Telegraph Company's lines and after numerous modifications of apparatus and circuits finally reached its maximum efficiency about 1884. In the year 1886 there were about two hundred quadruplex sets in operation in the United States, these, it was estimated, providing additional, or "phantom" wire facilities equivalent to 150,000 miles of line wire, the value of which was approximately eleven million dollars.

Much of the success of the quadruplex system between the years 1885–1895 is no doubt properly ascribed to the extensive employment of hard drawn copper wire for telegraph purposes, beginning in 1885. The period indicated was also prior to the

10. See TRANSACTIONS A. I. E. E., 1897, p. 139.

11. See "American Telegraphy and Encyclopedia of the Telegraph," Maver, p. 294.

12. *Ibid*, Chap. XXVII.

advent of high tension power transmission lines in proximity to telegraph circuits, the inductive disturbances from which undoubtedly have had a very detrimental effect upon quadruplex operation, and to which subject also further reference will be made.

As an instance of the extent to which duplex and quadruplex operation has been utilized in this country in proportion to existing wire mileage, it may be noted that in the case of the Baltimore & Ohio Telegraph Company which had a total of 50,978 miles of wire in operation in 1887, (reaching from Portland, Maine to Galveston, Texas, *via* New York, Washington, Chicago, St. Louis, etc.,) 23,482 miles thereof were assigned to the aforesaid duplex and quadruplex service, producing 56,553 miles of phantom circuits. Of the total miles of wire mentioned there were approximately 4,655 miles of No. 12 and 3,605 miles of No. 14 hard drawn copper;[13] 12,726 miles of No. 6 iron, 25,345 miles of No. 8 iron, 3,944 miles of No. 9 iron, and 252 miles of No. 12 iron wire.

In the years 1885–86 the Delany synchronous multiplex system[14] was in experimental operation on a circuit of the Baltimore & Ohio Telegraph Company's lines. On short lines this system gave the equivalent of six transmissions simultaneously, but owing largely to difficulties introduced by the static capacity of the line, its employment on long lines was not available at that time.

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13. This was doubtless the first extensive employment of hard drawn wire in telegraphy. At this time quite conflicting views were held as to the utility of this metal for overhead telegraph circuits; the advocates of silicon-bronze and phosphor-bronze wire claiming superiority for those materials. The experience of twenty-five years has, however, fully justified the favorable opinions of the pioneer users of hard drawn copper wire regarding its many advantages.

It may be further noted as an interesting item of telegraph history that owing to the expiration in 1880, through inadvertence, of the Canadian patent No. 4608, of April 10, 1875, covering the Edison quadruplex, that system was unprotected by patents in this country after the first mentioned date. A legal contest was, however, waged by the Western Union Company against the Baltimore & Ohio Telegraph Company for infringement of Stern's patent No. 126,847, of 1872, covering the application of the condenser to duplex and quadruplex telegraphy. An injunction *pendente lite* was denied by the courts on the ground that the original Stearns patent had been so broadened by successive re-issues as to raise reasonable doubt as to its validity. The matter was still in litigation when the defendent company was merged with the Western Union Company in October, 1887.

14. Desciibed in "American Telegraphy," Maver, Chap. XXI.

Sources of Electromotive Force in Telegraphy

As already noted herein gravity batteries as a source of e.m.f. for telegraph service have been almost entirely displaced in this country by machine generators. The type of generators used and the arrangement of equipment vary according to the local requirements.

In some instances the generators are driven by gas or steam power developed on the premises, but as a rule public service mains are utilized to operate the machines, either as motor-generators, or by means of separate electric motors. At points where the only commercial current available is alternating, it is customary to operate from this source an induction motor-driven direct-current generator which in turn furnishes power for the operation of direct-current motor-generators. In numerous cases where driving power to operate the motor generators is derived from public service mains, emergency gas or gasoline engines are installed to insure continuity of service in the event of prolonged interruption of the commercial power circuits. One method of arranging these machines in large terminal offices consists in arranging a certain number of them of equal voltage in series, thereby furnishing a range of e.m.f. from, say 40 to 400 volts, the machines being tapped by the various main line or local wires as required, the local and single wires taking from 40 to 150 volts, respectively, the duplex circuits taking current at 200 volts and the quadruplex circuits at about 350 volts. As currents of both polarities are employed in these systems, two sets or gangs of machines in series, as stated, are employed. Another method of arranging dynamos in terminal offices is to employ from 7 to 14 machines which deliver e.m.f.s ranging from 40 to 400 volts the lower voltage supplying current for the operation of sounder circuits, automatic repeaters, duplex and quadruplex pole changers, transmitters etc. An e.m.f. of 125 volts is used for main line simplex operation, generally way wires having a number of offices on the circuit. Machines supplying respectively 200 volts of positive and negative polarity are allotted to duplex operation, while 385 volt machines of positive and negative polarity, respectively, provide current for quadruplex circuit operation. The general arrangement and appearance of these machines are shown in the accompanying illustration.[15]

Storage batteries also have been utilized quite largely in telegraph service as sources of current for the operation of main line

15. Described in "American Telegraphy," Maver, pp. 47-227.

and local circuits. In general these batteries are charged from public service direct-current mains, or by locally operated direct-current motor-generators. The comparatively large loss in transformation of power, from the mains to, and in the storage battery itself, together with the cost of attendance and maintenance of the motor-generators and the battery have acted as a deterrent to its extensive use in telegraph work, notwithstanding certain advantages in the way of constancy and reliability of current that such batteries may possess. The engineering departments of the commercial telegraph companies and of the larger railroad

FIG. 2*a*.—Typical arrangement of motor dynamos in telegraph work

companies have therefore followed closely those developments in the electrical art which aim to procure equally efficient and more economical transformation of electric power for telegraphic purposes, and the claimed advantages of various alternating-current rectifiers—vapor, electro-mechanical, and electrolytic—have been considered and tested. At the present time, for example, quite an extensive application of the electrolytic rectifier is being made by the telegraph companies here, in order to determine what dependance may be placed upon these methods of obtaining practically constant direct-current potentials from alternating-current sources. One of these rectifiers (the "Hickley") consists of a solution or electrolyte, say, phosphate of soda, and electrodes of carbon and aluminum, contained in a vessel *V*, Fig. 3, to which are attached radiator loops *R* which permit circulation of the solution (necessary on account of the heat developed in the electrolytic cell) thereby preventing the weakening of any portion of the electrolyte more than another. The direct current supplied by the rectifier is of course, pulsating, but owing to the condenser effect of the cells whereby a portion of the negative current is recovered, currents are derived which are sufficiently steady for average telegraph requirements. With this rectifier 80 volts direct current are procurable from 110 volts alternating current mains. The durability of the solution and electrodes of this rectifier depends largely upon the amount of energy delivered, but if not overworked the rectifier will not require renewal oftener than once each year; assuming daily operation of the device. A suitable transformer *T* is utilized to give either higher or lower voltage than that supplied by the available alternating-current mains, the rectifier being constructed to supply e.m.fs. ranging from 6 to 1000 volts. It may be noted also that some use is being made of small step down transformers of the bell-ringing type for the purpose of obtaining low voltages to operate call circuits, etc., operated in connection with telegraph systems.

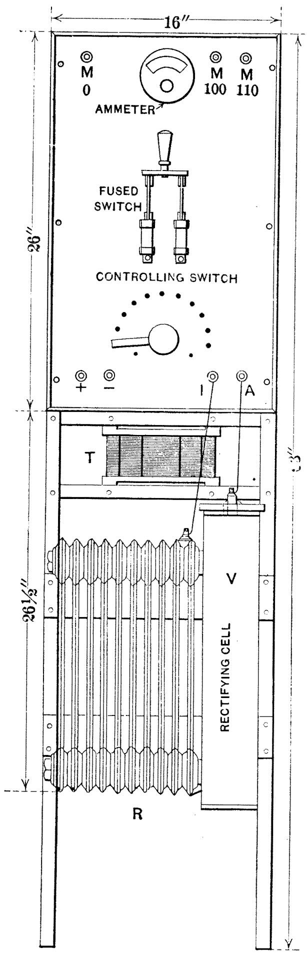

Fig. 3.—The Hickley rectifier

Telegraph Printers

It has long been recognized by certain telegraph authorities, that an ideal system of telegraphy would be a simple and reliable page printer, capable of transmitting and receiving say from 600 to 1000 words per minute on circuits of from 200 to 1000 miles in length. To the inventor of such a system will ensue wealth and fame. It is hardly conceivable, however, that a telegraph printer can be devised that will not possess a number of prominent defects that will act against its general employment; for example, the necessity of preparation of the message for transmission, and its comparative expensiveness and complexity. The first defect would preclude its use on hundreds of stock exchanges and "broker" circuits; the second would debar it from thousands of small way wires. These disadvantages are inherent also in all automatic machine telegraph systems, electro-magnetic or electro-chemical. The superiority of the Morse manual system above all other systems in the foregoing respects is universally admitted.

Reference has already been made in the opening remarks of this paper to the "House" printer. This printer was followed in America by the so-called "Combination" printer, and by the Phelps printer,[16] and in Europe by the Hughes and the Baudot systems, all of which retain the objectionable features of printing the received characters on a strip of paper. Moreover these systems are comparatively slow in operation, not attaining a speed of more than 60 words per minute in one direction, or in each direction if duplexed, although the Baudot system when operated on the synchronous multiplex plan increases quite materially the carrying capacity of a circuit. For some time past in America efforts have been made to obtain higher speed page printing telegraph systems; that is, systems by which the received message will be printed on a regulation telegraph blank ready for delivery. Several different systems of this kind have been recently placed in operation in the United States, namely the Buckingham-Barclay[17] printer on the lines of the Western Union Telegraph Company, the Rowland multiplex printer,[18] experimentally on some of the lines of the Postal Telegraph Cable Company and the Wright printer, to be briefly described presently. The capacity of the Buckingham-Barclay printer is about 100 words per minute in each direction on a circuit 1,000 miles in length with repeaters midway. The capacity of the Rowland printer worked octoplex would be about

16. See "Electricity and Electric Telegraph," Prescott, Vol. II, p. 652.
17. Described in "American Telegraphy," Maver, Chap. XXVII.
18. Ibid.

280 words per minute on a circuit of moderate length, say 250 miles. The Buckingham-Barclay printer is quite extensively used at present and has been shown to possess marked advantages over its predecessors in printing telegraphy, and as previously noted has supplanted quite largely the Wheatstone automatic system in this country. It is possible, however, that a critical analysis now under way of the respective merits of these systems as regards rapidity, reliability, accuracy, and economy of operation may disclose results somewhat favorable to the Wheatstone system. It is not unlikely that, for the handling of the increased business due to public appreciation of the night "letter-gram" service recently inaugurated by the large telegraph companies in this country, resort may be had to the Wheatstone system or to one or other of the freely available rapid atuomatic telegraph systems mentioned herein, or to others that may be developed.* The merits of the Wheatstone system for service of this general nature has long been recognized in Europe especially in the British Postal Telegraph department where it has attained a speed of from 400 to 600 words per minute on the shorter circuits.

One notable advantage over printing telegraph systems possessed by the Wheatstone or other automatic systems, in which the received messages are translated by a copyist (in common with the Morse manual method, but not by any means to the same degree), is that signals mutilated in transmission that would be beyond recognition in the printed record, may often be deciphered correctly from the tape by an expert operator or copyist. Another important advantage of the Wheatstone system is that its main line apparatus is adaptable either to manual Morse or to high speed transmission by the simple movement of a small switch.

It must be noted, however, that the conditions now surrounding telegraph circuits (referred to elsewhere in this paper), such as high-tension inductive disturbances, and excessive retardation due to the presence of stretches of underground cable, were

*Under this "night letter" service the companies receive not later than midnight fifty word messages (or less) to be transmitted for delivery on the morning of the next ensuing business day at the standard day rate for ten words, one-fifth of the standard day rate for ten words being charged for each additional ten words or less in excess of fifty words in the night message. The companies reserve the option to mail these night telegrams at destination to the addressee. The messages must be written in plain English.

non-existent when the high speed automatic systems referred to were in practical operation, and these conditions, it may be anticipated, will reduce the speed efficiency in at least direct proportion to the sensitiveness of the respective systems. The night operation of such circuits, would, however, have the advantage of a minimum disturbance from parallel circuits, the exciting cause of which, except the stretches of underground cables, would be less in evidence. Unfortunately this does not apply to static inductive disturbances from adjacent high-potential transmission lines, which are in constant operation.

The Wright printer due to Mr. John E. Wright may be operated by ordinary typists unfamiliar with the Morse code, as the transmitter is equipped with a standard typewriter keyboard which may be operated at typewriter speed, and the depression of a key of which selects a combination of positive and negative impulses, which, passing to line select a corresponding letter for printing at the distant receiving typewriter. The electro-mechanism of the transmitter prints a tell tale duplicate of the outgoing message in page form. The transmitting potential is 385 volts of each polarity. The line instrument is a polar relay of the duplex type that operates locally a magnet which in response to given combinations of incoming currents is designed to control the movements of a type-wheel, capable in operation of selecting and printing a given letter, of revolving around its axis, moving perpendicularly in the line of its axis, and laterally across the message blank at right angles to its axis, all of which movements are reversible. The receiving typewriter prints directly in message form the received telegram, the blanks being fed to the machine by an attendant who watches the copy during the printing to guard against errors. The disposition of the letters of the alphabet the numerals and punctuation marks on the periphery of the type-wheel is such that in practice it is found that regardless of the position of the wheel any letter may be selected and printed with an average of three and one half current impulses from the transmitter. The speed of this printer in operation on lines up to 300 miles in length is about 40 words per minute in each direction.

It may be noted that in America, telegraph operators during recent years have adopted extensively a keyboard, and other semi-automatic devices for the transmission of the Morse alphabet, which devices quite largely increase the rapidity and facility of transmission over the regulation key method. American operators have also very generally adopted the typewriter for transcribing received messages. Primarily these instruments were adopted as labor saving devices, greatly reducing the mental and physical strain on the operator, and making it possible for operators who had "lost their grip" of key or pen, to return to the ranks of first class operators. The public appreciation of the typewritten copy was such also that the telegraph companies encouraged the use of the machine by increasing the compensation of typewriter telegraphers. Further, the use of the typewriter in combination with the marvelous abbreviations employed in the transmission of press matter, by code[19] considerably diminished the demand for rapid automatic or printing telegraphs, at least for that service, by bringing the performance of Morse working well up to what might be expected from printing

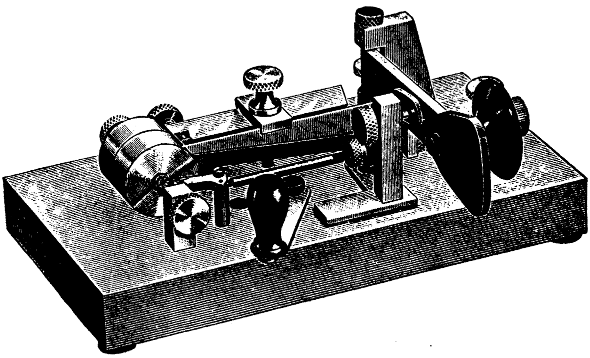

FIG. 3*a*.—The mecograph

telegraph systems. The semi-automatic transmitting key termed the Martin mecograph or modifications thereof is used by perhaps four-fifths of the operators of this country. Briefly, it consists of a contact, which when moved to one side manually by the operator makes a dash, and of a vibrating rod or pendulum, that when moved to the other side automatically vibrates (until stopped by the operator) in the act of so doing making any desired number of dots. It is estimated that 60 per cent more movements are required in sending by the ordinary Morse key than by this device, shown in the accompanying illustration, Fig. 3*a*.

DIRECT POINT REPEATERS

During recent years a demand has grown up for fast duplex telegraph service, in order to provide direct communication

19. See "Phillips Code," W. P. Phillips.

between large centres remotely separated. For instance, the vast amount of traffic which arrives at, and which originates at the large eastern cities of this country destined for China, Japan, the Philippines and other Asiatic countries requires that these cities shall have direct communication with the Pacific cable office in San Francisco. Formerly the arrangement of apparatus used in repeating from one multiplex set into another was that whereby the receiving relay controlled the sending transmitter through local connections, but the mechanical inertia of these instruments and the increased number of local contact points through which the operation was controlled did not conduce to high efficiency. The duplex repeater now used on both the Western Union and on the Postal Telegraph lines is known as the "direct point" repeater, and is similar in operation to the Wheatstone duplex repeater. By referring to Fig. 4 it will be seen that the arriving signal from the east will actuate the right

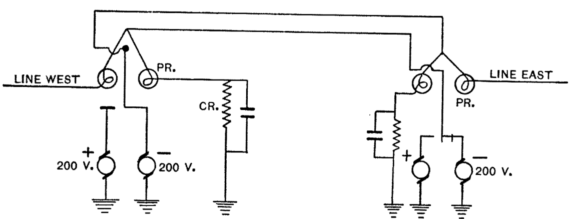

FIG. 4.—Direct point repeater

hand polar relay PR, thus placing for instance the armature of that instrument in contact with the 200-volt negative, e.m.f. which is given an outlet through the left hand polar relay to the line west, and signals arriving from the west are relayed to the line east by a reverse operation. It is now customary to wire up polar duplex and the polar side of quadruplex sets so that this efficient method of repeating may be utilized. Inasmuch as the local contact points of the polar relays are in this case employed to deliver line currents, special devices are provided to control local circuits for operating the reading sounders. For instance, in the Western Union type of duplex repeater the polar relays are equipped with double armatures, mechanically jointed together, but separated electrically, one contact controlling the line potentials, and the other the local circuit. The method employed by the Postal Telegraph Company is the well known "leak" arrangement. A single tap is taken off the armature contact of each polar relay and led to ground through a polar relay and a 20,000-ohm coil. Another method of accomplishing the same result is to substitute a 0.5-m.f. condenser for the 20,000-ohm coil thus obtaining the same response in the polar relay without any loss of current through the leak coil to ground. Indeed when the condenser is used in place of the leak resistance, the polar relay may be done away with, the circuit leading directly from condenser through a sounder and to ground. In this latter case the armature and stop adjustments of the sounder are set so that the signals are all made on the upper stop screw.

The type of duplex telegraphy now universally employed in this country is that in which the well known double-current principle is employed, and by means of the direct repeating relays

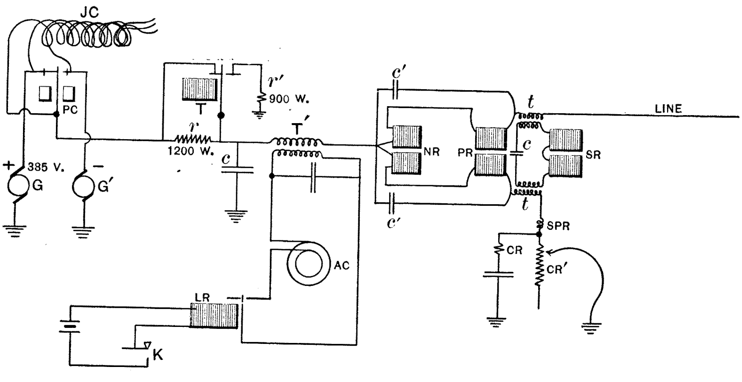

Fig. 5.—Phantoplex on quadruplex circuit

mentioned, very long distances are spanned, for instance across the continent from New York to San Francisco, by many diverse routes. Ordinarily from four to six repeaters are used in these transcontinental circuits, and the speed of transmission is at least equal to the ability of the operator to manipulate the key. Ordinarily the differentially-wound polarized relay is employed.

Superimposed Systems. "Phantoplex" and Van Rysselberghe

Since Varley[20] there have been many workers whose aim it has been to increase the capacity of a single wire or a wire already in operation as a duplex or a quadruplex by superimposing thereon one or more pulsatory phantom circuits.

In the accompanying diagram (Fig. 5) is shown an arrange-

20. Varley's British patent, No. 1044, 1870.

ment of a "phantoplex" circuit on a quadruplex circuit that is in actual operation in many places in this country and by means of which a "sextuplex" is obtained.

In the figure one station only is shown. *G*, *G′* are the sources of e.m.f., for the quadruplex. *P C* represents the pole changer, *T* the transmitter with its shunt and leak resistances; *N R* indicates the neutral relay, *P R* the polar relay, and *C R*, *C R′* the compensating resistance of the quadruplex system, the local circuits of which are omitted in the drawing for the sake of clearness. As the operation of the quadruplex is generally understood,[21] it will be necessary only to describe the phantoplex portion of the system. *A C* is a high frequency generator, the circuit of which is controlled by a local relay *L R* and a key *K*. In the circuit of *A C* is a transformer *T′* the secondary coil of which is in the transmitting portion of the quadruplex system. Condensers *C* and *C′* provide a path for the high frequency currents past the quadruplex relays. *t* and *t′* are small transformers, the primary of *t* being in the main line, the primary of *t′* in the artificial line; and in the secondary circuit of which transformers is the phantoplex polar relay, which in turn operates a reading sounder not shown. This arrangement of transformers *t*, *t′* obviously renders relay *S R* irresponsive to the outgoing currents of *A C*, but still permits it to respond to the high-frequency currents from the distant station. An unretarded path for the pulsatory currents is provided by a grounded condenser *C* at each station. The high-frequency currents of the phantoplex circuit are of a strength below that necessary to operate the quadruplex relays, but the armature of the phantoplex relay *S R* being properly biased by spring tension responds to the high frequency currents. Incidentally there is shown in this figure at pole changer *P C* a "coil" condenser *J C* known as the "Johnson" coil consisting of three separate coils of German silver wire wound on a wooden bobbin with an air core, the spool being about seven inches long and an inch in diameter. The coils are thoroughly insulated from one another by a double covering of cotton saturated with paraffine. One end of each winding is left open, the other end being connected as shown in the diagram. This device is efficacious in eliminating the sparks at the contact points of the pole changer.

In many cases Morse duplex circuits or portions of them are used simultaneously as telephone circuits, the wires of two such

21. See "American Telegraphy," Maver, p. 217.

duplex telegraph circuits being employed as one metallic circuit for telephonic purposes. One such arrangement is depicted in Fig. 7. Here *P C*, *P C* may represent the pole changers at a terminal (or a repeating station as shown in Fig. 4) of two duplex circuits, furnished with e.m.f. by generators *G*. The Wheatstone bridge method of rendering the polar relays irresponsive to the home pole changers is used, the arms of the bridge being formed of a double retardation coil *R C* which is found to be an efficient, practical device. In some cases the armatures of the polar relays *P R* are equipped with retractile springs so that the polar duplex apparatus may be availed of for simplex operation when desired, which result is accomplished by disconnecting one contact *b b* of the pole changer from a generator. These relays also have double local contact points on the armature levers *a*, *a′* shown theoretically in the figure, one of which controls the local reading sounder *S*, the other sounder *S′* in a branch office. The telephone apparatus utilizing the two duplex circuits *D C*, *D C* is shown at *T*. *c*, *c*, *c*, *c*, represent 4 m.f. condensers; *i*, *i* are 30-ohm retardation coils. This arrangement of the telephone, in one instance, is used successfully on duplex telegraph circuits to a distance of 360 miles, the entire length of the duplex circuits being 1000 miles without repeaters.

Composite circuits (originally the Van Rysselberghe simultaneous telegraph and telephone system)[22] are employed in this country and Canada very extensively; notably by the American Telephone & Telegraph Company, also by the telegraph departments of several large railway companies. Between New York and Boston alone at least fifty leased telegraph wires are in daily operation on long distance telephone circuits, and this dual use of circuits is being rapidly extended in telegraph practice, all new line construction being designed with this end in view as noted elsewhere herein, the increased earning capacity of the wires thereby gained being the obvious incentive thereto.

Inductive Disturbances on Telegraph Circuits

In the pioneer days of telegraphy when routes were being sought for pole lines, the rights-of-way of the existing steam rail-

22. For an account of the first experiments with this system (which has now grown to such large proportions) by Prof. F. Van Rysselberghe in this country (1885-1886), see article in *Electrical World*, October 6, 1888, by William Maver Jr., by whom also it may be of interest to note the first set of Van Rysselberghe's apparatus for simultaneous telegraphy and telephony was by request installed experimentally on a circuit of the American Telegraph and Telephone Company between New York and Philadelphia in the Spring of 1890. (March 1-5.)

roads were utilized wherever possible for the obvious reason that, as the proper movement of trains required the constant use of the telegraph, the questions of construction, maintenance, and prompt repairs were thus solved to the best advantage of the railroad and the telegraph companies. The growth of telegraph traffic was however, rapid, and between the larger centres, at least, additional pole lines on highways were soon built to meet the constantly increasing demand for wires. In the course of events also the time arrived when the displacement of the steam locomotive by the trolley car and electric locomotive for train haulage introduced the high-tension transmission circuit, which,

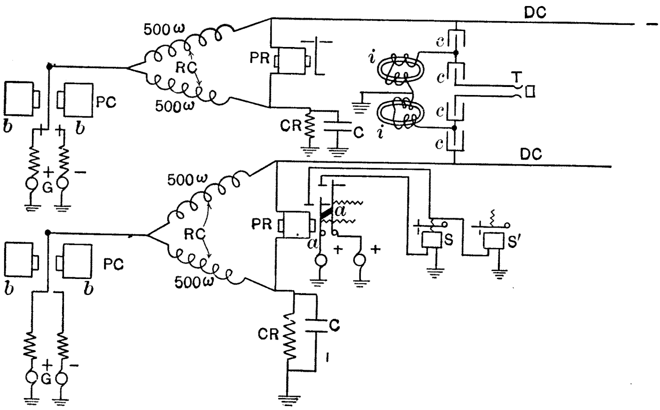

FIG. 6.—Simultaneous (duplex) telegraph and telephone

being naturally erected along the railroad tracks, at once menaced the value of a railroad right-of-way for telegraph purposes. It developed, also, that long distance transmission lines carrying high-tension alternating currents in numerous instances began to parallel the railroad rights-of-way as generally affording the most direct and favorable routes between cities, thereby adding another disturbing factor to the operation of telegraph lines following the same routes.

Apart, however, from the serious inductive disturbances due to the close proximity of such high-tension transmission lines, the subject of inductive disturbances on telegraph lines is not a new one, for mutual inductive disturbances between telegraph circuits were encountered as remotely as 1876 in the dry climate of some of the western states, on lines operated as simplex Morse circuits extending from Omaha, Nebraska to Salt Lake City, Utah.

Upon the introduction of the quadruplex shortly thereafter mutual induction between parallel wires manifested itself as a disturbing element at numerous points, due to the comparatively high e.m.f.s then used on quadruplex circuits, about 300 volts; and as, in the ordinary operation of telegraphy, single wires grounded at each end are employed, the well known method of transposing the wires at intervals to obviate mutual induction effects was not available as a remedy. Fortunately the reduction of efficiency due to this source of inductive disturbance was not very marked, and could, generally speaking, be overcome by an increase of e.m.f. at the terminal stations to 375 or 400 volts.

One of the first methods suggested to eliminate, or ameliorate the disturbances due to mutual induction was devised and tested by Mr. Chas. H. Wilson in 1876, in the western part of this

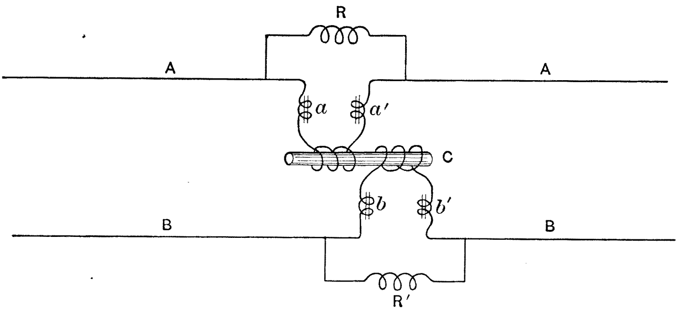

FIG. 7.—Wilson mutual induction neutralizing device

country. The method is indicated in Fig. 7 as applied to single wires*. The object of the arrangement is to set up by means of small transformers C, currents in wire A, opposite to those induced in wire A, by wire B, and contrariwise. R, R' are adjustable resistances, a, a', b, b' are small choke coils. This arrangement was subsequently used on quadruplex lines between Chicago, Buffalo, and Pittsburg, but not very successfully owing to the lag caused by the employment of the transformers C in the circuit which augmented the period of reversal to such an extent that the No. 2 side of the quadruplex systems was detrimentally affected thereby.

The continual extension of power transmission and other high potential circuits in close proximity to telegraph circuits however created inductive disturbances so inimical to the operation of the telegraph that further means were sought to effect a remedy,

*See "The Speaking Telephone," Prescott, 1878, p. 362.

short of changing the route of the telegraph pole lines, and a number of corrective devices have been suggested some of which in practice have been fairly successful under certain conditions and in certain localities, but have not always met the requirements elsewhere.

One of these means of obviating harmful induction from high tension power circuits on single Morse wires, due to Mr. E. W. Applegate is shown in Fig. 8 in which a resistance R, consisting of a carbon stick is connected across the main line contacts of the relay $M L$. By means of this shunt the rapid induced currents from neighboring alternating current circuits are given a path past the relay, and chattering of the armature is further avoided by increasing the tension of the retractile spring S. It was found that these devices tended to impede the action of

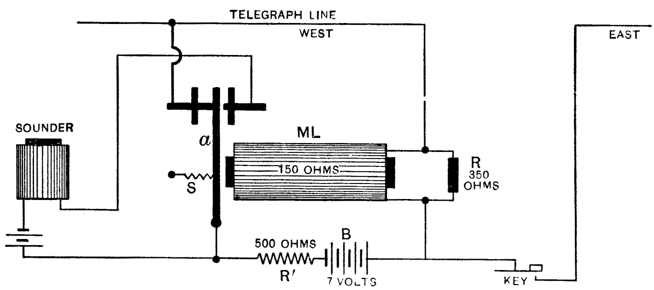

FIG. 8.—Applegate " Static pick-up."

the armature a, to overcome which tendency an extra battery B, of six cells are added, which by partly magnetizing the relay cores when the armature is on its back stop, effects this result. This device which is termed a " static pick-up " has been successfully used on a number of telegraph circuits where metallic circuits had been resorted to owing to the inductive disturbances from a frequently unbalanced 60,000-volt three phase system that parallels the telegraph circuits for a distance of eleven miles. The employment of this arrangement made it possible to resume single wire operation.

Another plan for obviating inductive disturbances on telegraph wires, due to Messrs. Blakeney and Chetwood, is shown diagrammatically in Fig. 9. A C is the disturbing line. When key K is open the induced currents oscillate harmlessly to earth via i' c', and n', while the regular Morse signals traverse the relay coils *via* the inductive resistance n, and non-inductive resistance n', when key K is closed.

A brief description will now be given of one of the more recent methods put into practice for the purpose of offsetting inductive disturbances on telegraph circuits due to the close proximity of high tension electric traction circuits resulting from the electrification of the New York, New Haven and Hartford Rail-

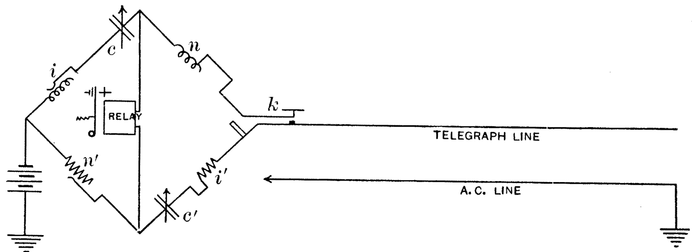

FIG. 9.—Blakeney and Chetwood inductive disturbance diverting device

way. To nullify electro-magnetic induction, current transformers $C\ T$ with a 1:1 winding, Fig. 10, are inserted in the telegraph lines at intervals of two miles. To neutralize electrostatic induction the secondaries of potential transformers $P\ T$ are used in connection with condensers C as outlined in the figure. The primaries of the transformer are placed in a special neutralizing wire or in the disturbing wire itself. By placing a

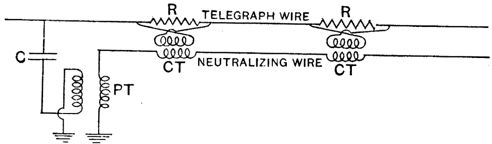

FIG. 10.—Inductive disturbance neutralizing device

number of secondary coils in multiple, one neutralizing wire may suffice for a number of telegraph wires. As the neutralizing wire is subject to the same inductive effects as the telegraph wires, the currents developed in the former may be arranged to oppose those due to the disturbing wire.[23]

23. For further details of this general subject see "Telegraph and Telephone Systems as Affected by Alternating Current Lines", J. B. Taylor, Trans. A. I. E. E., Oct. 1909.

It has been found in practice that the neutralizing of inductive effects by the foregoing arrangement is seriously interferred with by escapes from direct current trolley lines which enter and energize the transformers. Variations in load on the alternating current line, phase distortion, etc., also add materially in preventing anything more satisfactory than an amelioration of the harmful inductive effects. Furthermore, in this particular case, the slight improvement noted is obtained at the loss of three copper neutralizing wires, in addition to the first cost and maintenance of the additional apparatus required. In general it may be stated that the various devices offered hitherto as inductive disturbance correctors have been rather of a palliative than of a positive remedial nature, and inasmuch as the tendency is to increase the use and the potentials of high tension transmission circuits, it appears evident that to meet or evade this situation successfully constitutes one of the most serious problems now confronting telegraph engineers. The basis of a solution of the problem may possibly be found in subsequent remarks herein.

Main Line Relays

The ohmic resistance of relays used in Morse telegraphy has undergone numerous variations during the past forty years in this country. Relays wound to 1200 and 1500 ohms were not uncommon. At one time the resistance of main line relays was calculated on the assumption that for the best results the total resistance of the relays in a circuit should be equal to the resistance of the line wire.[24] Thus on a circuit 300 miles in length, measuring, say 15 ohms per mile, with fifteen stations on the line, the relays would be wound to 300 ohms. There was, however, little or no uniformity in the winding of the relays and but little supervision of the quality of the copper used in the winding, which in the early sixties of the last century varied in commercial copper from 14 to 85 per cent that of pure copper. Measuring instruments of accuracy were at the time referred to a rarity in this country and no proper methods of ascertaining the condition of the lines as regards electrical resistance and insulation were in vogue. In 1867 the late Mr. C. F. Varley, the well known English electrician, was retained by the Western Union Telegraph Company to visit the United States for the purpose of making a thorough investigation of the electrical conditions of the lines and apparatus of that company.

24. " Modern Practice of the Telegraph ", Pope, 1869 p. 125.

Following a thorough study of the subject supplemented by hundreds of tests of the lines, insulators, relays, batteries, etc., Mr. Varley presented a voluminous report to Mr. William Orton, President of the Company, December 20, 1867.[25]

The report detailed in extenso, the condition of the equipment as disclosed by the tests, and made numerous recommendations for the improvement of the general service, such as the making of soldered joints, a reduction in the resistance of the relays used, and their re-winding to a uniform resistance of 130 ohms, the wire used to be the best copper obtainable. He also recommended that fewer poles per mile be used in line construction and that a smaller number of wires be worked from one main battery—in fact that a separate battery be provided, for each wire.

Prompt action was taken upon Mr. Varley's report and recommendations, and very marked improvements followed thereafter. Mr. Madison Buell, for instance, in an article on " Low Resistance Relays ",[26] recounts that on the important circuit on which the Atlantic cable traffic between New York and Plaister Cove, N. S., was transmitted the repeaters were found to have relays ranging in resistance from 500 to 1,500 ohms. The relay of the " Milliken " repeater at St. John, N. B., had a resistance of 1,500 ohm. The relays at Boston, Portland, and Bangor had an average resistance of 1,200 ohms. All of these relays were rewound to 80 ohms. Also, many improvements were made in wire jointing, insulation, and leading-in wires at all offices, with the result that whereas on this circuit before these changes were introduced six repeaters were necessary in bad weather and in clear weather three to four repeaters, after the aforesaid improvements were made but two repeaters were required in bad weather, and only one in clear weather to operate the circuit at top speed.

In the course of time, however, relays of 150 ohms were adopted as the standard for simplex Morse circuits. For duplex and quadruplex service the neutral relays were wound to 200 ohms, the polar relays to 400 ohms, (each coil of the differential windings) and for many years these resistances have been the standard. But within the past 8 or 10 years, there has been a still further reduction of the

25. Report of Cromwell F. Varley, Esq., " On the Condition of the Lines of the Western Union Telegraph Company." Mss. by Mr. J. D. Reid, lithographed. Copies in Wheeler Library, also in Mr. Maver's library and probably in that of the Western Union Telegraph Co.

26. *Telegraph Age*, Jan. 1, 1903.

resistance of main line relays (to 37½ ohms) on many of the commercial and railway telegraph way wires with a very pronounced improvement in the operation of the circuits, especially in bad weather. At the present time the tendency of American practice is to the employment of lower e.m.f.s at the terminals of the circuit and to lower resistances in the relays for multiplex working. During the period when No. 9 iron wire was the standard for telegraph purposes, and when the insulation resistance of the lines, was far below present day requirements, a high e.m.f. was necessary in order to maintain proper current values, but by the substitution of low resistance copper conductors in place of iron wire and with improved line construction, the way has been paved for the employment of lower voltages, and relays of much reduced resistance in multiplex operation. Thus some very satisfactory results have been obtained recently in different parts of the country on quadruplex circuits using e.m.fs. as low as 200 volts on well insulated lines of comparatively low resistance (2 ohms per mile) and with polar relays wound to 100 ohms and neutral relays to 50 ohms. The length of the cores of these relays has been somewhat increased. The "potential" resistance of 600 ohms (usually inserted between the current generators and the multiplex apparatus) in these instances has also been reduced to 300 ohms, and the "proportion" resistance and "leak" shunt in the Field key system from 1200 to 600 ohms, and from 900 to 450 ohms, respectively. The objective in these modifications of the prevailing practice is to reduce the mutuul induction between parallel circuits and to render the relays less sensitive to inductive disturbances from any source.

Some Telegraph Engineering Details

It might be supposed that telegraph engineering has to do mainly with purely physical and technical questions, but the close relationship existing between the handling of traffic (telegrams, leased wires, etc.) and the machinery employed in handling it, is such that the telegraph engineer, perforce, finds himself involved in the study of traffic details which he cannot well omit without loss to the economies of operation. This for example obviously requires keeping in the engineer's department an accurate record of existing wire facilities, data as to the daily efficiency of operation of all circuits (especially multiplex and automatic circuits) and information as to their electrical condition, together with carefully prepared tabulated records of details pertaining to methods of traffic movement and the amount of traffic handled on the respective circuits throughout the system, in order at once to enable the engineers to determine whether existing facilities are being utilized to the best advantage, or whether additional facilities, or modifications of the arrangement of present facilities may be deemed advisable. Information of this kind is especially important as a guide in the matter of underground construction and cable work extension. Thorough engineering organization results, amongst other things, in placing the engineer's department in a position to intelligently and promptly decide all strictly engineering and related traffic questions that are continually arising in the operation of a large telegraph system.

The graphic method of mapping circuits indicated in the accom-

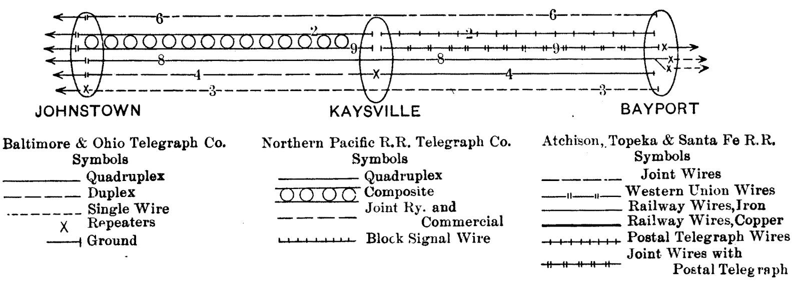

FIG. 11.—Graphic method of mapping telegraph circuits

panying diagram Fig. 11 to show at a glance the routes of the various wires, their allotted numbers, how operated, offices entered, material of wire, by whom owned, etc., has been found of great utility wherever used. The scheme which is clearly susceptible of many amplifications was probably first employed in the engineering department of the Baltimore and Ohio Telegraph Company in 1885–88 by one of the present writers and it may be of interest to note that details of the nature indicated relating to over 50,000 miles of actual wire were shown on a map four feet long by 3 feet wide. The accompanying specimens of blank forms for certain reports were also used in the operation of the same company, the information derived therefrom enabling the engineer's department to maintain an intelligent supervision of the circuits that resulted in a clearly perceptible enhanced earning capacity in the case of numerous circuits. Somewhat contrary to

TRAFFIC BLANK

To...Supt. CLEVELAND, O., FEBRUARY 15, 1886

Statement of Messages Handled in this Office For the Week Ending..............................

No. of Circuit	From	To	Single	Duplex	Quadraplex		Dates. Messages Sent and Received.						
					A Side	B Side	1	2	3	4	5	6	7

To...Supt. INDIANAPOLIS, IND., FEBRUARY 13, 1886

Report of the Working of the Single and Multiplex Systems in this Office, Week Ending Sat., Feb. 20

Date	Name of Circuit	How Assigned	Commencement of Delay	Termination of Delay	Nature of Delay

expectations these reports were prepared by chief operators or clerks at no additional expense. As will be readily understood the knowledge that the operation of all circuits was under constant impartial supervision was not overlooked by those directly in charge of the operation of the circuits.

A comprehension of the condition of the insulation resistance and conductivity of every circuit, open or in cables is manifestly of great importance to the engineering department and reports of the tests of conductors for these properties are promptly forwarded to the engineer's department periodically.

The Telephone in Electrical Testing

In America the tangent galvanometer has long since been set aside and simpler and quicker methods of circuit testing and fault localizing have been adopted. Many tests, such as those for insulation resistance and conductivity are now made with high resistance voltmeters, especially where earth currents from adjacent grounded trolley circuits (which frequently indicate an e.m.f. of 15 to 20 volts) are not troublesome. The milliammeter is also used for making insulation resistance measurements not exceeding one megohm and for other electrical tests. The telephone receiver is used as an indicator in many tests. This instrument in connection with an "exploring" coil is largely utilized for localizing faults in aerial cables and in underground cables, especially where the latter are laid in conduits. In making these tests a high frequency current is established in the defective conductor and the exploring coil, a semi-circular coil of fine wire in circuit with the telephone, is moved from point to point along the cable sheath, the indications in the telephone increasing or diminishing as the defect is reached. The telephone receiver as a testing device is particularly advantageous for practical purposes as it places in the hands of the electrical worker or "trouble hunter", an instrument at once portable, and easily understood, and one that is not readily deranged by rough handling. Where a head-band is used to support the receiver the hands of the workman are free.

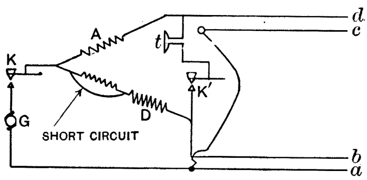

Fig. 12

For quickly determining by means of the telephone as an indicator the distance of a break in a cable conductor when the insulation is normal, one method is as follows: Select three conductors similar electrically to the open conductor b and adjacent to each other, a, being next to b; c, being next to d and connect as shown in Fig. 12. G, is a source of alternating current. For cables approximating 1000 feet in length the generator should give from 40 to 130 volts. The resistance of arm A may require to be 100, or 1,000 ohms. To make this test the four wires should be opened at the distant end. Keys K, K' are then closed and the resistance of arm D or rheostat is varied until minimum sound is heard in the telephone receiver, when:

$$\frac{L\,R}{R'} = F$$

where L is the length of the cable in feet, R, the resistance of arm A, R' the resistance of rheostat D, and F is distance to break in feet.

The Varley and Murray tests are still the standards for making accurate measurements for faults in conductors, and the Wheatstone bridge method for accurate resistance measurements.

Pole Line Construction—Aerial versus Underground Conductors—Notes on Duplex and Quadruplex Operation

Owing to the confusion and general disarrangement of business that usually follows the prostration of the telegraph wires by severe sleet or wind storms in this and other countries, every notable occasion of this kind has been followed by insistent demands on the part of the interested business communities that measures be taken to prevent a recurrence of these disarrangments. So much has this been the case that in Great Britain, at least, where such storms are quite frequent, and where owing to the geographical shape of the country the loss of telegraphic communication due to the effects of such storms has been felt with peculiar force, these demands have been met by the British government in the laying of an emergency telegraph cable between London and North Britain. The fact that such unanimous demands are made for the prevention of even a temporary loss of the telegraph between important centers is, it may be remarked, a rather notable acknowledgement of the indispensibility of this public utility as a part of the commercial and social structure of a country.

Apart from the very important matter of maintaining uninterrupted telegraphic communication regardless of weather conditions in the interests of the general public it may safely be assumed that the various telegraph authorities in this country have not been unmindful of the financial losses sustained by the telegraph upon the occasion of each recurring collapse of poles and wires, and that every possible remedy therefor has been most carefully considered. Furthermore, telegraph lines are not only subject to widespread damage from abnormally severe sleet and snow storms, but are also in many places exposed to the ravages of forest fires, avalanches of snow, washouts due to floods, and to destruction by lightning. Again the average life of a pole line in all parts of the country probably does not much exceed ten years. Consequently, if the financial and engineering difficulties in the way of placing telegraph wires underground on a large scale had not been practically insurmountable, that solution of the problem, unquestionably, would have been long ago adopted. But it is well known, for instance, that the increased static capacity and mutual induction of the conductors carried in cables tend to reduce very materially the length of circuit that may be used in satisfactory telegraph operation. Already indeed the presence of a comparatively limited amount of underground cable in the circuits passing through the principal cities of this country has reduced very preceptibly the speed of signaling and the general efficiency of automatic and multiplex telegraph circuits in this country. Being therefore aware of the great technical and financial difficulties that would attend the placing of wires underground generally between cities and towns over the expansive territory of this country, the question of building stronger pole lines, and of employing larger and stronger wires has been frequently proposed by telegraph engineers. The well known "A" and "H" methods of setting wooden poles of course have received due consideration, and in trials have been found to add considerably to the stability of lines. In addition however to doubling the expense for poles, further objection to the use of these methods, especially where the telegraph lines are on a railroad right of way, is the extra space required for setting, which very often is not obtainable. Another plan tested was that of using worn out track rails, set up in "H" form and braced one foot apart. The cost of setting these rails is, however, rather high, being about eleven dollars per unit. In especially exposed places the plan of doubling the number of poles from say 50 to 100 per mile, has been adopted with considerable success. A reduction of the height of poles and an increase of their girth has also been advocated and there is now a tendency in that direction. It is very probable that pole lines built in the future will when possible be built of poles considerably less than 35 feet in height (the present general practice) with head and side guys located about every half mile regardless of the contour of the line. On heavy loaded lines with the poles set about 100 feet apart reduction of the leverage obviously increases the efficiency of guying. In the construction of a thirty-wire line by using ten-pin cross arms a 25-foot pole would generally leave sufficient clearance.

The employment of re-inforced concrete poles for telegraph purposes has been suggested as offering a solution of the problem as regards durability and reliability[27] but has not gained much headway hitherto, principally owing to the present high cost of such poles and also to the excessive cost of transportation. Even, however, if experience should show that cement poles will possess the ability to withstand the strains brought to bear on them by wires heavily coated with sleet, there still remains the unfortunate fact that the wires themselves may break under the strain. It would of course, be a decided gain to avoid the total loss of miles of pole line by the collapse of the poles like bricks in a row—a not infrequent occurrence under present conditions.

In relation to the immediately foregoing remarks, it may not be amiss to digress here to suggest that since the telegraph lines are not put up merely for a day or a year, that a combination of concrete poles, or towers of equal strength and durability with perhaps some form of housing for the wires along permanent and isolated rights of way may be among the possibilities of future telegraph engineering, since such a plan offers promise of reliability of operation without the detrimental accompaniment of impaired efficiency of the telegraph service that follows the placing of telegraph conductors underground. In view of the importance of the subject further reference may here be made to the reduced efficiency of quadruplex telegraph operation within recent years, in some cases amount-

27. (See paper by Mr. G. A. Cellar, " Experiments with Concrete Poles" Proceedings, Association of Railway Telegraph Superintendents, 1907, p. 144)

ing to 50 per cent, due to the increased amount of telegraph conductors placed underground in cables in cities. In other cases certain quadruplex circuits have been abandoned because of inductive disturbances from parallel high tension transmission lines. It is a well established fact that prior to the introduction of these disturbing factors, duplex and quadruplex telegraphy in this country had attained a high degree of efficiency. Thus, for instance, it was formerly common practice to operate four, six or more quadruplex circuits between New York and Boston on open parallel lines, each with an efficiency equivalent to four wires worked simplex, and certain quadruplex circuits between New York and Chicago were operated as a rule with an efficiency of at least 90 per cent.

In the equipment of the quadruplex circuits to which special reference is now made, the ordinary horse-shoe polarized relay, with flat armature, and short cored neutral relay were employed without any devices to aid the operation of the No. 2 side excepting the Edison device of the back contact and repeating sounder attachment to the neutral relay. It is well known also that in isolated sections at the present time quadruplex circuits are still operative at high efficiency. It would appear evident therefore that a restoration of the original efficiency of this exceedingly important arm of the telegraph service would be alone an aim worth the best effort and thoughts of telegraph engineers and executives. A return to the former or greater freedom from inductive disturbances would also vastly enhance the opportunities for the utilization of some of the readily available rapid automatic telegraph systems, which as previously intimated the introduction of night letter telegram service may render imperatively necessary in the very near future.

Returning briefly to a consideration of the matter of obtaining a permanent, non-inductive, non-retarding system of telegraph routes, it is clear that utilizing the suggested towers or reinforced concrete poles, with housed wires to afford mechanical protection against storms, incidentally thereby guarding against undue variations of insulation resistance, (a great desideratum for numerous reasons) and by the proper selection of routes at a suitable distance from high-tension lines thus evading their disturbing inductive currents, an immediate improvement in the operation of circuits would be obtained. There would, however, still remain to be dealt with, the detrimental effects due to the presence of conductors in underground cables leading into and out of cities and towns. This difficulty could, however, be obviated by placing the main operating departments of telegraph offices on the outskirts of such cities, from which offices loops might be run from duplex and quadruplex circuits to the various branch and brokers officers without detriment to the operation of the multiplex main circuits. All wires not required for the actual handling of traffic in a given town would in such cases enter the main operating room on the outskirts of the city and pass on without entering the city proper. In many small towns the telegraph lines following the highways enter at one end of the town and pass out at the other end, a custom that has frequently involved placing a comparatively large amount of cable in an unimportant locality considered from a telegraphic standpoint. By the plan suggested, only wires needed locally would enter the place and that by the shortest route to the business center, thereby minimizing the amount of cable required for the proper transaction of telegraph business at that point.

It is unnecessary here to comment on the economies and improvement of operation that could be rendered possible by even a partial adoption of the foregoing suggestions, further than to remark that a proper consideration of the subject will show them to be manifold and of great value.

It had been intended to include in this paper a general reference to recent improvements in the interior equipments of telegraph offices and also to describe the methods and materials now employed in aerial and underground telegraph cable work in this country, but owing to the brief time available for the preparation of the paper it has not been practicable to carry out that intention.