SETTING TYPE BY TELEGRAPH.

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Any person who has had occasion to examine the records of patents connected with telegraphy, must have been astonished at the number of printing telegraphs invented during the past sixty years. In the United States alone over four hundred printing telegraph patents have been issued since the invention of the electric telegraph. These patents embrace about 150 distinct printing telegraph instruments or systems; and yet, with the exception of the stock-tickers and the Hughes printing telegraph, it is only within recent years that two or three really successful machines have emerged. In hardly any other field of human endeavour has so much labour resulted in so little return. There are many reasons for this want of success; but they are all due to the extreme complexity of the conditions to be fulfilled, and the absence of any technical literature explaining what these conditions are. With one or two exceptions, telegraph engineers, realising the difficulties of the subject, have left it alone, and printing telegraph inventors have, in most cases, been outsiders. In fact the whole of the problems connected with the handling of type, including typewriters, type-setting, type-casting, and similar machines, have proved very refractory, and the best solutions have often come from outsiders, who have stepped in where experts feared to tread, and have in this way blundered into unexpected success. The complexities culminate in the printing telegraph, because in that case the problem is to set type at a distance. The type may be fixed on the circumference of a wheel, or may exist as separate type on the ends of type-bars, as in most typewriters, or as loose type in a type-setting machine; but in all cases the problem is to set type—that is to say, to bring a particular type to a particular printing point in the shortest possible time, and in the case of the printing telegraph to do that at a distance over a single telegraph wire.

It may be pointed out, in passing, that all telegraph systems, from the Morse key upwards, are printing telegraphs more or less developed, and that a completely developed telegraph system must be a printing telegraph. Telegraphy is one of the few branches of human activity in which the tendency to substitute machinery for human skill has not yet made much progress; but the advantages to be gained are considerable, and there is every indication that the era of fully-developed machine-telegraphy has now arrived. The subject is very large, and it will be necessary to confine attention, in this paper, to the class of printing telegraphs used, or being tried, by telegraph administrations for the transmission of ordinary commercial and press messages. For this class of work the stock-ticker systems are of course unsuitable, their field being the urban distribution of news, with some possibilities as local feeders to the general telegraph system. The Hughes printing telegraph is widely used for general traffic on the Continent of Europe, where about three thousand of these instruments are in service; but the Hughes prints the messages on a tape, and its speed is limited by the manual skill of the operator. For a long time there has existed a need for increased capacity of transmission, printing in page form, reduction in the percentage of errors in transmission, and increased economy of labour. During the last few years there has been a remarkable outburst of activity amongst printing telegraph inventors desirous of meeting these requirements. The Baudot system, widely used in France, dates back to about the year 1880; but the Rowland, the Buckingham, the Murray, and the Siemens and Halske systems are all products of the past four or five years. It is with systems of this kind that this paper proposes to deal.

The Essential Features of Telegraphy.

If we disregard the small class of telegrams that merely express emotions, the essence of telegraphy is control. When A sends a telegram to B, it promotes or restrains the actions of B, and B frequently reciprocates by controlling the actions of A. Telegraph systems, therefore, belong, not to the class of producing or distributing, but to the class of controlling mechanisms. From the point of view of the theory of machines, the only possible form of controlling mechanism is the lock and key. It is for this reason that telegraph instruments consist almost entirely of ratchet mechanisms, including the complicated permutation locks that form the main feature of all the modern high-speed printing telegraphs. At the transmitting station certain ratchet mechanisms are used to impress permutation patterns on a small stream of energy which flows through the intervening space from the sending to the receiving station. It is these peculiar patterns impressed on the energy stream that operate the permutation locks of the receiving mechanism, and thus subsequently determine the motions of the recipient of the message.

Hence the fundamental feature of printing telegraphy, and therefore of all practical telegraphy, is the kind of patterns or permutations transmitted. In telegraphy these patterns are symbolic. The word, as spoken, has to be broken up into letters, and the letters translated into special telegraphic symbols. On the other hand, the essence of telephony being direct communication, we are forced to use a method preserving the exact form of the word symbols that we habitually use. This results in the employment of excessively complicated patterns or variations of the energy stream, so that about thirty impulses per letter are required in the telephone, as against about four per letter with the Morse alphabet. That is to say, the telephone saves labour by giving direct communication only at the expense of very heavy wire cost. The telegraph, by using the symbolic method of representing letter sounds, effects an immense economy in the number of signals per letter, thereby effecting a great economy of wire, but only at the expense of increased labour cost for translation. It is the object of machine telegraphy not only to increase the saving of telegraph wire still further, but also to reduce the labour cost of translation and writing by the use of suitable machines. The simplicity of these machines and the saving of wire cost depend on the fewness and simplicity of these signals. It is in this reduction in the number and in the simplification of signals that there will be found to lie not only the fundamental distinction between the telegraph and telephone, but also the fundamental criterion of all telegraph systems—What number and what kind of signals per letter do they require? For a given wire, the fewer the signals the more the business that can be passed over it; and for a given amount of business the fewer the signals the cheaper the wire that can be used. And with the increase of distance the cost of the wire becomes all-important. Pupin self-inductance coils are being applied to help the telephone, but they are equally applicable to the telegraph. On the other hand, if we can do without inductance coils so much the better; and the way to achieve that result is to use as few signals per letter as possible. Hence nothing can alter the fundamental criterion—What number and what kind of signals per letter does the system use? And so far as the class of work dealt with by telegraph administrations is concerned, the telegraph systems with the best signals for long-distance work will, in the end, supplant all others.

Telegraph Signalling Alphabets.

A little consideration of the facts will show that the codes of signals or telegraphic alphabets that meet all the requirements for signalling by means of an electric current through a telegraph wire are comparatively few in number. If we first regard the matter from a metaphysical point of view, it will be found that all signals have a Space aspect and a Time aspect. Signals in which the meaning depends on the space aspect may be conveniently described as space signals. In the broad sense these are telegraphic, and they appeal to the eye. Signals in which the meaning depends on the time aspect may be conveniently described as time signals. In the broad sense these are telephonic, and appeal to the ear. For instance, a signboard may extend over 10 feet and 100 years; but the intelligence conveyed does not depend on the duration of the signboard. It is a space signal. On the other hand a Morse signal in a wire may extend over half a second and 500 miles. In this case it is the time aspect which is significant. It is a time signal. In a printing telegraph the space signals forming the written message have to be converted into time signals, in order to be sent over the telegraph wire. The wire signals must occupy various positions in time, because, for commercial reasons, the wire cannot occupy various positions in space. That is to say, there must be only one wire.

At the receiving end of the wire the time signals have to be again converted into space signals if they are to reach the brain of the recipient through his eyes, and that is a necessity, because the average citizen does not know Morse. It is the time signals in the wire that it is so important to economise.

It is not possible in this paper to go fully into all the possible kinds and best forms of telegraph signals, but the following summary will be sufficient to preserve the thread of the argument.

Unlike telephonic signals, all telegraphic signals are built up out of definite units (Morse dots or half-waves). It is not possible to signal telegraphically by varying the duration of these units. Nor is it desirable to signal by varying the amplitude of the units, as that introduces the weakness of the quadruplex. If weakness is to be avoided,

SIGNALLING MATERIAL

TELEGRAPHIC UNITS

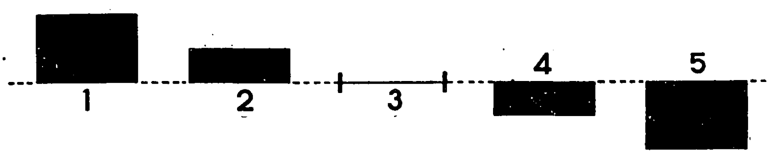

FIG. 1.

TYPES OF CURRENT

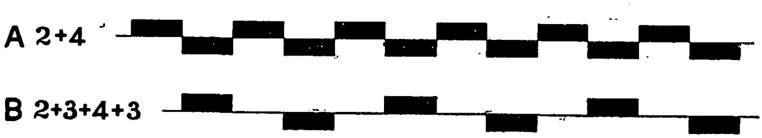

FIG. 2.

the meaning of the signals must not depend on varying amplitude or duration of the units, but only on varying permutations of the units. Fig. 1 shows the only units ever used in practical telegraphy.

In regard to units 1 and 5, it is obvious that bad weather is always a critical time with aërial telegraph wires, and, from a business point of view, a telegraph system employing the quadruplex method of two variations of current strength that can always be relied upon to fail during bad weather—thereby doubling the trouble—is disastrous. Two variations of current strength are also undesirable for underground cables, the inductive trouble between neighbouring wires being severe with the strong current needed. Quadruplex types of current are therefore clearly not suitable for a first-class printing telegraph, and they are useless for any telegraph system that has to work over long distances.

As for the zero unit 3, one of the worst evils with which telegraph engineers have to contend is the inductive interference between neighbouring wires, leading to the mutilation, and sometimes to the obliteration of signals. Experience has shown that the best remedy is always to keep sufficient current flowing in the wire to preserve a positive or a negative value in spite of the parasitic currents. This at once rules out the zero unit on long lines with a number of wires, or in multiple-wire cables—that is to say, on busy lines where a printing telegraph would find its chief employment. Thus units 1, 3, and 5 are excluded, and A (Fig. 2) is the only reliable type of current for a high-speed printing telegraph on overland lines or multiple-wire cables. It is this type of current that is employed in the Baudot, Murray, Rowland, and Buckingham systems, and it is the ordinary "double-current" of the British telegraph service. This one familiar fact, that alternating current must be used, sweeps into oblivion at least three-fourths of the printing telegraphs invented during the past sixty years.

For single-wire ocean cables, where there is no inductive trouble from neighbouring wires, the zero unit can be employed, and as only short impulses are permissible, B (Fig. 2) is the only type of current that is used in ocean-cable work.

There remains the question whether the shape of the signalling units is important from the point of view of machine telegraphy. About ten years ago there was a brisk discussion in some of the electrical journals in regard to the advantages of the simple harmonic curve or sine wave for the transmission of power by the alternating current. A group of American scientific men, headed by Professor Rowland, who contended that the sine wave was the best, took it for granted that the best method of transmitting energy was also the best method of transmitting intelligence, and advocated the use of the sine wave in telegraphy. Certainly if Smith wants to make Jones spin round like a dancing dervish, the best way might be for Smith to transmit sine waves to Jones; but in practice, Smith always wants to make Jones perform an excessively complicated and irregular series of motions, and for this purpose it is essential to transmit similar motions by introducing upper harmonics in a fragmentary, non-periodic, and very irregular way. Even if it were possible to signal by means of sine waves, there is against the sine wave arrangement the practical disadvantage that special machinery would be required to generate the sine waves, and also to repeat them, as an ordinary repeater would at once send them on as square signals. So far as undulatory signals are concerned, there is, of course, nothing to prevent them being applied to any system of machine telegraphy if desired.

A and B (Fig. 2) being the sole permissible types of current, it only remains to build up alphabets or codes of signals by introducing irregularities or patterns by various substitutions of units. Space will not permit of more than a few of the alphabets of practical importance being referred to. The simplest of all these alphabets is that employed in the Hughes printing telegraph. It is as follows :—

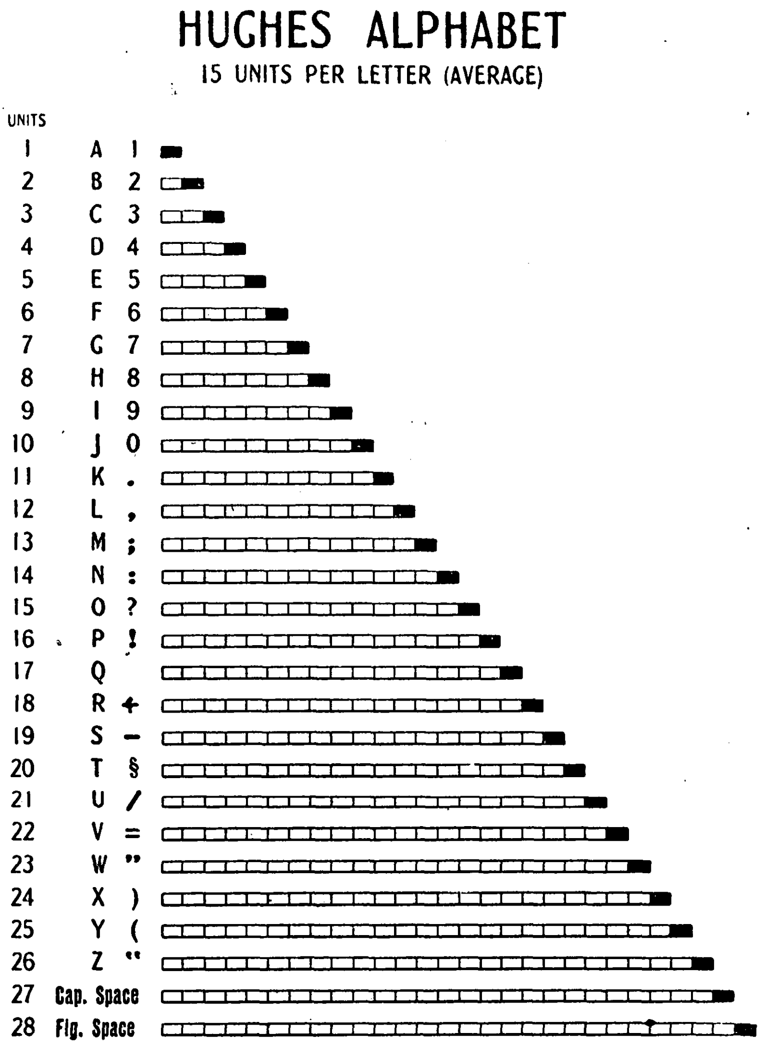

FIG. 3.

On the average there are about 15 units per letter in the Hughes alphabet. There is only one current unit, but there are no less than 14 zero units.

The number of units in the Hughes code can be reduced by using positive and negative units—"A," for instance, being a positive unit, and "B" a negative unit; but the most satisfactory way to reduce the number of units is to resort to more complex permutations. Perhaps the simplest alphabet so formed consists of the permutations of two current units in eleven different positions, with the proviso that not less than one zero unit must intervene between two current units. This gives forty-five permutations. This alphabet is the basis of the Rowland system, and may, therefore, be appropriately called the Rowland alphabet. It is as follows:—

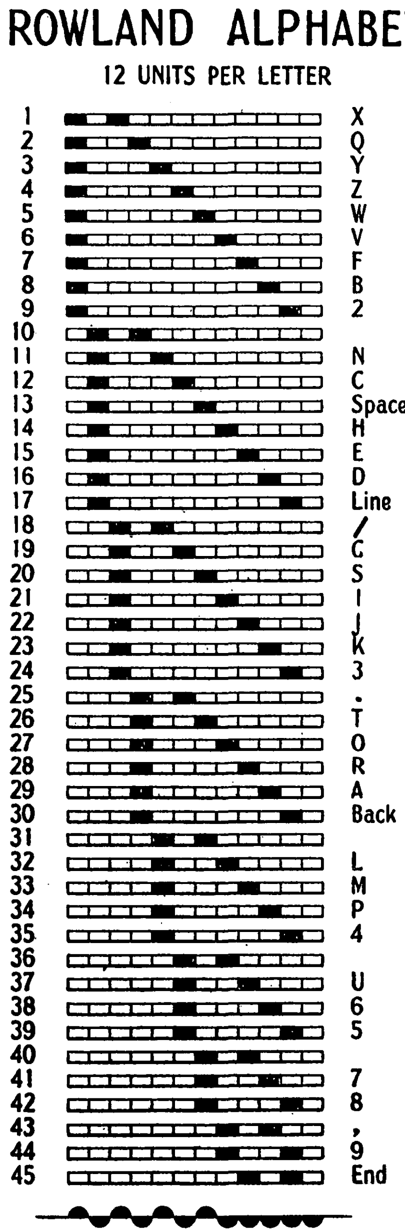

FIG. 4.

In the Rowland alphabet, as each current unit must be separated by at least one zero unit, a zero unit has to be added at the end of all the letters making it a 12-unit alphabet, and the exigencies of the Rowland

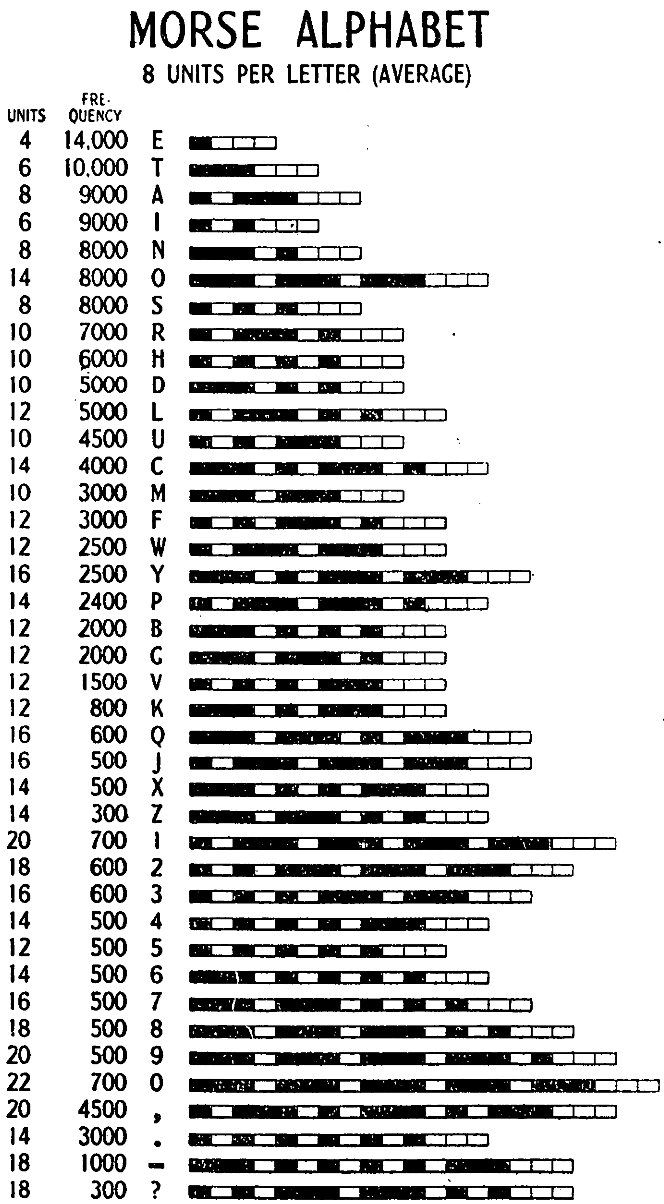

FIG. 5.

system require an extra unit, making 13 units per letter. In order to secure the advantage of "double-current" working, this alphabet, as used in the Rowland system, is to some extent masked by being built up out of an alternating current. (See foot of column in Fig. 4. This shows the 45th letter of the Rowland alphabet as actually transmitted.)

The beautiful automatic photo-printing telegraph system developed by the Siemens & Halske Company, in Berlin, is based on the same Rowland alphabet, but in this case it is not masked by the introduction of alternating current. Each letter is represented by two short impulses, one positive and one negative, in eleven different positions.

If we remove the restriction that each current unit must be separated by at least one zero unit, we can at once make better alphabets. The only condition to be observed is that not more than two different units must be employed, in order to leave the way open for the use of the alternating current. We can, for instance, build up the familiar Morse alphabet with positive and zero units, as on p. 562.

Or we may substitute negative units for zero units, and so conform to type A (Fig. 2). The only point requiring mention is that the unison device in the Morse alphabet consists of a negative or zero dash of 3 units, which is used for this purpose only. As the result of long experience with the Wheatstone, the British Post Office has found that the average Morse letter is equal to four complete reversals—that is to say, 8 units. For manual signalling of all kinds, the arrangement upon which the Morse alphabet is built is not only good, but it is practically the only arrangement possible. There are only two different time intervals, namely, 1 unit and 3 units. For manual signalling, intervals of 2 and 4 units are not sufficiently distinct from 1 and 3. With machine telegraphy, on the other hand, time can be divided with great accuracy, and the use of more than two time intervals presents no difficulty. Consequently with machine telegraphy a shorter alphabet than Morse is possible.

Further, although the Morse alphabet is ideal for manual signalling, it has a grave disadvantage for machine telegraphy. The letters are of unequal length. Only those who have made a careful study of the printing telegraph problem from a mechanical point of view, can realise the extreme importance of this question in constructing a printing telegraph. Uniformity is the key to success in machinery. It makes for simplicity. With all machinery, simplicity, other things being equal, is of prime importance, and owing to the delicacy and inherent imperfection of telegraphic machinery, the need for simplicity in this case is overwhelming. That simplicity can only be secured by a signalling alphabet in which all the letters are of equal length. It is the same necessity that has compelled the use of letters all of the same width in typewriters. The Morse alphabet, however, has been in possession of the field so long, and telegraph officials in English-speaking countries are so saturated with Morse traditions, that it would be impossible to introduce a new alphabet if the operators had to learn it. Fortunately with machine telegraphy that is not the case. All the operator has to do is to learn typewriting. As a single illustration of the mechanical advantages of an equal-letter alphabet, such as that used in the Baudot and Murray systems, it may be mentioned that a keyboard perforating instrument to produce the Morse tape for the Wheatstone transmitter, requires a group of nineteen punches and their corresponding parts, as against only five punches and their corresponding parts in the Murray keyboard perforator. As an automatic printing telegraph requires about four keyboard perforators at each end of a circuit, if an equal letter keyboard perforator can be constructed for £20, and an unequal letter perforator costs £60, there is a difference of capital cost of about £300 per circuit in favour of the equal letter alphabet. This is a large item if many circuits have to be equipped, to say nothing of the fact that cost of maintenance is roughly proportional to capital cost.

The alphabet used in the Buckingham printing telegraph has the peculiarity that it is both equal and unequal. It uses the Morse dot and dash, but as each letter is represented by six impulses, three positive and three negative, it is not necessary to use the negative dash solely as a unison mark as in Morse. Letters are distinguished by counting every sixth impulse, which is a negative dash, as in the Morse alphabet, but the negative dash is also used for building up the letter permutations. The result is that the Buckingham is an equal-letter system at the receiving station; but at the sending station it is involved in the complexities of an unequal-letter alphabet. The Buckingham alphabet is shown on p. 565.

The length of the letters in the Buckingham alphabet averages about 10½ units, as may be proved by counting the number of units in each letter, and then counting the letters in several sentences and averaging.

The Best Machine Telegraph Alphabet.

Unquestionably the best alphabet for machine telegraphy is that used in the Baudot and Murray systems. It is the shortest of all practicable telegraph alphabets, in fact the shortest possible, and it is an equal-letter alphabet, consisting of five units per letter. The permutations are made up out of impulses of 1, 2, 3, 4, and 5 units' duration, both positive and negative (or positive and zero). Being an equal-letter alphabet, the signals can be divided off into letters by measurement. There is, therefore, no need for a unison signal to separate the letters as in Morse. Hence there is no space between the letters. The result is that impulses frequently extend from one letter into the next, and the average number of marking impulses per letter in the Murray system is only about 1¼, and a trifle more in the Baudot. In the Rowland there are four and a half marking impulses per letter. The Rowland alphabet, therefore, sends about three and a half times as many signals per letter as the Baudot and Murray alphabet. The apparent Murray alphabet, as it appears in the perforated transmitting and receiving tapes, is shown in column B, Fig. 7, and the signals transmitted by this tape are shown in column C. Column A gives the frequency of the occurrence of the letters of the alphabet.

The apparent Baudot alphabet as it is transmitted is shown in column D.

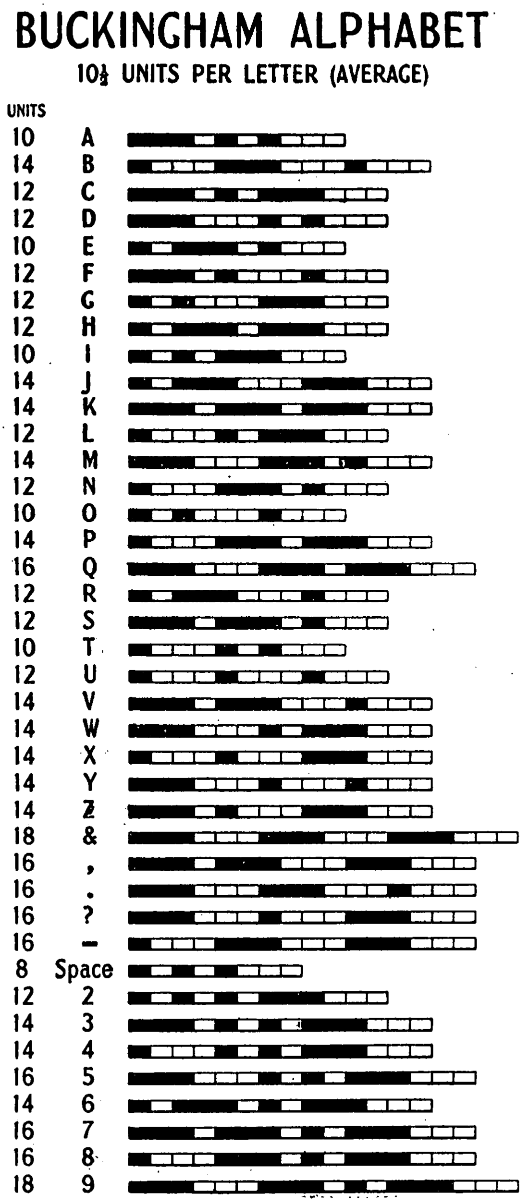
BUCKINGHAM ALPHABET
10½ UNITS PER LETTER (AVERAGE)
UNITS
10 A
14 B
12 C
12 D
10 E
12 F
12 G
12 H
10 I
14 J
14 K
12 L
14 M
12 N
10 O
14 P
16 Q
12 R
12 S
10 T
12 U
14 V
14 W
14 X
14 Y
14 Z
18 &
16 ,
16 .
16 ?
16 -
8 Space
12 2
14 3
14 4
16 5
14 6
16 7
16 8
18 9

FIG. 6.

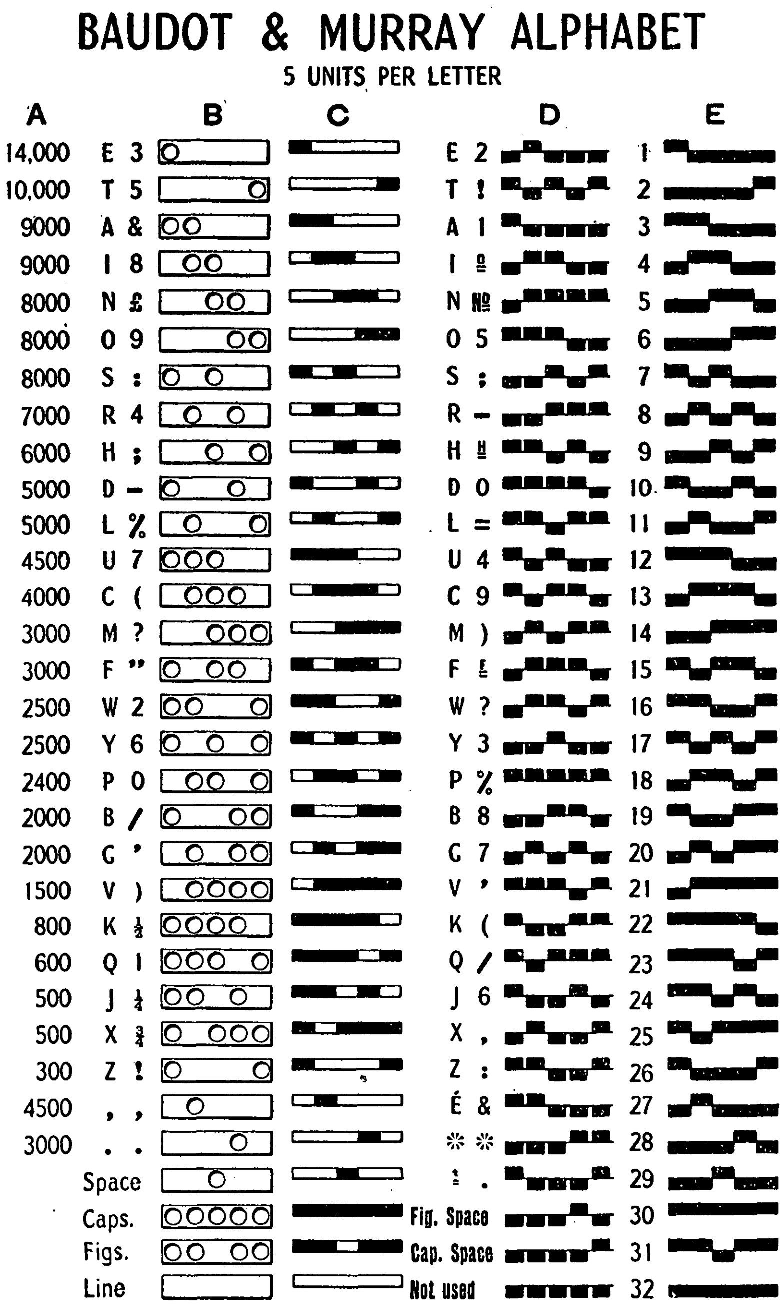
BAUDOT & MURRAY ALPHABET
5 UNITS PER LETTER
A B C D E
14,000 E 3
10,000 T 5
9000 A &
9000 I 8
8000 N £
8000 O 9
8000 S :
7000 R 4
6000 H ;
5000 D –
5000 L %
4500 U 7
4000 C (
3000 M ?
3000 F "
2500 W 2
2500 Y 6
2400 P 0
2000 B /
2000 G '
1500 V)
800 K ½
600 Q 1
500 J ¼
500 X ¾
300 Z !
4500 , ,
3000 . .
Space
Caps.
Figs.
Line
E 2 1
T ! 2
A 1 3
I 4
N Nº 5
O 5 6
S ; 7
R – 8
H 9
D 0 10
L = 11
U 4 12
C 9 13
M) 14
F £ 15
W ? 16
Y 3 17
P % 18
B 8 19
G 7 20
V ' 21
K (22
Q / 23
J 6 24
X , 25
Z : 26
É & 27
28
29
Fig. Space 30
Cap. Space 31
Not used 32

FIG. 7.

Actually the space between the unit signals in the Baudot is very small, and the groups of positive and the groups of negative signals run together into single signals, even in passing over a comparatively short line. The Murray alphabet is always worked with alternating current, so that the real Baudot and Murray alphabets as they actually go over a telegraph line are identical, and are shown in column E.

The only difference is in the allotment of the letters to the various permutations, the Murray arrangement being designed to punch as few holes as possible in the paper tape. Baudot, in a paper on his system in the *Bulletin de la Société Internationale des Électriciens*, vol. xi., credits the authorship of this alphabet to Wildman Whitehouse, in 1853, but the Whitehouse patent of 1853 gives only the alphabet shown in column B, Fig. 7, which was proposed by Morse and others, and is so obvious that no merit can be claimed for its use. To Emile Baudot belongs the credit of having been the first to use what I have described as the real Baudot alphabet. This is the shortest possible telegraph alphabet fulfilling the conditions already set forth, and it is the ideal alphabet for machine telegraphy. It was the natural outcome of the Baudot system. In the Murray system the instruments had to be specially designed with the express object of using this alphabet. It is the foundation of the great success achieved by the Baudot system during the past twenty years, and no system of machine telegraphy can hope for any wide and permanent success on land unless it uses this alphabet. Other alphabets, especially the Morse, will no doubt continue to be used with machine telegraphy for particular purposes, but the Baudot is the one alphabet that has any prospect of coming into general use for machine telegraphy. It bears the same relation to machine telegraphy that the Morse alphabet does to manual telegraphy. They are each without a rival in their respective spheres. Actually so far as the alphabet is concerned the Murray system has a slight advantage over the Baudot, because in the Murray system correcting impulses are generated from the signals themselves, whereas in the Baudot system two correcting units are required for every four letters, and on the average two units have to be allowed for retardation. Thus in practice there are six units per letter in the Baudot system and five in the Murray.

So far as ocean cabling is concerned, the number of possible alphabets is very limited. The Morse, as used for cable work, is shown in column A in Fig. 8 for the sake of comparison with the only equal-letter alphabet for ocean-cable work that is shorter than the Morse, namely, that shown in column B.

Cable Morse averages about 7·4 units per letter, and the equal-letter alphabet about 6·4, the advantage being about 10 per cent. in favour of the equal-letter alphabet. The use of this set of permutations (three different units in three different positions) as a telegraphic alphabet appears to have been first proposed by Cooke in 1836. So far it has not been put to any practical use, but there are interesting possibilities connected with it which will be referred to later on. It may be noted in passing that I have arranged the permutations so that fourteen of the most frequently used letters are the same as Morse.

Cooke's arrangement only provided for the twenty-six letters of the alphabet, and it does not seem to have been published.

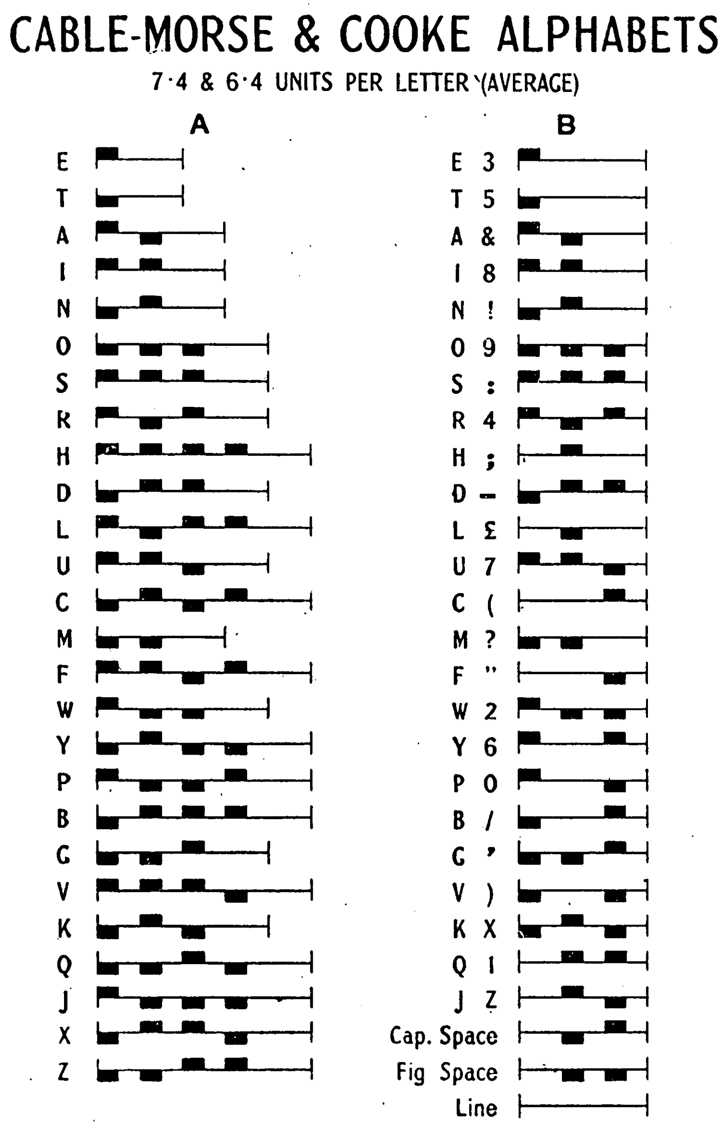

FIG. 8.

Summing up, the order of merit of the leading printing telegraph systems, from the point of view of economy of line-time by using the shortest alphabet or code of signals, may be set out as follows :—

	Five Letters.	Five Figures.
Murray	25 units	35 units
Baudot	30 ,, ...	30 ,,
Morse	40 ,, ...	74 ,,
Buckingham	50 ,, ...	74 ,,
Siemens & Halske ...	60 ,, ...	60 ,,
Rowland	65 ,, ...	65 ,,
Hughes...	75 ,, ...	75 ,,

With figures there is a slight difference, owing to the use of figure prefixes and suffixes in some cases and not in others. The foregoing estimate for figures is based on the figure group 13579. It will be noticed that with figures the Morse alphabet comes out badly. By way of a practical comparison the word PARIS is given in each of the alphabets, on p. 570.

SYNCHRONISM, ISOCHRONISM, AND UNISON.

Investigation having shown that the Baudot alphabet is the best, the next question is how to utilise it—and, in fact, any telegraph alphabet—as the basis of a printing telegraph system. As already explained, when there is only one wire or channel of communication, the conversion of space signals into time signals and back again may be regarded as the chief operation in printing telegraphy. If there were five wires, as at A in Fig. 10, the signals would remain space signals throughout. If, on the other hand, there is only one wire, as at B, Fig. 10, then there must be some means of putting the line successively in connection with the space signals 1, 2, 3, 4, 5, so as to collect them as time signals; and at the other end of the line there must be an arrangement to enable the wire to distribute its time signals successively to the space-signal positions 6, 7, 8, 9, 10. At each end of the line there must be an oscillation or rotation of some mechanism adapted for collecting and distributing the signals. This is one of the chief features of printing telegraphy, and therefore of all telegraphy through one channel. In the Baudot and Rowland systems we have complete rotation; a revolving contact arm sweeping the space signals successively into the telegraph line as time signals from a fixed contact-wheel and distributing them in the same way at the other end. In the automatic telegraphs the contact-wheel becomes infinitely large, that is to say, a rack, such as the Wheatstone transmitting tape. In this case, owing to the size of the wheel, it is impossible to have a revolving contact arm. Instead, the contact-arm is fixed and the wheel or tape-rack revolves. In B, Fig. 10, for instance, it makes no real difference whether the contact-arm revolves and the contacts 1, 2, 3, 4, 5 remain stationary, or *vice versâ*. The effect is the same in both cases. In nearly all printing telegraphs a revolving wheel distributor is used. In the case of the Hughes the distributor and the type-wheel are one and the same. In the stock-tickers it is a little ratchet-wheel on the same shaft as the type-wheel. In the Baudot, Rowland, and Buckingham the distributor is an entirely separate

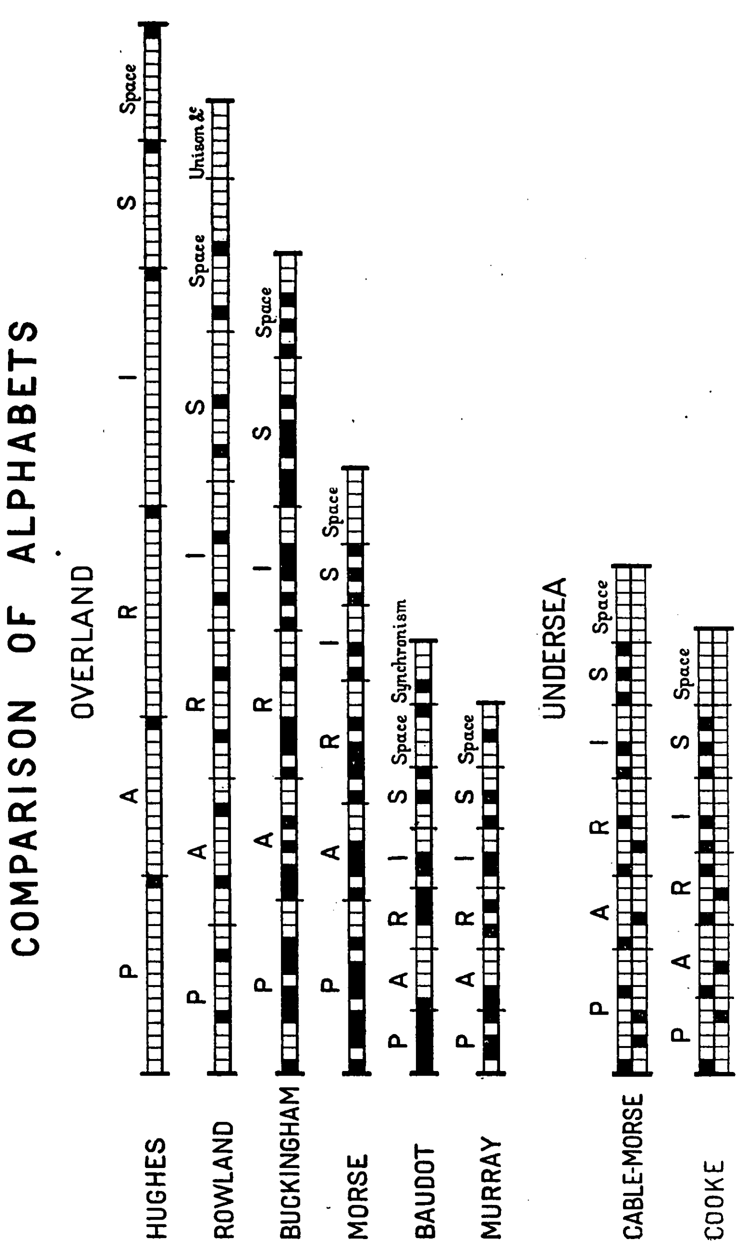
COMPARISON OF ALPHABETS
OVERLAND
HUGHES
ROWLAND
BUCKINGHAM
MORSE
BAUDOT
MURRAY
UNDERSEA
CABLE-MORSE
COOKE
P A R I S Space
Unison &c
Synchronism

FIG. 9.

mechanism from the type-wheel, and is connected with it in a very complicated manner. In the Murray system the distributor is a punch-arm and a moving paper-tape, that is to say, a portion of a rack. In this respect it closely resembles the Wheatstone recorder, but instead of inking the tape it punches holes in it. In the method of translating and printing after distribution of the signals, the Murray system differs from all previous printing telegraphs, and it belongs rather to the class of automatic type-setting machines, such as the monotype; and for the purpose of automatic type-setting in the ordinary acceptation of the word it was indeed originally designed.

It is owing to the necessity for converting space signals into time signals and back again that all telegraph systems using one wire or

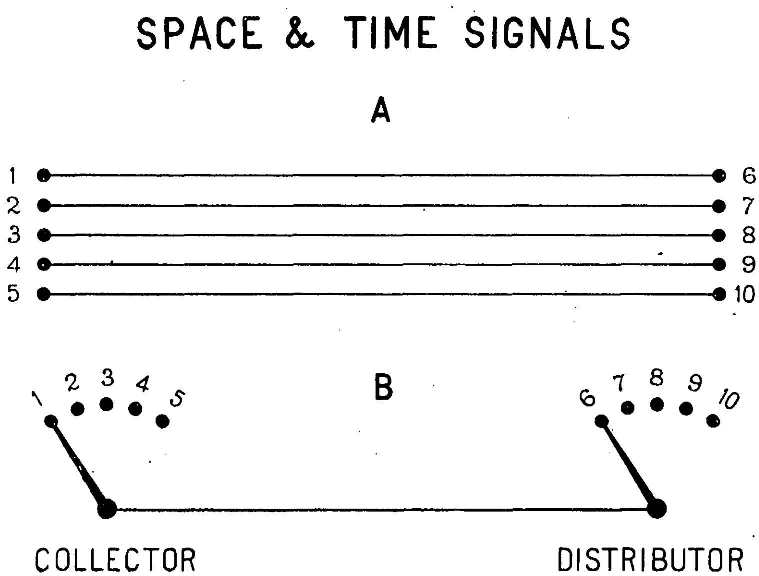

FIG. 10.

channel of communication involve "synchronism," "isochronism," and "unison." As already pointed out, if we had five wires instead of one, intelligence would be transmitted by space signals only. There would then be no need for a unison device, because each letter would stand by itself distinct, and there would be no synchronism, and only isochronism in respect of successive letters. With one wire the collector and distributor must both maintain the same speed—they must be isochronous—or the signals will get mixed up and lost. For instance, the sounder must work at exactly the same speed as the Morse key, though there may be considerable lag. There must also be a unison mark to distinguish the letters, the negative dash being used for this purpose in the Morse alphabet. The terms "unison," "synchronism," and "isochronism" are often very loosely used, but in telegraphy—

"Unison" is the method adopted for correctly dividing off or distinguishing the groups of letter signals.

"Isochronism" means identical speed of two bodies at a distance from one another.

"Synchronism" means identical speed and phase of two bodies at a distance from one another.

It is a physical impossibility to secure synchronism between a driving and a driven body, and in telegraphy all so-called synchronous systems are really only approximations to synchronism, and the more precise the synchronism required, the worse the system. Isochronism on the other hand is not only easy to secure, but may be made perfect.

In Fig. 11, if we take a shaft, D, with three wheels, A, B, C, keyed to it, and if B is the driving-wheel, then the speed of all three wheels

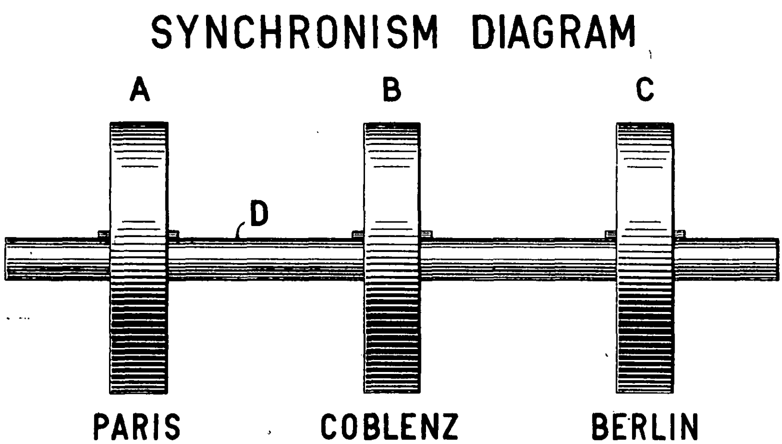

FIG. 11.

must be identical or the shaft will break. That is to say, the isochronism is perfect, but the synchronism is not. The friction of the air on A will twist the shaft D and cause A to lag behind B. If D is a large steel shaft a few inches long, the lag will be infinitesimal, but if D is a telegraph wire 500 miles long, the lag becomes a serious factor. Although it is physically impossible to secure synchronism between a driving and a driven wheel, B and A, it is possible to secure synchronism between two driven wheels, A and C. The Baudot is usually worked as a synchronous system, and Fig. 11 is the method adopted in a Baudot repeating station. For instance, in the quadruple Baudot working between Paris and Berlin there is a repeating station at Coblenz, which controls the speed and phase of the instruments in Paris and Berlin. Coblenz is the driving-wheel B, and A and C are Paris and Berlin. This clever scheme secures perfect synchronism over 700 miles (1,100 kilometres) separating the two capitals, but unfortunately it is a thing that can only be done once, and in any case it does not really get rid of lag. The retardation of the signals has still to be allowed for. Hence there is a physical limit of say 500 miles (800 kilometres) to even approximate synchronism in telegraphy. Abandoning synchronism and relying simply on isochronism, the phase may differ to any extent, and the limitation of distance imposed by synchronism is at once removed. The Baudot has to abandon synchronism in order to perform its greatest feats. To get six transmissions over one wire between Paris and Marseilles, 550 miles (880 kilometres), two wires are used, one to send six messages simultaneously to Marseilles, and the other for six return messages to Paris. In this way lag or retardation is of no consequence as long as the signals remain clear, isochronism or identical speed being all that is required. Similarly, in working through 560 miles (900 kilometres) of single-wire ocean cable between Marseilles and Algiers, two transmissions of thirty words per minute each are secured in one direction through one cable, and another cable is used for the return messages. Between Marseilles and Algiers the difference of phase on the Baudot instruments amounts to about 90 degrees. The Murray system makes no attempt to secure synchronism. It is an isochronous system, and the duplex balance is used to secure working in both directions on one wire, the Murray system, like the Wheatstone, working very easily in this manner. Retardation under these circumstances ceases to be important, because the distributor need only keep step with the arriving signals, which might, if necessary, take five minutes on the journey. This arrangement has also the advantage that ordinary repeating stations can be used.

I would, therefore, prefer to describe as synchronous a telegraph system that endeavours to obtain sufficient identity of phase between the collector and distributor, to be able to work in both directions over one wire without resorting to the duplex balance. In this case the collector and distributor are identical in form, and can interchange their functions at will. A system relying on identical speed only, and the duplex balance for working both ways on one wire, is what, I think, should be described as an isochronous system.

What has been said about translation, collection, and distribution of signals may be summarised in the following chain of operations, forming the essential features of all printing telegraph systems :—

1. Message recorded in Roman or other type, or script handed in for transmission.
2. Translation into telegraphic space signals.
3. Collection of the telegraphic space signals in the form of time signals.
4. Transmission of the time signals over a single telegraph wire.
5. Distribution of the time signals in the form of space signals.
6. Translation of the telegraph space signals into Roman or other type characters.
7. Recording of the Roman or other type characters in the form of a message for delivery.

Although this chain of operations is complete in itself, something more is required for a high-speed printing telegraph. With a good telegraph alphabet, such as the Baudot, the capacity of a telegraph line for transmitting messages is so great that one operator cannot keep it fully occupied. If the line is to be completely utilised, it must, therefore, be given in turn to several operators. This involves some species of rotating mechanism. Hence the employment of several operators to send signals in rotation is only an extension of a process already in use. In Fig. 10, at B, it merely involves extending the number of space-

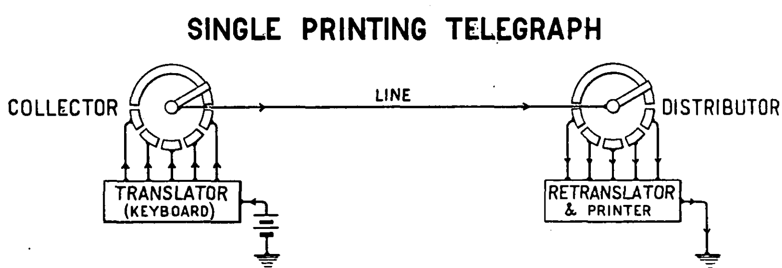

FIG. 12.

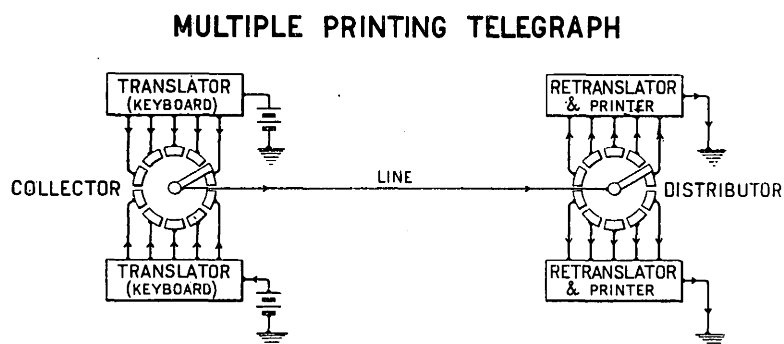

FIG. 13.

signal contacts at each end of the line. The employment of several operators is therefore easily and naturally provided for.

The operators may take turn about in transmitting (1) letters, or (2) messages. The first is the multiple method, of which the Baudot is the best example; and the second is the automatic method, of which the best-known form is the Wheatstone. The Murray system is simply a fully developed Wheatstone system using the Baudot alphabet. Each of these methods—the multiple and the automatic—has advantages and disadvantages which it is not possible to discuss here, beyond saying that the two methods appear to be in a sense complementary to one another, each being capable of doing work for which the other is not so well suited.

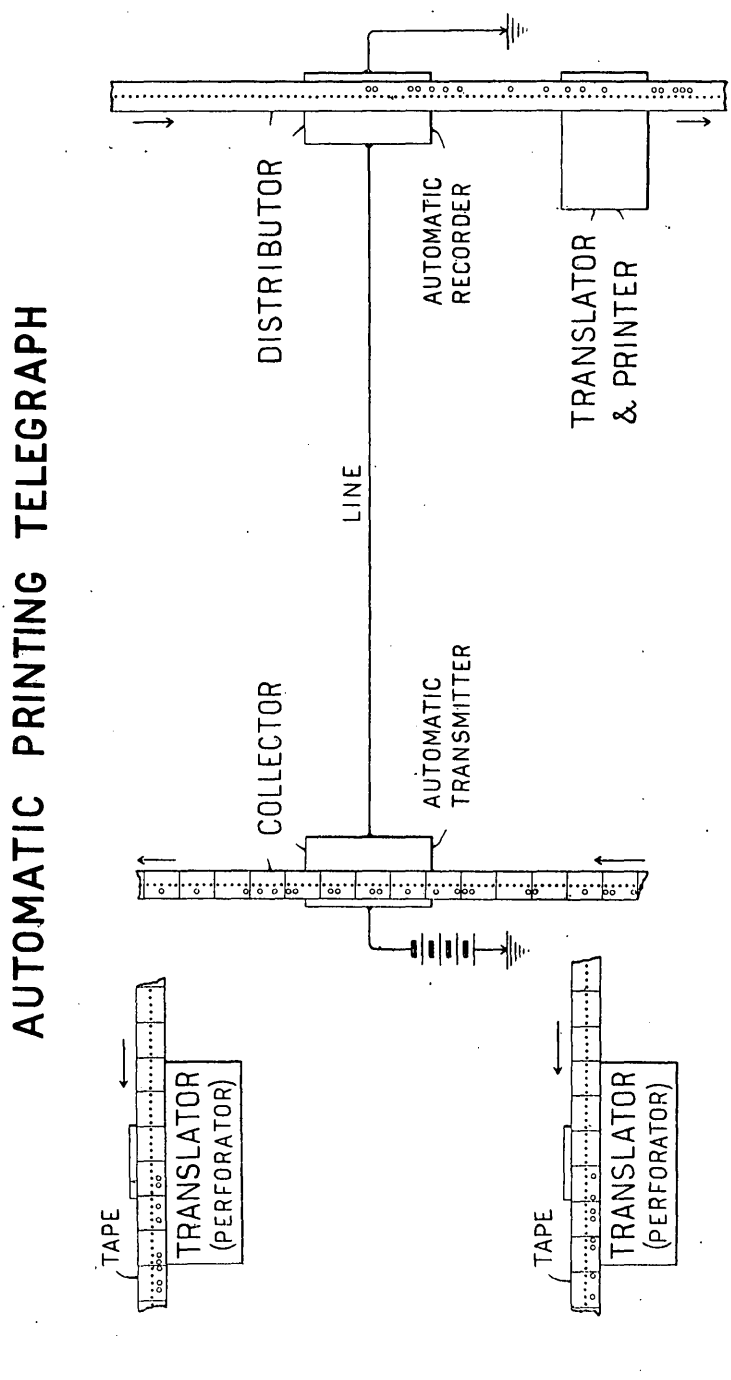
AUTOMATIC PRINTING TELEGRAPH
DISTRIBUTOR
AUTOMATIC RECORDER
TRANSLATOR & PRINTER
LINE
COLLECTOR
AUTOMATIC TRANSMITTER
TAPE
TRANSLATOR (PERFORATOR)
TAPE
TRANSLATOR (PERFORATOR)

FIG. 14.

Figs. 12, 13, and 14 illustrate these and other points mentioned. Fig. 12 is a diagram of a single printing telegraph for one operator. Fig. 13 shows the multiple method by which several operators transmit single letters turn about. Fig. 14 shows the automatic method for transmitting messages turn about. It will be seen that the multiple and automatic methods differ only in degree and not in kind.

THE MURRAY AUTOMATIC SYSTEM.

The Murray automatic system may be taken as an example of the practical application of the principles that have been described.

THE MURRAY TAPE, AND THE CORRECTION OF ERRORS.

As already explained, the collector and distributor in the Murray system each consist of an oscillating arm or lever, and a moving band of telegraph tape about half an inch wide, the messages being recorded

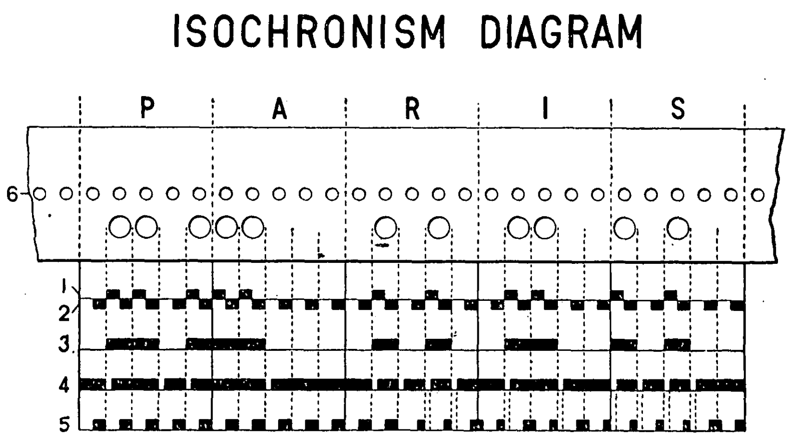

FIG. 15.

as perforations in the tape. The oscillation of the lever is a subsidiary feature arising out of the employment of tapping instead of sliding contacts. Relatively to the direction of motion of the tape, the lever or arm is stationary. Formerly the transmitting and receiving tapes were unlike, but they have now been made identical. Fig. 15 shows a piece of this tape perforated with holes representing the word "PARIS," while beneath it, on line 3, are shown the main-line time signals which this tape transmits, or which produce this tape at the receiving station. For the sake of clearness the main-line signals are shown as made up of positive and zero units. The system can be worked in this way, but it is preferable, as already explained, to use positive and negative units (double-current), zero positions being filled with negative units. Each letter permutation occupies half an inch lengthwise of the tape, each letter space being divided up into five equal units. Any one or more of these units may be perforated with a message hole. This gives 32 permutations. Following the example of the Hughes and Baudot, one of these groups is used as a figure shift and another as a letter-shift, and there are about 52 type characters. It is possible to use 84 characters, but the additional complexity is undesirable, and 52 characters have been found ample for all requirements. The central row of feed-holes in the tape 6, Fig. 15, is punched beforehand at an immense speed by pulling the tape through between a punch-wheel and a die-wheel. The same method is now used for perforating sheets of postage stamps, and it can be carried out on a manufacturing scale as soon as a demand arises.

While describing the tape, an important point in regard to automatic printing telegraphs may be explained. So far as commercial telegrams are concerned, a serious objection to direct-transmitting page-printing telegraphs is that errors show up badly in the printed message, and operators have to work slowly and carefully to avoid making mistakes. Telegraph operators are remarkably accurate, but in spite of the best care and skill, errors are frequent. Any one who is accustomed to using a typewriter knows how difficult it is to write a page of type-written matter without striking at least one or two wrong letters. In four cases out of five there is consciousness of the error as soon as it is made, and steps can be taken to correct it. In tape-printing telegraphs, like the Hughes and Baudot, the errors and the succeeding corrections can be cut out of the tape before it is pasted on to the telegraph blank, and there is then nothing to disfigure the telegram, and make the recipient uneasy about its accuracy. With a direct-transmitting page-printing telegraph this cannot be done. A wrong key depressed is an error printed at the other end of the line, and the correction following only magnifies the blot. All automatic systems of telegraphic transmission in which there is preparation of the message beforehand, possess the potentiality of correcting an error before transmission. In the Wheatstone automatic system, for instance, this process is known as a "rub-out." When an operator at a Wheatstone puncher makes a mistake he can pull the tape back and punch it full of holes, thereby obliterating the mistake. In this case the mistake is represented by a series of dots on the received tape, and the transcribing clerk passes over it. In automatic telegraph systems, in which a printing machine takes the place of the receiving operator, it is a comparatively simple matter to arrange that the printer shall imitate the action of the operator by remaining inactive when dots only are coming over the line. In this way no trace of the error appears in the printed message. This, for instance, is done in the Buckingham system. In the Buckingham system, however, as with Morse, the groups of letter signals on the transmitting tape are of varying length. It is consequently not possible to pull back the transmitting tape letter by letter in the keyboard perforator. It has to be adjusted by hand, or pulled back unit by unit, a process necessarily involving some loss of time, and many corrections in this way would materially reduce the output of the operator. In the Buckingham system also it is necessary to rub out everything as far as the end of the previous line. Hence, to correct a single letter a whole line may have to be rubbed out. With automatic systems like the Murray, using an alphabet in which the letter signals are all of the same length, the transmitting tape, while being prepared in the keyboard perforator, can be pulled back instantly letter by letter by depressing a lever. If an operator strikes a wrong key, all he has to do to rectify his error is to strike the back-spacing lever, the letter-shift key, and the desired letter—the work of a moment. A word of six letters can be blotted out in this way in a few seconds, and no trace of the correction, not even a blank space, will appear in the printed message at the other end of the line. This relieves the operator from the dread of striking a wrong key, the strain on his attention is less, and he can work faster without working harder. One or two automatic type-setting patents have included schemes for correcting errors in the perforated tape; but, as far as I am aware, the Buckingham was the first printing telegraph to adopt a plan for invisible correction, and the Murray system was the first, and, so far, is the only system having the power to correct instantly single letters or words.

The First Translation.

The messages for transmission are punched in the tape by keyboard perforators of a very simple character. These translate the Roman letter space signals into the space signals of the five-unit telegraph alphabet. Fig. 16 is a general view of this translating instrument, with the cover on and the lid opened like a piano, ready for operation. Fig. 17 shows the instrument with the cover removed. At the back there is a box holding a condenser to suppress the spark at the punching contact. On top of this box rests the ordinary Wheatstone tape-feed wheel. In front is the actual perforator, which includes a punch-block with five punches and an electromagnet, the armature of which punches on its front stroke and feeds the tape forward one letter space on its back stroke. This magnet does the whole of the work, and there are only two electrical contacts, one a punching contact and the other a letter-counting contact to indicate the length of the lines for the page-printing. There is also a typewriter keyboard with thirty-three keys, the touch and depression of which have been made very light and short to increase the speed of operation. A simple selecting or translating mechanism completes the machine. On the right may be seen the lever for pulling the tape back letter by letter when a correction is necessary. The correction is made by striking the letter-shift key (Caps.). This punches five holes in a letter space, and so blots out all other permutations which may have been previously punched. At the other end of the line this signal leaves the printer unaffected, its function being to shift the action of the printer from figures to letters. The signal may be repeated half a dozen times so as to blot out a whole word, and there will be no trace of the error in the printed message. As the tape is divided off by printed cross-lines into letter spaces, it

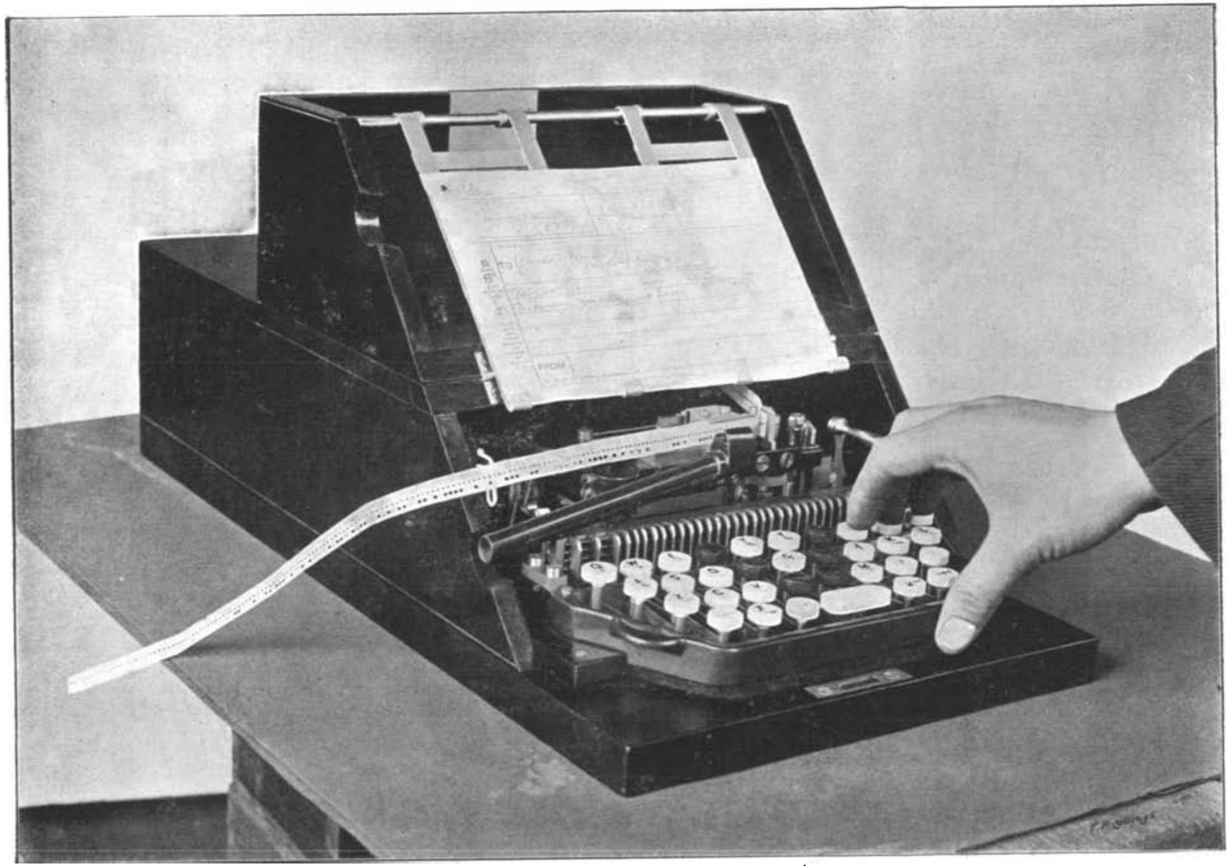

FIG. 16.—Murray Keyboard Perforator ready for use.

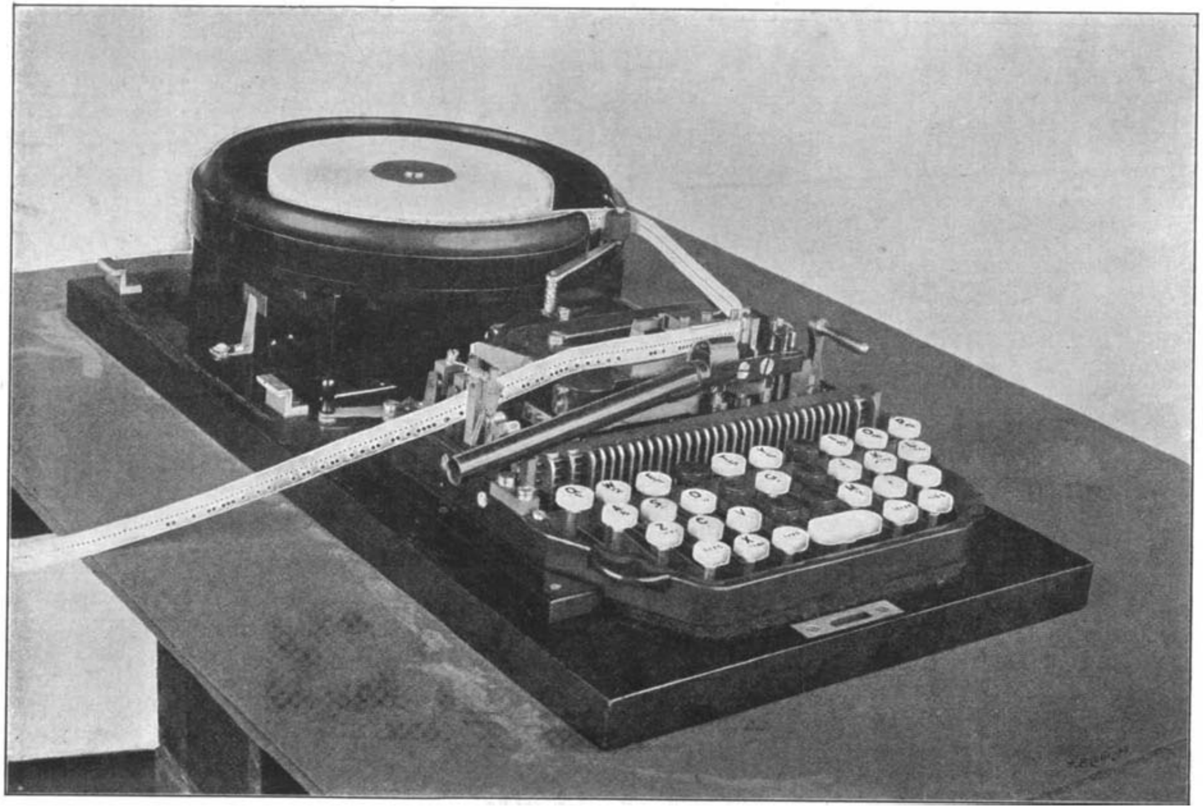

FIG. 17.—Keyboard Perforator with cover removed.

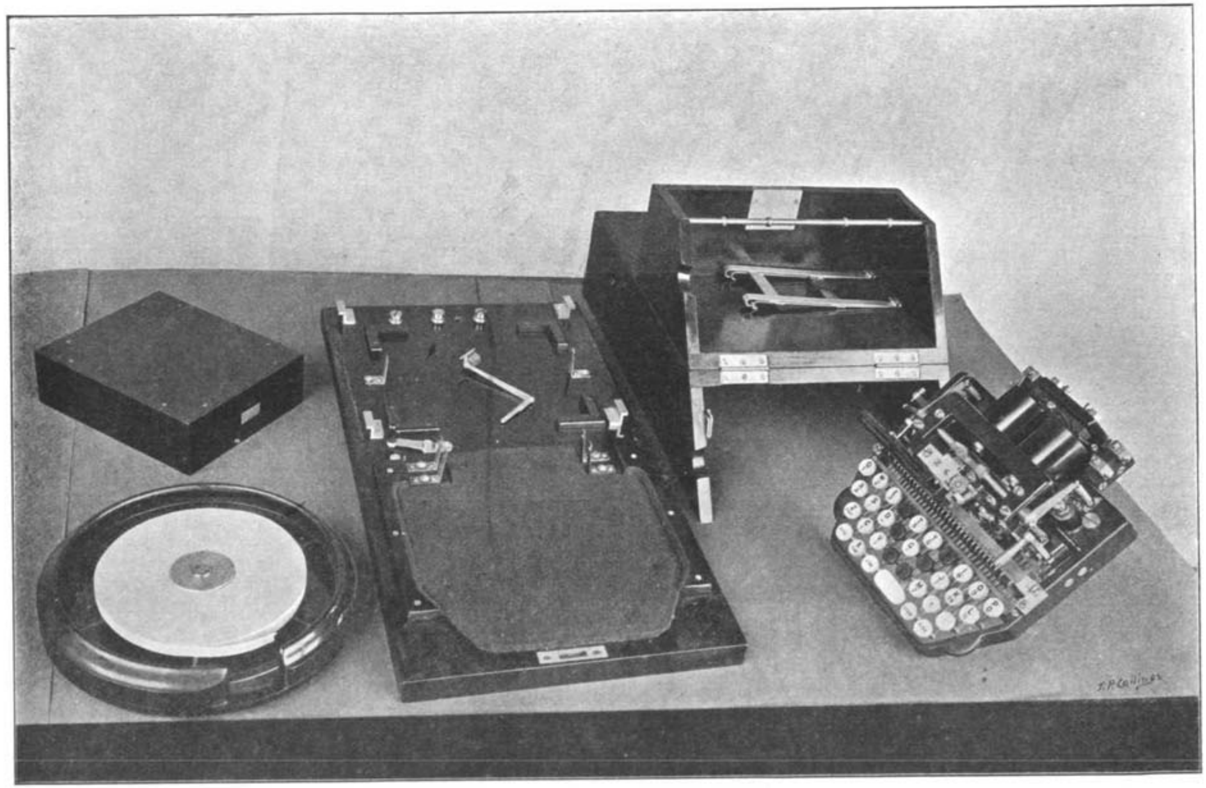

Fig. 18.—Keyboard Perforator lifted apart.

is practically as clear as print, and an operator can learn to read it in a week. It is not necessary to read the tape, but as it is easily learnt the perforator has been so designed that the perforated tape is visible up to the last letter punched just above the keyboard and below the message being perforated. In this way, what Wildman Whitehouse, in his remarkable patents of 1853 and 1854, describes as a "home record" is supplied for those telegraph administrations that require it.

The keyboard perforators can be constructed to work on any telegraphic voltage, or on a 110 or 220 volt electric-light circuit, and the current consumption is small—about one-third of an ampere during the momentary depression of each key.

Speed of Operation on a Keyboard.

So many keyboard machines for producing perforated tape have been made during the past twenty or thirty years, that it is unnecessary to go into further details, beyond saying that the whole machine and any part of it have been made instantly removable and interchangeable. There are no screws, or terminals, or wires to be unfastened. If an instrument or any part of it is out of order, it is simply lifted away and another put in its place. Fig. 18 shows the parts separately. The key buttons are in rows of different colours and of slightly different heights to facilitate operation without taking the eyes off the copy—an essential condition for high speed on a typewriter keyboard. This mode of working is not so difficult as might be supposed, particularly when the operator is trained from the first to write in this way. A young telegraph operator in Berlin learned to write on one of the Murray keyboards in a fortnight, at the rate of 120 letters (20 words) per minute without looking at the keyboard, and this operator, after several months' practice, reached a speed of 436 letters (72 words) per minute in the same way. This is an exceptional case, and the operator was accustomed to piano playing, but it illustrates the possibilities of this method. The Hughes is habitually operated without taking the eyes off the copy, and in America the linotype operators have, during the past year or two, made a notable increase in their speed by adopting the same plan, though the linotype keyboard is very large and contains ninety keys.

It may be mentioned in passing that there is much misconception about the speed of manual operation of keys and keyboards. In reality it is much below what is generally supposed. It is a subject of great importance to telegraph administrations, and it has special bearings on the printing telegraph problem; but there is not space in this paper to do more than point out that the average speed on a typewriter keyboard is not more than about 120 letters (20 words) per minute. Experiments with typewriter-keyboard instruments during the past year or two in England, Germany, and the United States have been very disappointing to telegraph engineers, owing to the exaggerated ideas that had previously prevailed about the advantages of such an arrangement. The remedy, as already mentioned, is to train the operators to write without looking at the keyboard. It is possible that in this way the average speed may reach about 180 letters (30 words) per minute, or about double the average speed of a good Morse key operator. As the Murray system uses the five-unit alphabet, the five permutation keys of the Baudot system may be substituted for the present typewriter keyboard in the perforator. This would have the drawback that the operator would have to learn the permutations, the operator and not the machine then doing the translation; but it would have the advantage that the operator could keep his eyes on the telegram as easily as with the Morse key. In fact two sets of these permutation keys can be used, one set for the five fingers of each hand, to be worked alternately. But with properly trained operators the typewriter keyboard is undoubtedly the best.

Collection and Transmission.

The perforated tape, containing a batch of three or four messages, having been prepared, the next step is automatic transmission, that is to say collection of the space signals and transmission as time signals. There are two well-known methods of automatic transmission of telegraph signals from a paper tape. The first is the direct method, in which metallic brushes make electrical contact directly through the holes in the tape. The second is the indirect method employed in the Wheatstone automatic transmitter. This utilises the principle of the Jacquard loom, the signals being transmitted by the intervention of a number of small levers and rods controlled by the perforated tape. Experience has shown that the indirect method of transmission is more reliable than the direct method, and it has the additional practical advantage that by adjustment of the levers and contacts the relative duration of the positive and negative units can be regulated with great nicety. Another advantage of the indirect method of transmission is that the mechanism for perforating the transmitting tape is simpler and quicker than that required for making tape for direct transmission by contact brushes.

The object of the Murray single-line transmitter is to produce, from a series of adjoining but separate holes (1, Fig. 19) in a tape, not a series of short dots like 6, but a continuous telegraphic signal 3, such as would be produced by a contact brush passing over the slit or elongated perforation 2, equal in length to all the holes 1. The mechanism has also to break or reverse the current 4 when one or more unperforated units of tape 5 intervene, and to maintain this zero or reversed current in the line until one or more perforated units of tape occur. It is a process of integrating or producing a continuous signal from a series of discontinuous holes. The object is to reduce as far as possible the number of signals transmitted over the line by making the instrument transmit the real Baudot alphabet. If it were not for this arrangement the number of signals that would have to be transmitted to produce the Murray tape would be nearly double what it is now. It will be seen presently that at the receiving station there are instruments which exactly reverse this process. They differentiate or split up the wholesale signals into their retail units, thereby producing at the receiving station a replica of the transmitting tape.

As there is only one row of message-holes in the tape, the Murray transmitter, in its improved form, is a considerable departure from the Wheatstone model. In the Wheatstone the signals depend on the relative positions of message-holes arranged in two rows. In the new Murray transmitter the signals depend on the relative positions of perforated and non-perforated units of tape. The mechanism is shown in Fig. 20 (collector). The tape and the transmitter together form the collector. There is the usual Wheatstone star-wheel 15 to feed the tape forward by means of the central row of holes, rack and pinion fashion;

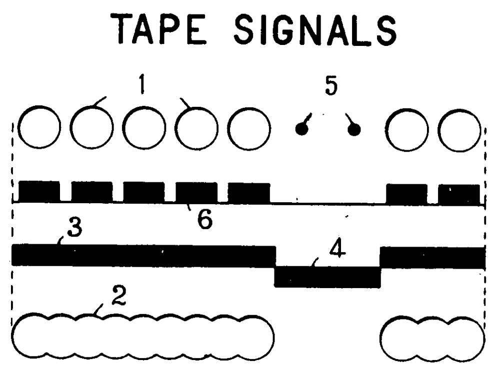

FIG. 19.

but in place of the two small upright rods used in the Wheatstone for entering the holes in the tape, there is a single rod 1. This rod is pivoted at one end of a horizontal thrust-lever 2. This thrust-lever is in its turn pivoted near its middle on a vertical lever 3, oscillating on the centre, 4. This vertical lever is kept oscillating steadily by a small eccentric wheel 5 and connecting rod 6, of the same kind as that employed in the Wheatstone transmitter. The thrust-lever 2 has a tooth 7 on its under side, which rests against a pin 8 in the vertical lever 3. The result of the oscillations of the vertical lever 3 is to cause the horizontal thrust-lever 2 to oscillate also. The free end 9 of this thrust-lever is placed close to the two free ends of two converging thrust-bars 10 and 11, which are pivoted one on each side of the pivot 12, of an ordinary Wheatstone contact lever 13. These converging thrust-bars are lightly pressed against a friction roller 14 by two small steel wire springs. The usual Wheatstone jockey roller 17 ensures the contact lever 13 making firm contact and remaining either on contact 18 or on contact 19.

When the machine is in operation, and tape perforated with a message is being fed through in the ordinary Wheatstone manner, the small steel rod 1 reciprocates regularly against the paper tape 20, as may be seen from the dotted arc 16 described from the centre 4. It makes one reciprocation for each unit of the tape, the eccentric wheel 5 making ten revolutions for one revolution of the star-wheel 15, the spindles of the two wheels being connected by ten to one gearing as shown by the large dotted circle. If there is a message hole in the tape, the tip of the rod enters the hole and the complete motion of the rod is unobstructed. This permits the thrust-lever 2 to move as if it were one piece with the vertical lever 3, and the oscillation causes its free end to strike the free end of the lower thrust-bar 11, connected with the contact lever below the pivot 12. This throws the contact lever over on to the marking contact 18. If at the next oscillation the small upright rod again enters a hole in the tape, the same action is repeated, but the contact lever being already against the marking contact, and held there by the jockey roller 17, no change is made in its position, and marking current continues to be sent out to line. No further repetition of message-holes in the paper tape makes any change in the position of the contact lever; but if a non-perforated unit of tape intervenes, then the small rod 1 is obstructed by the tape, and the oscillation of the vertical lever 3 causes the rod 1 to depress its end of the thrust-lever 2, thereby raising the other end 9 of the thrust-lever, which then, in the course of the oscillation, strikes the upper thrust-bar 10. This throws the contact lever over on to the spacing contact 19, thereby breaking the marking current and throwing spacing current into the line. If in the next oscillation another non-perforated unit of tape intervenes, the same action is repeated, but as the contact lever is already resting on the spacing contact, no change in its position takes place, and spacing current continues to be sent out until a perforation occurs in the tape. This, by the action already explained, throws the contact lever over again on to the marking contact. It is always the first of a series of perforated units or the first of a series of non-perforated units of tape that operates to throw the contact lever over from one contact to the other. By this means the space signals punched in the tape are converted into time signals of the real Baudot alphabet.

There are a number of details connected with the transmitter, but the only one worth mentioning is the method of getting rid of bias—that is to say, the method of ensuring that the positive and negative half-waves or units shall be both of the same length. In the Wheatstone transmitter, bias is shown by the galvanometer needle inclining to the right or left according as the positive or the negative half-waves are longer, when reversals are sent. The contacts are then adjusted till the bias ceases to show on the galvanometer. The best that can be said for this arrangement is that it is rough and ready. In the Murray transmitter a more precise and scientific method is used. The eccentric wheel 5, Fig. 20, makes one complete revolution for each half-wave, positive or negative. A small steel pointer 21 is inserted in the eccentric wheel, and on the frame of the machine there is a short scale 22. If the transmitter is driven very slowly by hand the galvanometer needle will be observed to come to zero at the moment when the

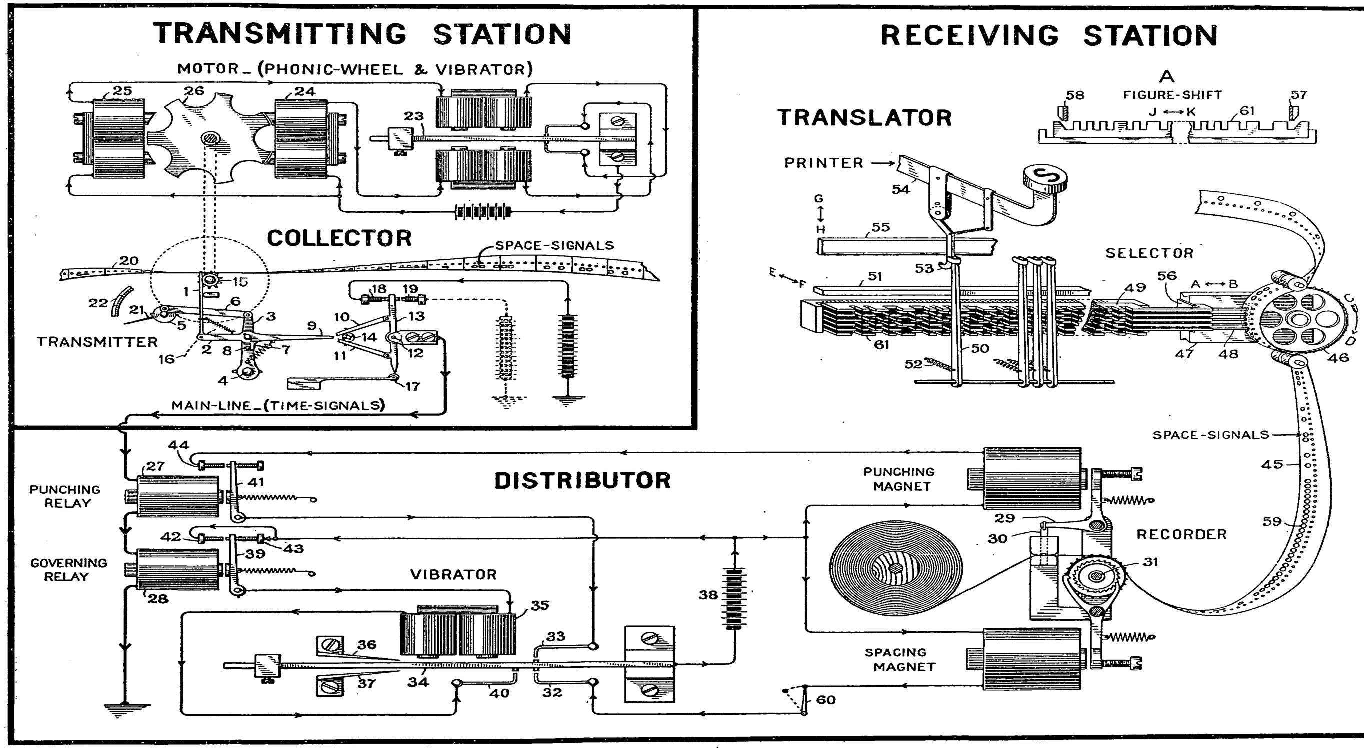

Fig. 20.—General Diagram of Murray Automatic Printing Telegraph System.

positive or the negative contact is broken. If the pointer points to the same division on the scale for a positive break as for a negative break, then there is no bias, and the positive half-wave is the same length as the negative half-wave. If, on the other hand, the pointer is alternately in advance and in retard for each half-wave or unit, then bias exists, and the contacts have to be adjusted till it disappears. As each half-wave or unit is equal in length to the circumference of the circle described by the tip of the pointer 21 it will be seen that bias is not only shown on a magnified scale, but is exactly measured. Absence of bias —that is to say, correct timing of the signals, is important in all systems of machine telegraphy, including even such simple apparatus as the Wheatstone automatic, and the indicator just described leaves nothing to be desired as far as the Murray system is concerned.

Fig. 21 is a general view of the transmitter. At the back may be seen the rectangular frame of a La Cour phonic wheel motor that drives the transmitter. This motor is more clearly shown in the general diagram of the system, Fig. 20. A vibrating reed 23 sends electrical impulses alternately to the two motor magnets 24 and 25, and these keep the notched armature 26 in steady rotation. This armature 26 drives the star-wheel 15 and eccentric wheel 5. The arrangement is in reality an electrical pendulum with the action reversed, the pendulum driving the escapement wheel, the two magnets being the two pallets of the escapement which pull the escapement wheel 26 round step by step, though the inertia of the wheel is sufficient to ensure uniform motion. The vibrating reed being isochronous in the acoustical sense, the speed of the motor is the same for all amplitudes of vibration. That is to say, variation of current strength has no effect on the speed of the motor. The speed is remarkably uniform, and the motor is ideal for the purpose and gives no trouble.

This single-line transmitter has several advantages over the Wheatstone instrument, the chief one being that there is a direct thrust against the contact lever from the driving mechanism, independent of the strength of the paper tape. Hence this thrust can be made strong in order to give very firm contacts.

THE DISTRIBUTING MECHANISM.

The distributor at the receiving station consists of two relays, a vibrating reed, and a recorder. In practice the main-line signals pass through an ordinary polarised relay to earth, this relay operating two local relays; but for the sake of clearness the main-line signals are shown passing direct through the two local relays 27 and 28, Fig. 20, to earth. It is by means of these two relays that the rest of the distributing mechanism is controlled. The recorder, which punches the message-holes in the receiving tape, is also shown in Fig. 20. This recorder consists of a punching magnet and a spacing magnet. The punching magnet operates a punching lever 29 and a punch 30. This punch corresponds with the small rod 1 in the transmitter. The punch reproduces the motions of the rod, and thereby reproduces the perforations in the tape. On short circuit the punch and the rod may be seen to be working precisely in step with each other. The spacing magnet feeds the tape forward unit by unit by means of the escapement and star-wheel on the motor-driven spindle 31. In order to secure the alternating action of these two magnets, the contacts which close their respective circuits are arranged one on each side, 32 and 33, of a vibrating reed 34, driven by a magnet 35. As the reed vibrates, short impulses are sent alternately to the punching and the spacing magnet. When there are no signals passing in the main line, a special device (not shown) cuts out the spacing magnet by opening the switch 60, and so stops the tape; but as long as a message is passing the vibratory action of the spacing magnet is continuous, and the tape is fed forward at a fixed speed. The punching magnet works alternately with the spacing magnet, but only when there is marking current in the main line, the punching relay 27 controlling the circuit of the punching magnet. The oscillations of the tongue of relay 27 and of the vibrating reed must therefore be not only isochronous, but also synchronous. Between sending station and receiving station isochronism only is needed, but between the receiving instruments on the same table synchronism is essential. This is the case not only with printing telegraphs, but with all machines. The parts must move synchronously or the machine will not work. Fortunately, practical synchronism, when it is a question of a few inches and not of miles, is very easy of attainment. In the Murray system it is achieved in the following manner, which also of course secures the needful isochronism between the two stations.

The Method of Securing Isochronism.

The reed 34, kept vibrating by the magnet 35, beats against buffer springs 36 and 37. These limit the amplitude of vibration, and, as the energy imparted to the reed must find some outlet, the frequency is increased. Without buffer springs the amplitude of vibration varies in proportion to the strength of the current through the reed magnet, but the frequency is wonderfully uniform. The reed is then isochronous in the acoustical sense. With a fixed amplitude determined by the buffer springs the frequency varies with the strength of the current. The reed is no longer isochronous. Its speed becomes very sensitive to variations of current, and can therefore be controlled by controlling the current to the reed magnet. If the circuit of the reed magnet 35 is traced from the battery 38, it will be found that it has two break-points—one at the contact of the tongue 39 of the governing relay 28, and the other at the reed contact 40. The punching and governing relays are identical in all respects, and they are driven by the same power, so that their synchronism is perfect. (They are driven wheels only a few inches apart.) The tongue 39, therefore, moves in exactly the same time as tongue 41. Hence as long as tongue 39 oscillates synchronously with the reed, tongue 41 will do the same. In fact, the two relays might be replaced by one relay with two tongues. The back and front stops, 42 and 43, of the governing relay are electrically united, so that at the beginning and end of a main-line signal when the tongue of the governing relay crosses from one contact to the other, there is a momentary break in the reed magnet circuit during the time of the transit of the tongue. This transit time can be varied to a considerable extent by adjusting the position of the contact stops. Opening the contacts increases the governing effect and closing them diminishes it. The reed magnet 35 breaks its own circuit at 40 in the usual vibratory way. If the reed 34 is oscillating in synchronism with the relay tongue 39, then full vibratory impulses will flow through magnet 35, as the two contacts at 39 and 40 will be opened and closed simultaneously. But if the reed tends to go faster than the arriving signals, then the two contacts 39 and 40 no longer open and close together, but more or less alternately, and the current impulses in the magnet 35 are more or less clipped. This reduction in the supply of energy to the reed at once reduces its speed till the contacts are again simultaneous. In practice the receiving vibrator is set to run about 2 or 3 per cent. faster than the arriving signals, and the governing action of the two interfering break-points in the same circuit results in the establishment of a steady dynamic balance between the accelerating tendency of the reed and the retarding tendency of the arriving signals. The effect is exactly the same as that produced by two taps in a water-pipe. If both are opened and closed together the water flows through in gushes; but if they are opened and closed alternately no water gets through, and more or less water gets through accordingly as the taps are opened and closed more or less alternately. By this means the relay tongue 41 not only vibrates at the same speed as the reed 34, but preserves the same phase. That is to say, tongue 41 touches contact 44 at the same time as the reed touches contact 33, even when the reed is making seventy-five vibrations per second (150 words per minute). But the tongue 41 does not move for every vibration of the reed. For instance, if there is a 4-unit marking signal coming over the main line, then the tongue 41 closes on its punching contact 44 for an interval of 4 units' duration, and the reed then makes four vibrations, touching the contact 33 four times, and in this way punching four successive holes in the tape by the alternate actions of the punching and spacing magnets. The transit intervals of the tongue of the governing relay 28 might be said to be like the teeth of an old saw. Some are there and some are not, but such as remain are all at unitary distances from one another (see line 4, Fig. 15). So also with the signals, and there are always enough signals to govern. Actually one correction per letter is sufficient, but on the average there are not less than two and a half, because each main-line signal gives two corrections, one at the beginning and the other at the end of the signal. As a matter of fact the governing action may be stopped during the arrival of as many as six or eight letters without upsetting the isochronism, and if a line disturbance or other cause throws the reed out of step it comes in again within five letter spaces—that is to say in half a second at a hundred words a minute. The reed is only in step as long as signals are coming over the line, and it goes out of step at the end of a batch of messages, but five space signals at the beginning of a new batch of messages bring it in again ready to record the messages. By this arrangement the necessity for sending correcting impulses over the main line to secure isochronism is avoided, the correcting impulses being generated locally from the arriving letter signals themselves. In this respect the Murray system has followed the excellent example set by the Hughes.

The isochronism diagram, Fig. 15, illustrates the co-operation of the current impulses. It shows a section of receiving tape punched with the word "PARIS." Beneath are the current impulses, indicated by black bars. Line 1 shows the impulses given to the punching magnet by the successive contacts of the reed 34 with the contact 33. Line 2 shows the uninterrupted succession of impulses to the spacing magnet from the reed contact 32. Line 3 shows the main-line signals. This illustrates the great saving of line signals effected by the special arrangements of the collecting and distributing mechanisms. Without these special arrangements it would be necessary to transmit over the main-line the signals shown in lines 1 and 2, that is to say, about five times as many signals as are now required. Line 4 shows the gaps in the circuit of the reed magnet 35 made by the crossing from contact to contact of the tongue 39 of the governing relay. Line 5 shows the impulses generated by the reed contact 40. As long as these impulses do not get into step with the gaps in line 4 they are not interfered with; but directly they do they get clipped, as shown for the sake of illustration in the second half of line 4. The speed at the two stations can, of course, be varied by altering the position and size of the weights on the vibrating reeds at the two stations.

A speed of no less than 900 letters (150 words) per minute in one direction has been reached with this recording mechanism, at which speed the punching magnet has to punch seventy-five holes per second, and the punching and spacing of the receiving tape have been perfectly performed at 960 letters (160 words) per minute, or eighty holes per second. Even this is not the limit, and it is possible that the speed might be forced up to even 1,200 letters (200 words) per minute. As half the time is required for spacing, the punching of eighty holes per second means that the punching magnet operates in $\frac{1}{160}$th of a second. As it takes a pressure of about 2 lbs. to force the punch through the paper, the punching magnet can not only operate with considerable speed, but also with considerable power. For ordinary commercial telegraphy there is no necessity for such high speed, and it is probable that, if the Murray system comes into general use in preference to other systems, the speeds required will be from about 240 letters (40 words) up to about 720 letters (120 words) per minute.

The transmitted signals having been correctly distributed along the receiving tape 45, Fig. 20, by the recording mechanism just described, the tape may then be used in its turn for again transmitting the signals over other circuits, or it may be run through the printer to translate the signals into printed letters. As the signals when retransmitted are sent on in as perfect shape as from the original transmitting station, it is possible to transmit messages in this way at a high speed to any distance overland—from London to Calcutta, if need be. Owing to the power to retransmit from the received tape, it is also possible to transmit messages from any number of stations A, B, C, to station D, and to sort out the messages there and retransmit automatically in accordance with the addresses to any stations E, F, G, any one or more of which may again retransmit messages requiring to be sent on still further.

The Second Translation and Printing.

If the tape is not required for retransmission, then the tape signals have to be translated into Roman letters and printed. The essential features of the Murray printer are shown in the general diagram, Fig. 20. The tape is fed along letter by letter (five units at a time) by a star-wheel 46, carried on a shuttle 47, which is kept reciprocating in the directions shown by the double arrow A–B, by means of a cam, each reciprocation rotating the star-wheel one letter space as shown by the arrow C–D. The shuttle carries a die-plate coinciding with the circumference of the star-wheel, and having five holes corresponding with the message-holes in the tape. Five rods 48, fixed in the ends of five slotted combs 49, are free to enter the five holes in the die-plate if they are not obstructed by the paper tape which passes between the rods and the die-plate. On its inward stroke the shuttle with its die-plate presses the tape, with a letter group of perforations, against the ends of the five rods 48. Rods that are opposite holes in the tape pass through into the die-plate, and the positions of the corresponding combs are not altered. But in the case of non-perforated units of tape the corresponding combs are thrust back about $\frac{1}{16}$th of an inch. By this means one particular group of slots in the combs, and only one out of fifty-six, is brought into alignment so that a latch or cross-bar 50 can drop into it. Although only four latches are shown, there are fifty-six of these small levers, one for each of the fifty-six permutations or groups of slots. The latches or cross-bars are supported by a universal bar 51 just clear of the teeth of the combs. At the right moment this bar drops in the direction of the double arrow F–E and leaves all the cross-bars resting on the combs; but only one out of the fifty-six is selected by the particular aligned group of slots corresponding to any particular group of holes in the tape.

From the point of view of the theory of machines, the combs form a complicated system of fifty-six inverse permutation locks. The fifty-six cross-bars are the bolts or latches, and the universal bar 51 is a universal key. The locks are continually being closed in different ways by the tape, and the universal key 51 is continually opening the locks. The tape, however, is only an intermediary. The locks are really closed selectively by the keys of the perforators at the transmitting station, the keys of the perforators being real keys in the ordinary sense of the word, and not nominal keys like those of a typewriter. The letter signals sent over the line are an exact copy of the wards of the keys of the keyboard perforators. This intricate system of keys and locks is inevitable in all cases where complex control is needed. Amongst other instances it is used in systems of railroad interlocking gear. In outward appearance there is no resemblance between the Baudot and the Murray telegraph systems, but the principle of the permutation locks is the same in both cases. Fig. 22 A shows the system of permutation locks in the case of the Baudot, and Fig. 22 B that employed in the Murray system. As the Baudot prints from a type-wheel, the locks are arranged round a wheel, and as the Murray prints by means of the straight row of keys of a typewriter, the locks are arranged as a rack. Fig. 23 shows an average permutation letter signal of the Baudot and Murray systems, the Morse, the Rowland, and the Hughes drawn on the same scale, and, for the sake of illustration, in the form of ordinary keys.

Let us assume that latch or cross-bar 50 in Fig. 20 has been selected. This cross-bar, under the action of its spring 52, throws a hook 53, attached to a typewriter key 54, under a striker-bar 55, which is continually oscillating in the directions shown by the double arrow G–H, and the typewriter key is in this way sharply depressed so as to print. The object of this arrangement is to secure speed and smoothness of

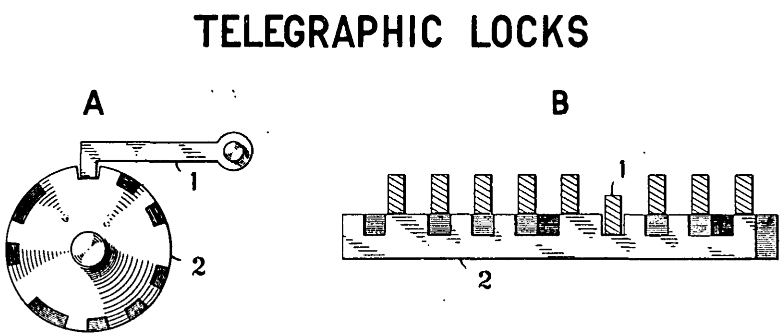

FIG. 22.

action. The moment the hook 53 is engaged by the striker-bar 55, the system of locks can be opened by the universal bar 51 and closed again with a fresh letter permutation simultaneously with the printing of the last letter. This arrangement practically doubles the speed of the printer. The shuttle on its outward stroke restores the combs to their original positions by means of the plate 56, which engages with inward projecting teeth on the overhanging ends of the combs. The cycle of operations, including the rotation at the right moment of the star-wheel 46 through one letter space, the reciprocation of the shuttle 47, the reciprocation of the universal key-bar 51, the oscillation of the striker-bar 55, and the return of the combs to zero position ready for the next letter, is performed by the usual battery of cams to be found in all automatic machines in which the cycle of motions is short and repeated millions of times. When the cycle of automatic motions includes hundreds of different successive motions and is only repeated thousands of times, we find, in place of cams, a chain of perforated cards, or similar devices, as in the Jacquard loom. When the cycle of motions to be performed is infinite and is performed only once, we get the perforated tape of the automatic telegraph. In this case the tape only repeats when it has to influence the motions of a large number of individuals, that is to say, in the case of press dispatches. In the case of a telegram to a private individual the tape is used once only. In other words, the motions with which telegraphy has to deal are enormously more complicated than those in the most complicated known system of weaving. That is probably one explanation of the slow progress that has hitherto been made by machine telegraphy.

Although in the Murray printer there are only five combs with rods 48, there is a sixth comb 61, which in one position causes figures to

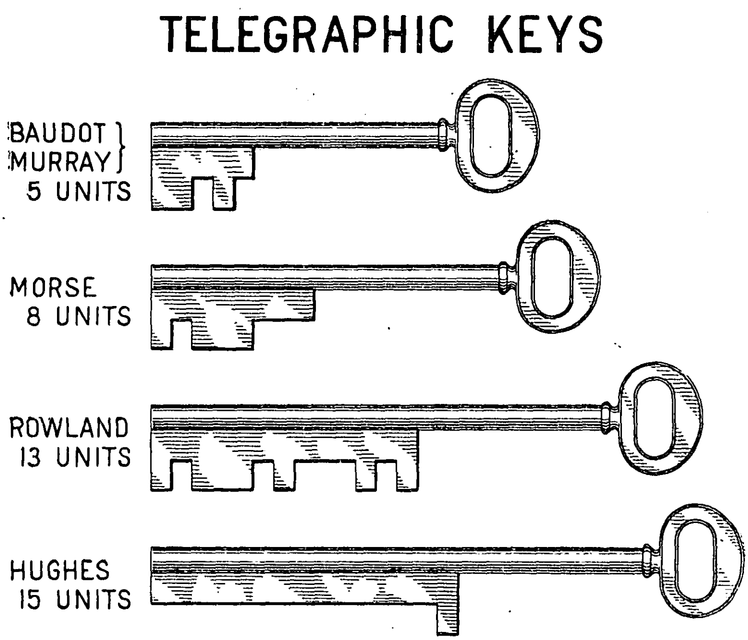

FIG. 23.

be selected and in the other position letters. It is operated by two special cross-bars, one at each end. This arrangement is shown more clearly at A, Fig. 20. At each end of this comb will be noticed a V-shaped slot, and the two cross-bars shown in section at 57 and 58 carry wedge-shaped pieces for striking the edge of these V-shaped slots. When a figure-shift signal is transmitted, it selects the figure cross-bar 58. This drops into its group of slots, strikes against the sloping edge of the figure-comb slot, and moves the comb $\frac{1}{16}$th of an inch to the left in the direction J, thereby opening the figure-locks and closing the letter-locks. A letter-shift signal succeeding a group of figures operates 57, which restores the figure-comb to its original position, in which the machine prints letters. If the letter-shift signal, ooooo (Caps), is repeated, no further action takes place, and the printer remains idle till a letter signal comes along. Thus, in the tape at 59, Fig. 20, there is a correction consisting of five letter-shift signals, which have been used to "rub out" a wrong word of five letters. For the reason just given the printer remains idle during these five letter spaces, and there is no trace of the error in the printed message.

An interesting point is the method of securing unison. In the Murray system the question of unison is removed from the line to the tape. As with the Wheatstone recorder tape, it is a question of correctly dividing up the signals on the tape. With the five-unit alphabet each letter occupies five units, or half an inch on the tape. Hence to divide up the signals properly we have to start at the right unit and then measure 5 units at a time. The star-wheel 46,

METHOD OF SECURING UNISON

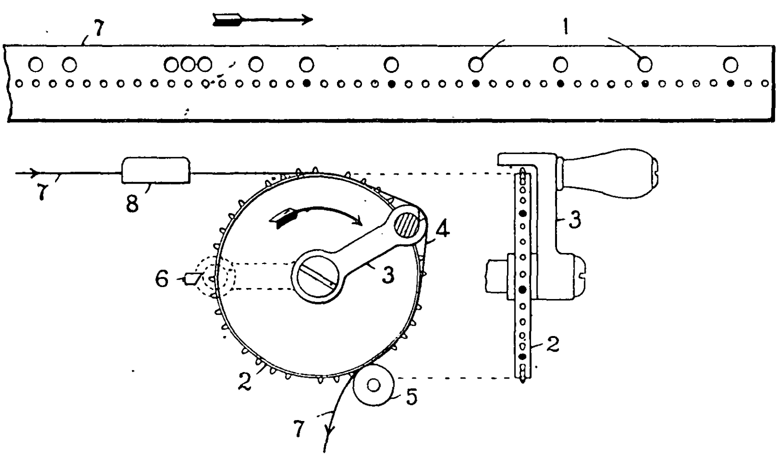

FIG. 24

Fig. 20, does the measuring, and all that is necessary is to place the tape properly on the star-wheel. To enable this to be done with facility, each batch of messages begins with four or five space signals, as shown in Fig. 24 at 1. The space signal is a perforation in the third-unit position. In the star-wheel 2 it will be noticed that every fifth tooth is omitted and the vacant tooth positions blackened. The tape 7 is inserted in the machine so that the space holes 1 come opposite the missing teeth of the star-wheel which show up black through every fifth central hole in the tape, as shown for the sake of illustration by the blackened centre holes in the tape opposite the space signals 1. The tape is then in unison. In the event of it not being in unison, it can be put in step by rotating the small unison arm 3. This bags up the tape as shown at 4, and advances the tape on the star-wheel to the extent of one unit. A maximum of four and an average of two revolutions of the unison arm 3 brings the tape into step. The roller 5 is spring-pressed, so that it gives way and permits arm 3 to pass. The unison arm when not in use is held locked in the dotted position by the spring-tooth 6. 8 is a guide for the tape. The missing teeth in the star-wheel and the space signals show at a glance at the beginning of a message whether the tape is in step. If a line interruption causes the unison to fail in the middle of a message, two or three revolutions of the unison arm by the attendant set all right again. This does not often happen, however, as a line interruption must be complete for at least seven letters before the unison can be affected. Momentary interruptions do not disturb it. Apart from occasional line interruptions the receiving mechanism perforates the tape with surprising accuracy. On short circuit it will run for hours without making a single false perforation.

In regard to the printing of the messages on telegraph forms, there are four motions of the sheets of paper to be provided for, two horizontal and two vertical, as follows :—

Horizontal	... ...	{ Letter feed. Line feed.
Vertical ...	... ...	{ Column feed. Page feed.

The letter feed is already performed automatically by the typewriter. To provide for an automatic line feed, there is a small letter-counting device on the keyboard perforators. This indicates the end of a typewriter line of about seventy letters. A key is then depressed which punches a line signal in the tape. This is transmitted to the receiving station, where it operates a special key of the typewriter, which throws in a clutch, causing automatic mechanism to pull the typewriter carriage back to the beginning of the line. The same action provides the column feed up to a new line by a simple arrangement used in most modern typewriters. The page feed is more complicated and has not yet been made completely automatic in any printing telegraph, although there are several automatic page feeders giving good service with printing presses. In fact, many of the modern illustrated magazines are printed automatically from a pile of cut sheets by this means. At present, in the Murray system, the page feed is managed as follows : A stop signal is transmitted on the tape at the end of each message, and this not only runs the typewriter carriage back to the beginning of a new line, but also stops the printer. The attendant then pulls out the finished message by hand, and by a simple device it automatically tears off at the right point, leaving the next telegraph blank pulled in to the right starting point. The attendant then presses a button, which starts the printer on the next message. The process is quite rapid. Later on it may prove worth while to make the page feed completely automatic. The printer will then feed itself from a pile of cut telegraph blanks, and toss out the finished messages like tickets from a cash register. The chain of mechanisms will be completed by an automatic folding and enveloping machine, which will fold the telegrams and thrust them into transparent envelopes and seal them so that only the addresses will show through.

The printer, two views of which are shown in Figs. 25 and 26, is now driven by a small motor consuming about 40 watts for a speed of 140 words per minute. This motor also supplies the power for automatically returning the typewriter carriage to the beginning of a new line. Fig. 27 is a general view of a set or "station" of the apparatus. Only one keyboard perforator is shown; but in practice three or four are needed.

CAPACITY OF THE MURRAY SYSTEM.

The speed of the printer is now not less than 900 letters (150 words) per minute, and the automatic portion of the mechanism runs perfectly up to about 200 words a minute. Unfortunately, however, no typewriter yet constructed will stand the strain of more than about 720 letters (120 words) a minute in continuous service. The received tape may be divided into sections and run through two printers when the apparatus has to be worked at top speed. Under existing conditions, however, high speeds for handling commercial messages are for many reasons undesirable, and a maximum of 120 words a minute in each direction seems to meet all requirements.

In practice with the Murray system—as with all other telegraph systems from the Morse key upwards—the average output is not more than about 50 per cent. of the maximum. Time and patience will no doubt stop some of the leaks; but others, such as errors caused by line interruptions, seem to be incurable. The British Post Office has now had the Murray apparatus in use for seven hours a day for about eighteen months between London and Edinburgh, handling ordinary commercial telegrams, and the German Post Office has been giving it a prolonged trial between Berlin and Emden, and is now equipping two circuits with the improved apparatus. The Russian Post Office has also decided to give it a trial, and has ordered Murray apparatus to equip two circuits. In this case one of the conditions is that the system must transmit Latin or Russian characters at will. I understand that the experience of the British Post Office is that five operators at each end of a Murray circuit, equipped with the apparatus in its original form, can exchange about 200 telegrams an hour, and under favourable circumstances occasionally as many as 240 per hour. With the new motor-driven printer, with automatic line feed, invisible correction of errors, and other improvements, it is estimated that it will be possible for six operators at each end of a Murray circuit to exchange about 300 messages an hour. That is to say, twelve operators on one Murray circuit will be able to do the work of sixteen men on two Morse quadruplex circuits, or at lower speeds eight operators will be able to do the work of twelve. Actual tests show that the improved printer has a maximum speed of five messages a minute, so that the working

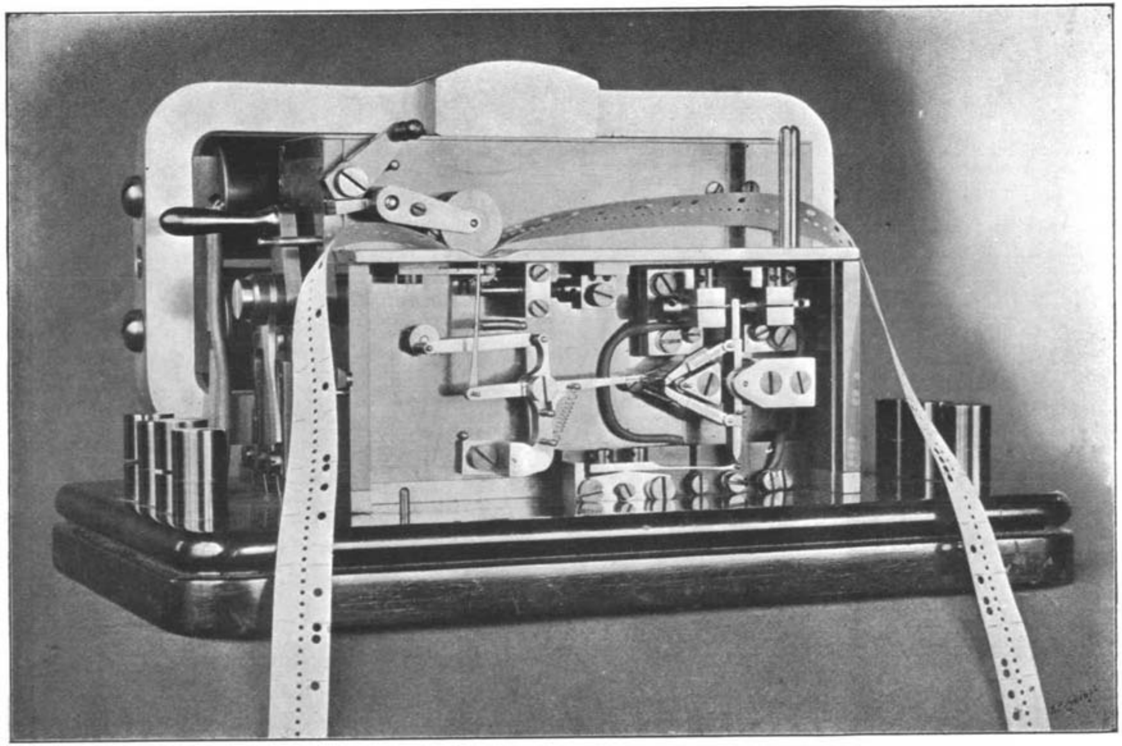

FIG. 21.—Single-line Transmitter.

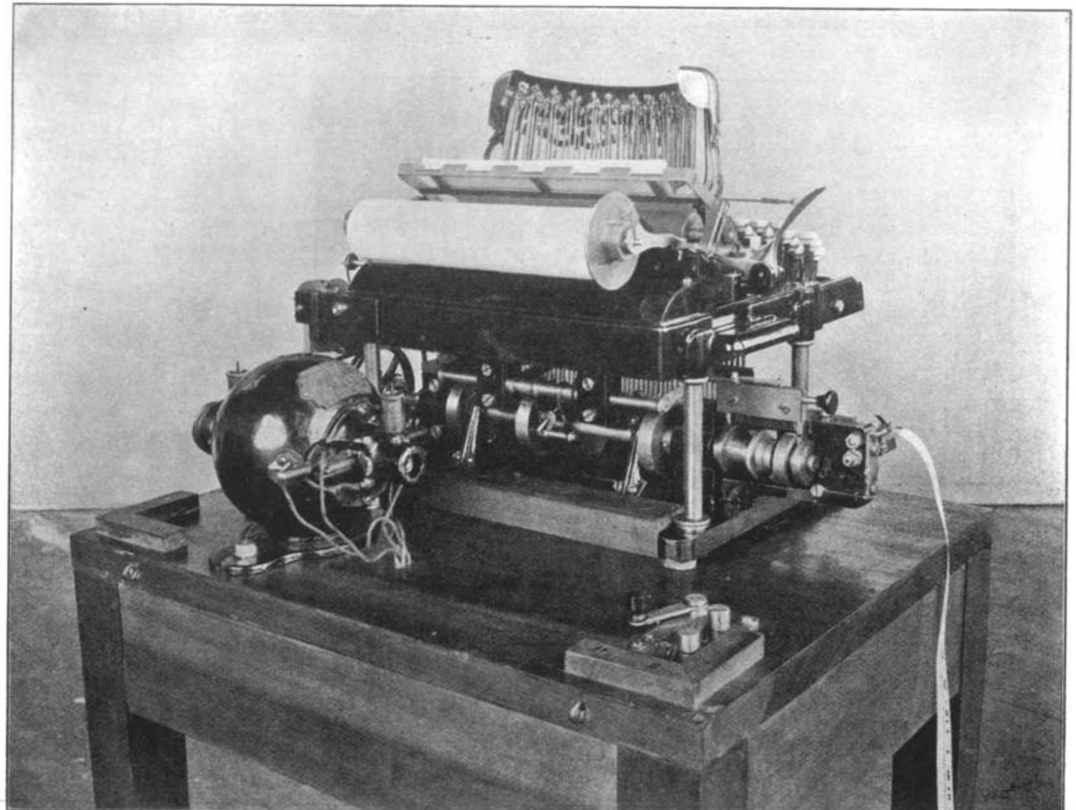

FIG. 25.—Murray Printer complete with Typewriter.

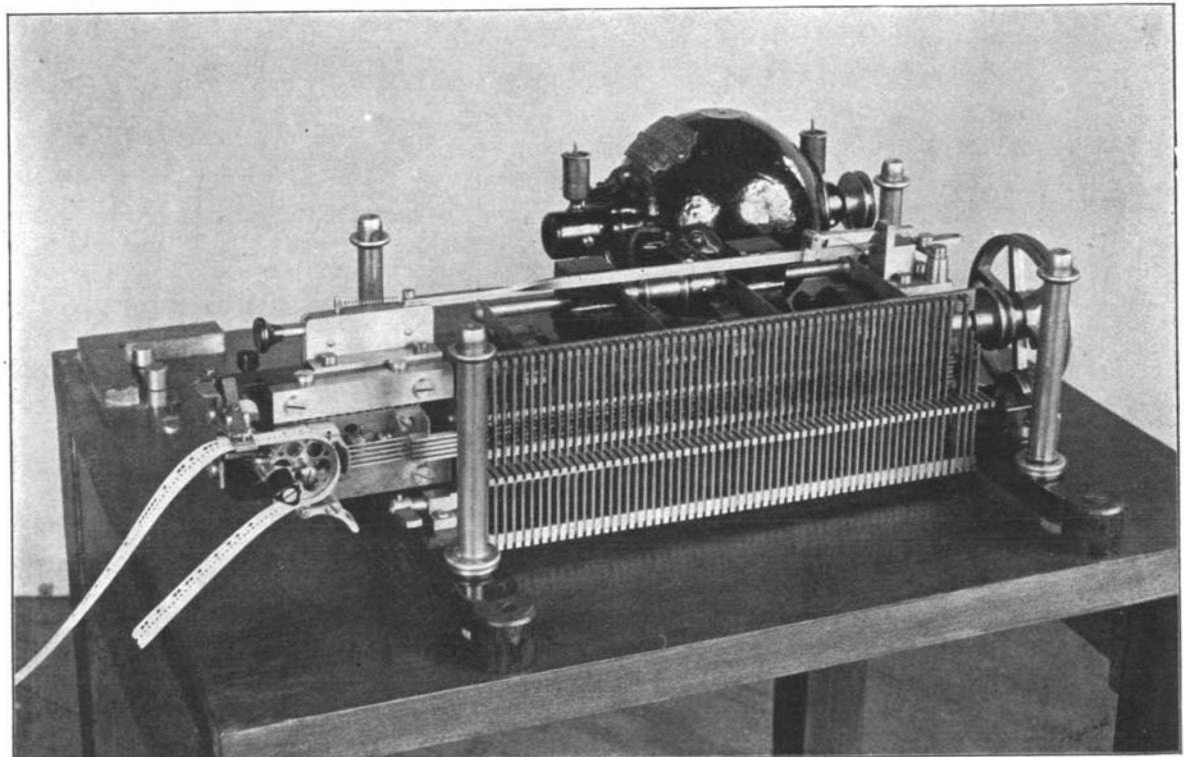

FIG. 26.—Murray Printer with Typewriter removed.

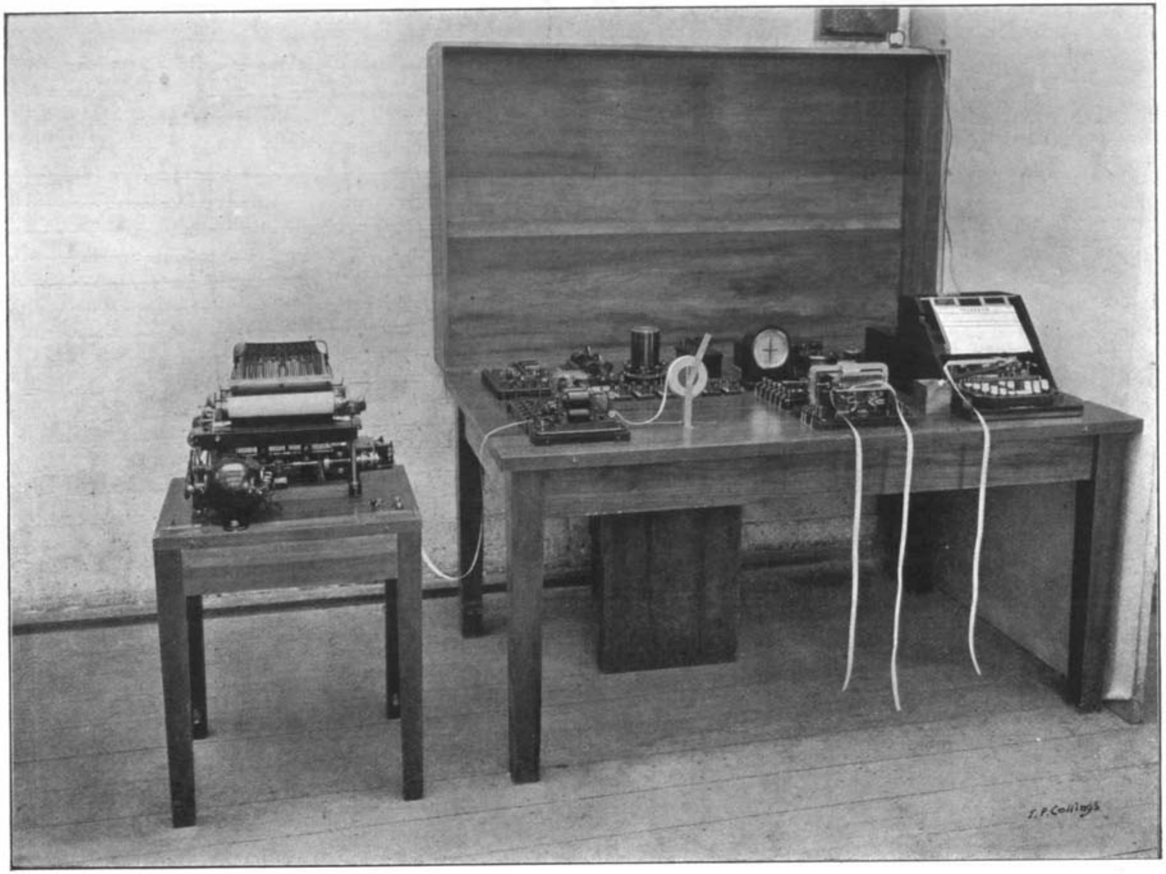

FIG. 2.—General View of a Set of Murray Apparatus.

average may be safely put at 150 messages an hour. A weak point with many printing telegraph systems is durability. I understand that in this respect the Murray apparatus has proved satisfactory.

Automatic Typesetting by Telegraph.

Mention has already been made of the fact that the Murray printer was originally designed, not for telegraphy, but for automatic typesetting in the ordinary sense of the word, the idea, inspired by newspaper experience, having been to operate a linotype automatically by means of a perforated tape produced by a typewriter keyboard. Several machines of this kind are in successful operation, notably the Lanston Monotype. But of these inventions the Murray is the only one that has been designed on lines permitting of successful telegraphic development. In fact, in the case of the Murray apparatus the telegraphic development has been so successful that it has quite overshadowed the original typesetting idea. Three years ago the Linotype Company in New York offered to carry out the experimental work involved in applying the Murray key-selecting mechanism to the linotype, and want of time alone, owing to telegraphic developments, prevented me accepting that offer. It is obvious that it is just as easy to operate a linotype keyboard automatically by telegraph as to operate the keys of the typewriter used in the Murray printing telegraph system. No doubt this will be done in time, but the labour saving will not be very great. The cost of setting a column of news matter by the linotype is roughly about 3s. 6d. The automatic mechanism would double the speed, but, as an attendant would still be needed, there would only be a saving of labour of about 1s. 9d. per column, or a saving of only 15s. or 20s. per night even for large newspapers. This would hardly be sufficient to induce newspapers to start automatic typesetting by telegraph, but the possible saving of time is a more important feature. The saving of a few minutes is vital to newspapers at certain hours, and this may ultimately lead to automatic typesetting by telegraph; but there are many obstacles in the way. One is the necessity for press messages being revised, punctuated, corrected, and often cut down before being set up in type. The Murray is the only automatic apparatus making provision for this difficulty by allowing the editorial corrections to be carried out by the compositor while the type is being automatically set. All that can be said about automatic typesetting by telegraph is that it is a possibility of the future, and that if it is done at all it will have to be done on the lines of the Murray apparatus, because the Murray system alone is practical both from the newspaper and from the telegraphic point of view.

Typewriting Across the Atlantic.

Another interesting possibility, with better prospects of early achievement, is printing telegraphy in connection with ocean cables. This has been rendered possible by the Murray apparatus in conjunction with Mr. S. G. Brown's beautiful cable relay and perforator, and the Cooke alphabet shown in Fig. 8. A sample of this alphabet, perforated in a piece of automatic cable tape, is shown in Fig. 28. As this is an equal-letter alphabet it can be perforated in cable tape by a slightly modified form of the Murray keyboard perforator already described, and this tape can be transmitted in the usual way through an automatic cable transmitter. About two years ago the Eastern Telegraph Company used some tape that I had prepared with this alphabet to transmit from Porthcurnow, and no difficulty was found in reproducing the tape at Gibraltar by means of the Brown relay and perforator. The length of the cables from Porthcurnow to Gibraltar is 1,190 nautical miles (about 2,160 kilometres), and the KR of the cable used is 2·8 millions. A slightly modified form of the Murray printer has been designed to print from this tape. Six combs are provided with rods projecting alternately above and below to engage with the message holes on both sides of the tape, and there is a seventh figure-shift comb. Not only is this arrangement perfectly practicable, and the instruments all known to work well, but it has the advantage that, as the alphabet is about 10 per cent. shorter than

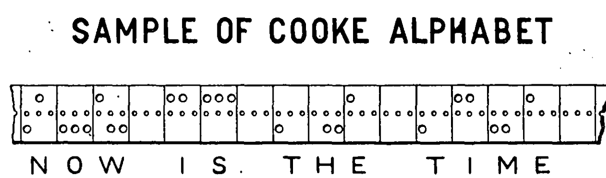

FIG. 28.

the cable Morse alphabet at present used, the carrying capacity of the cable is increased, roughly, about 10 per cent., a considerable gain when dealing with such an expensive investment as an ocean cable. It will also be noticed that fourteen of the most frequently used letters in this equal-letter alphabet are the same as Morse. Those accustomed to Morse cable tape will notice that the sample of tape in Fig. 28 can be read without serious difficulty, only one letter, H, being different from the Morse. With such a world-wide business as that of the Eastern Telegraph Company there are difficulties in the way of introducing the Cooke alphabet, but in the case of the Atlantic cables these difficulties do not exist. There is no technical obstacle in the way, and it is undoubtedly practicable with the aid of the Murray keyboard perforator, the Brown cable relay and perforator, and the Murray printer to work a typewriter in New York by playing on a keyboard in London. It is also possible by the same means to operate a linotype in a New York newspaper office by playing on a keyboard in London. For commercial reasons the possibility of automatically setting type across the Atlantic can never be of practical importance, but typewriting across the Atlantic is well within the bounds of utility, and want of time is the only reason why it has not been attempted. In fact, there are so many possible developments of the Murray apparatus that it has been impossible for one man unassisted to attend to them all.

A Brief Comparison and a Few Words About the Cost.

Putting aside these possibilities and returning to the subject of telegraphy on land, it seems to me that the Murray automatic system is pre-eminently adapted for long-distance work, iron wires, underground cables, and press dispatches. Its power of retransmission from the received tape, its high speed, its simplicity, and its provision for instant and invisible correction of errors, appear to make its position fairly secure for the classes of work just mentioned. But for short-distance traffic the multiple principle certainly will have a number of advantages when developed so as to save labour. This is the weak point with the multiple systems at present. They do not save labour. Of these systems the Baudot is, to my mind, undoubtedly the best. Like the Murray system, it is constructed on true scientific lines that permit of further development and adaptation to the needs of various countries. It works well through cables and over considerable distances (thanks to the Baudot alphabet), but its chief limitation, in addition to printing its messages on tape, is the use of synchronism, and for isochronous working over long distances it uses two wires, while the Murray uses only one. For short distances the theoretical capacity of the Baudot is enormous, probably not less than 5,400 letters (900 words) per minute—direct type-printed messages—but in practice not more than six transmissions at 30 words a minute each are attempted, giving a maximum of 1,080 letters (180 words) per minute. It is used on all the busy circuits in France, and Paris is connected with London, Hamburg, Berlin, Vienna, Rome, Milan, and Algiers by means of Baudot apparatus. Several sets are also in use in Brazil and in French Indo-China.

A large amount of inventive talent has been devoted to the Rowland multiple system, and I have no doubt that the clever engineers connected with this interesting apparatus will continue their improvements. Being a direct-transmitting page-printer, errors cannot be corrected without showing on the printed message, and the Rowland alphabet bars it from use on underground cables and for long-distance traffic. Its potentialities, however, for handling short-distance traffic are considerable. Its maximum speed is about 1,800 letters (300 words) per minute, duplex, over moderate distances; but so far, with the Rowland, as, indeed, with all other telegraph systems, including even the Morse key, there is a large gap between promise and performance. The Rowland system was tried and rejected by the British Post Office about three years ago. Since then several sets have been on trial on the Continent.

The Buckingham automatic system cannot retransmit like the Murray, so that it cannot cover such great distances nor retransmit news so conveniently to a number of centres. It does not correct errors so efficiently, it is not so rapid, and it is much more complicated; but it works very well over long distances of 1,000 miles (1,700 kilometres) duplex, giving a maximum speed of about 100 words a minute in each direction, and the mechanism employed is remarkably ingenious. It has been in commercial use by the Western Union Company in America for several years past, and it was tried and rejected by the British Post Office during the winter of 1903.

A very attractive scheme for high-speed printing telegraphy is the use of light and photographic paper for the printing process; but the systems employing this method have not yet got beyond the interesting stage. The Siemens & Halske photo-printing telegraph is the best up to the present, and it reaches a speed of 2,000 letters a minute in one direction, but the messages come out recorded on a damp photographic tape, an arrangement that does not seem very promising from a practical point of view.

The cost of the multiple and automatic high-speed systems of printing telegraphy may appear at first sight to be very high if we compare it with the cost of the Morse key and sounder, or with a Morse quadruplex set, and it is this comparison that telegraph administrations in English-speaking countries have habitually made, wrongly, as I believe. A Baudot sextuple outfit to equip both ends of one circuit costs, it is stated, about 20,000 francs, or, in round numbers, about £800. A complete outfit of the Murray system costs about the same at present, though it is expected that the cost of manufacture will be reduced when sets are made in numbers. In regard to the prices of the Rowland and Buckingham systems I have no information, but they can hardly be less costly than the Murray and Baudot. In any case, taking £800 as the cost of an automatic or multiple system, this is less than the cost of two linotypes, of which at least a score are to be found in most large newspaper offices. I understand that the French Post Office does not possess more than about 250 sets of the Baudot system. Many of these are only for double and triple transmission, so that even if we take the cost at as much as £300 per set (that is to say, equipment for one end of a circuit only) the total cost, apart from the cost of development, has only been somewhere about £70,000, a very small sum for such a large business as a telegraph administration to spend on special machinery that, at a cost of from £600 to £800 per circuit, will save a capital expenditure on wire, at £12 per mile, of from £2,000 to £12,000, compared with the Morse quadruplex; and that will, in the case of the Murray system, at any rate, save about 25 per cent. in labour compared with the Morse key and sounder.

CONCLUSION.

It has not been possible in this paper to do more than refer briefly to the special conditions to be fulfilled by successful printing telegraphs, to the relative advantages of the multiple and the automatic systems, the advantages and disadvantages of direct keyboard transmission and of indirect automatic transmission, the relative merits of the typewriter and other keyboards and keys, speeds of keys and keyboards, and the advantages of machine compared with hand telegraphy ; but there will no doubt be opportunities of dealing with these points in the technical journals at some future time. Nor has it been possible to touch upon the practical difficulties which have been encountered, chiefly in connection with page-printing. To enumerate only a few, there are special page-printing telegraph difficulties in handling short commercial telegrams, practical working difficulties arising out of line disturbances, checking, and corrections, difficulties based on the necessity for following the ordinary telegraph routine, which varies in each country, and difficulties connected with the use of suitable telegraph forms and preserving records of messages. Many of these difficulties are so small and impalpable that even men who have grown up in the telegraph profession have failed to recognise their existence until actually confronted with them. Their invisibility, however, has not made them any the less formidable, and the fact that they have been overcome is due to the cordial co-operation, advice, and assistance freely given by the telegraph officials in America, Great Britain, and Germany. The Postal Telegraph Company in New York and the Telegraph Administrations in London and Berlin have devoted to the Murray system not only time and money, but the best technical skill of their engineering staffs. And the results, I hope and believe, will prove satisfactory to all concerned.

Discussion at Meeting of March 2nd.

Mr. J. Gavey : I think we have all read Mr. Murray's paper and listened to his explanation of the working of his apparatus with a great deal of pleasure. His paper is very valuable, not merely from what it tells us, but from what it suggests. In view of the statement that he makes of the plethora of printing and writing telegraphs that have been invented and described, it will no doubt occur to members present to ask how it is that after so many years of telegraphic work the principal telegraphic administrations still use the old-fashioned Morse for the greater portion of the telegraphic business of the world. There are various reasons for that. Mr. Murray has given us some ; amongst others he states that the Morse alphabet is *per se* the ideal alphabet for manual transmission. But there are other reasons which have prevented so far the general use of machine telegraphy. The telegraphic public have been educated to a high degree of speed, and they demand the same rapid rate of delivery whether a message has to be transmitted over two or three miles or over hundreds and thousands of miles. Not only does a man in Glasgow expect his message to be delivered in London as quickly as a man in Westminster expects his to be transmitted to the City, but a New York man expects the same speed to London. The result is that there is a tendency to discourage any operation that intervenes between the receipt of a message at the counter and its passage over the wire, and again at the far end between its reception and its being handed over to a delivery messenger. The effect is that most telegraphic administrations have considered the ideal system to be a manual system, involving the use of the simple Morse key, in which the messages are brought up to the instrument at the forwarding station and despatched over the wires, while at the