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Teleprinters and Their Operation*

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IT is interesting to recall that telegraphy has the honor of being the first practical application of electricity in the service of mankind. The developments from the earliest experiments by Samuel Morse to the present day telegraph machine practice represent many years of effort by physicists and enthusiasts of many nationalities. This paper briefly mentions some aspects which have been fundamental in the development of start-stop printing telegraphs.

In the telegraph business, as in any other enterprise, it is good economics to provide over a route a system of telegraphy which has a carrying capacity generally equal to the traffic to be passed. In our own offices to-day the apparent anomaly is seen of Morse circuits differing very little from the early kind of equipment, surviving alongside modern high speed printing systems.

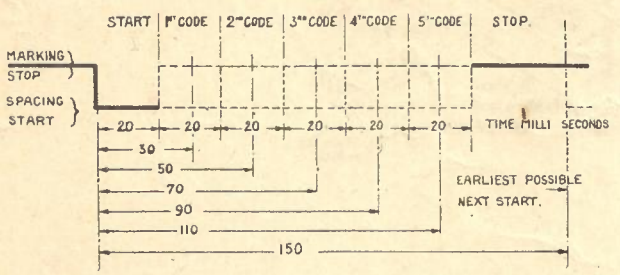

Fig. 1. Diagram showing Five-unit Code for Start-Stop Working.

There will always be an economic field of use for hand Morse working of low traffic capacity, for start-stop printing systems of medium traffic capacity, and for high capacity printing systems working at fast speed, over telegraph lines or channels, depending upon the community of interest obtaining between the centres connected.

Codes

Any telegraph system must be based upon the use of a code. Current impulses of stipulated duration followed by periods of "no current," convey intelligence in accordance with a pre-arranged plan. An early form of code was the Morse, and a further advance in transmission from the point of view of speed of working was to replace the period of "no current" by current of opposite direction, hence "double current" working. The Wheatstone system is, of course, a high speed telegraph system based upon double current Morse code working.

The Morse code does not readily lend itself to machine printing because of the variation in the number and length of the impulse elements, although a notable machine, the Creed Morse printer has given excellent service. The printed product from this somewhat complicated machine, which is fed with reperforated received tape, is in the form of a tape, and direct page printing as on an ordinary typewriter is not obtainable.

The Five-Unit Code.—This code, originally developed by Gauss and Weber, was improved by Baudot for multiplex working. The code, which is ideal for machine working, is the foundation upon which has been built the great success achieved in the development of machine printing telegraphs. In order to transmit the letters of the alphabet, figures and special characters, approximately 62 character combinations are necessary. The total number (x) of combinations of (n) things, all or some at a time, is given by the expression $x = 2^n - 1$, and the five-unit code gives 31 primary positions or combinations. By means of a figure shift device, such as functions on a typewriter, the requirements of 62 character positions are obtainable. The Baudot code was slightly altered for the Murray Multiplex system by Murray, and to-day the five-unit code is often referred to as the Murray code. The elements of the Baudot code are uniform in length, each character and each spacing signal comprising a combination of five negative and positive currents. The average word is taken as five letters and a space signal, or a total of six letters, and with the five-unit code, where each letter equals five units, this equals a total of 30 units per word. With the Morse code 48 units would be necessary and the ratio Baudot to Morse code is 5 : 8. The unit duration of the five-unit code being less than Morse provides a greater traffic capacity for the maximum frequency of transmission that is permissible over the channel.

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Machine Telegraphs

The signalling of approximately 62 (with figure shift) or 31 primary character combinations by means of a five-unit code through the medium of code bars needs a keyboard or composing machine. Conversely, the reception of five-unit signals needs a printer or translator to convert to printed characters. The composing machine may punch holes in a transmitting tape as with a Murray perforator, or may consist of a keyboard and transmitter combined as obtains in a Teletpye, Teleprinter or other directly transmitting start-stop machine.

system. The multiplex distributor brush arms are revolving continuously, whilst the teletype or teleprinter collecting and distributing device starts operating, completes one cycle, and then stops ready for the next train of five signal impulses. The continuously revolving system needs exact synchronism to collect and distribute the five-unit signals correctly. The so-called start-stop system need not have such exact synchronism, as any slight difference of speed is not cumulative. The difference in speeds relates only to one revolution as the devices are timed at each "start" and "stop" impulse.

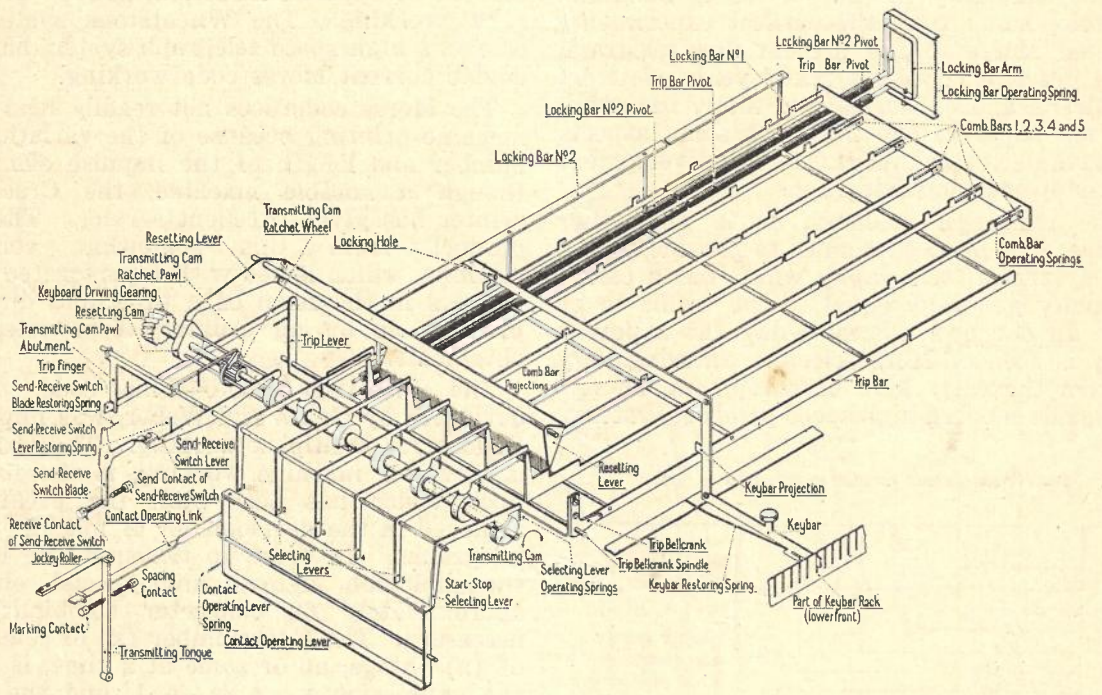


Fig. 2. Diagram of Transmitting Mechanism

A telegraph printing system based on the five-unit code needs, as well as the composing unit, a collector which passes the signal elements to the line, and a distributor which receives the signals and passes them on to the translating device or printer. The familiar Murray plateau and distributor functions as the collector on the transmitting segments and the distributor on the receiving segments. Without attempting a description of the Murray Multiplex system, it is desirable to refer to certain functions which are akin to, or contrasting with principles of the start-stop machine, whether teletype or teleprinter. The multiplex quadruple distributor collects and distributes four sets of five-unit signals per revolution, whilst the teletype or teleprinter deals with one set of five-unit signals per cam revolution. The latter is roughly equal, therefore, to one arm of the quadruple Murray

Murray likened his distributors to two clocks; not only must they keep exact time, but they must read the same time always. Similarly the start-stop machines may be likened to two stop watches, one of which may gain slightly on the other, but both are started and stopped after a given interval of time.

Morkrum Teletype, Model 12

The first type of modern start-stop machine was the Teletype, the distributor principle of which is perhaps more simple to grasp than in the teleprinter. It must be mentioned that the five-unit code necessary for signalling becomes virtually a seven-unit code in a start-stop machine. Fig. 1 shows the adaption of the five-unit code for start-stop working. A positive starting impulse precedes the five positive or negative combinations, and finally a negative stop

signal restores the device to the normal or passive condition ready for the next letter and start signal.

Briefly the teletype transmitting principle consists of key levers at right angles to five permutation bars which when shifted to the right by a key lever singly or in combination, act on five setting stops pivoted to the frame. Pivoted also to the frame are five bell cranks which control five sets of contact springs. On each bell crank there is a cam piece designed to enter a depression in five setting cams which are angularly displaced so that the bell cranks come into action successively. When one or more permutation bars are shifted, the setting stops engage the corresponding bell cranks and prevent them rising when the cam depression arrives. Those bell cranks not held by the setting stops rise into the cam depression and close their contacts. The contacts, on closing, energise a coil of a sending relay which is controlled by a bias winding when the other coil is non-energised. The set of closed and unclosed contacts energise or de-energise the coil of the relay, the tongue of which repeats positive or negative five-unit code signals preceded by the positive start impulse. In reality, six sets of bell cranks and contacts with cam positions are provided. The sixth set of contacts are normally closed in the position of rest and marking or negative battery is sent to line by the relay. The pressing of a key starts the machine and causes the cam to revolve, and the first impulse is sent by opening the sixth set of contacts which allows the bias winding of the relay to take control, and a spacing or positive start impulse is sent. On completion of the cam revolution the contacts of the sixth set are again closed and negative or marking is sent to line in the position of rest until the next letter is sent.

It will be seen that the teletype collecting or distributor function is similar in effect to the functioning of one arm or quadrant of the Murray multiplex sending ring in so far as the five impulses are concerned, although both systems are so mechanically and electrically different.

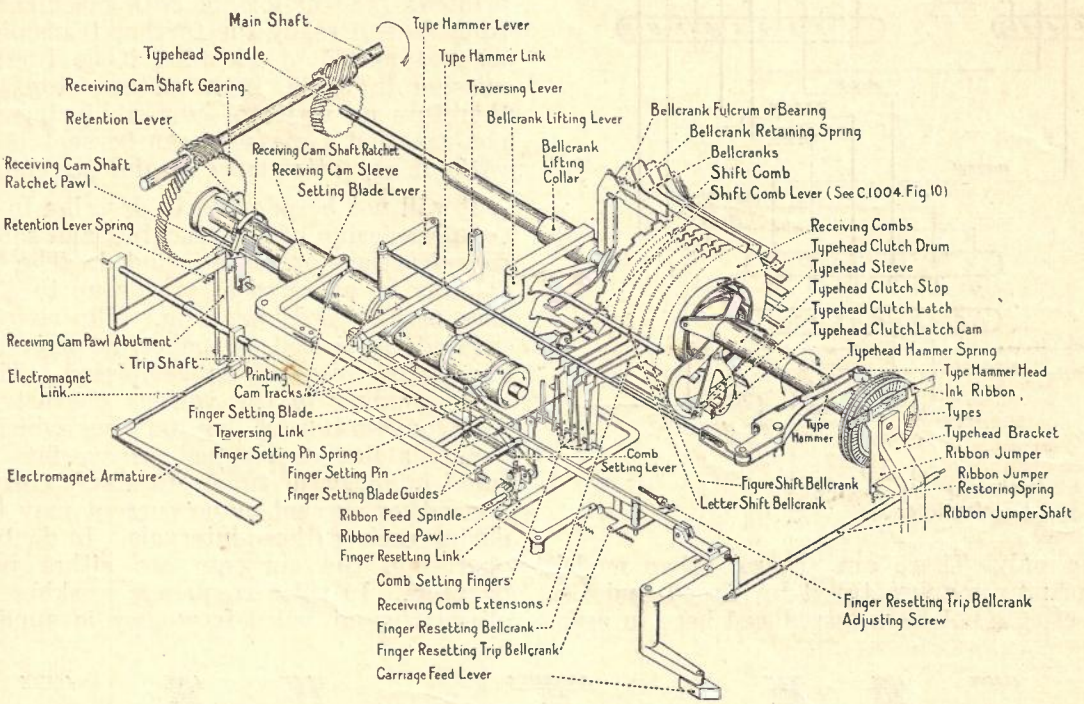


Fig. 3. Receiving and Selecting Mechanism

Keyboard Mechanisms

The composing machine or keyboard for converting the large number of typewritten characters into different combinations of the five code or permutation bars is worked upon a generally similar arrangement for the different systems, whether Murray perforator, teletype keyboard or teleprinter keyboard. The typewriter key levers each when pressed makes an engagement with notches or teeth on certain code bars at right angles to the key levers, with the result that a given number of the five code bars are moved to one side, the balance of the five remaining as before. The code bar combinations selected this way decide the setting in which positive or negative unit impulse trains are to be swept into the line.

Creed Teleprinter

The types of Creed Teleprinter in service in Australia are the model 7C transmitting and page receiving machine, and model 8C page

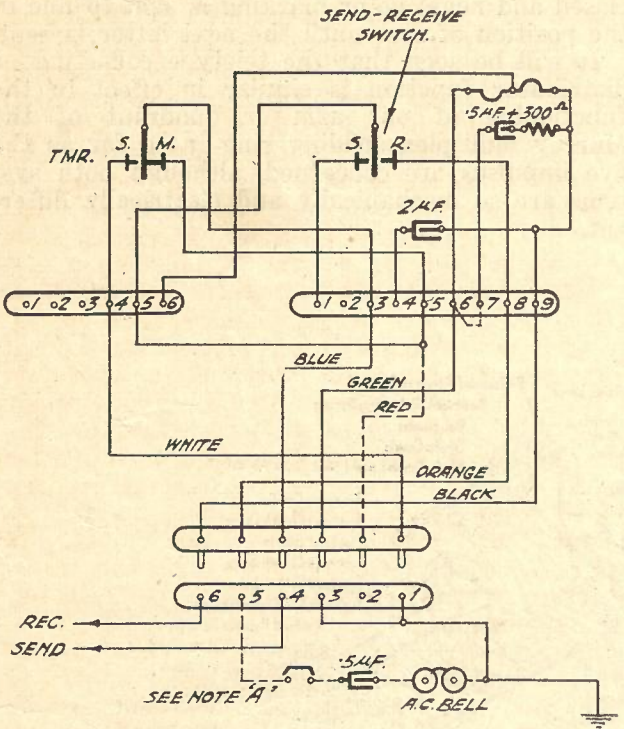


Fig. 4. Internal Connections of Teleprinter

receiving only. There are several other models of Teleprinter manufactured by Creed and Co., but these have not been introduced here in order that our equipment may be confined to a few standards. The several models can be equipped for tape reception instead of page reception but, owing to little or no demand here for tape reception, the tape fitments have not been imported.

The page model 7C is the standard model for point to point services, whilst the 8C model is the standard for stock ticker and similar multi-reception services. The teleprinter has a typewriter keyboard, and the home record on the sending machine and on the distant machine is printed in page form like a typewritten sheet. Skilled telegraphists are not necessary in the operation of the machine, and a typiste after a little tuition very quickly becomes proficient with the keyboard. When a key is pressed at the near end, the motor of the machine at the far end is started automatically and a character similar to that pertaining to the key pressed, is printed. The motors of both machines will continue to run ready for further transmissions but after a period of 1½ min., if no further transmission is made, both motors stop. There is therefore no waste of current during periods of non-use, and a message can be sent if necessary without any attendance at the far end.

It will not be possible to describe in detail the complex design of the machine, and some general considerations only are included. The teleprinter 7C may be operated at speeds up to 432 characters or 72 words per min. The characters are printed on a roll of paper in page form and sheets are torn off as completed. The signals corresponding to the various characters consist of a combination of five impulses which are sent over the line or channel during five successive equal intervals of time. In single current working, either current or no current may be flowing during each of these intervals. In double current operation, the currents are either positive or negative. In voice frequency working, a current alternating at voice frequency is applied to the line during a spacing signal and no current exists during a marking signal.

When a key is depressed it engages a clutch to which is coupled a series of cams, which latter in turn control the sequence of operations. The

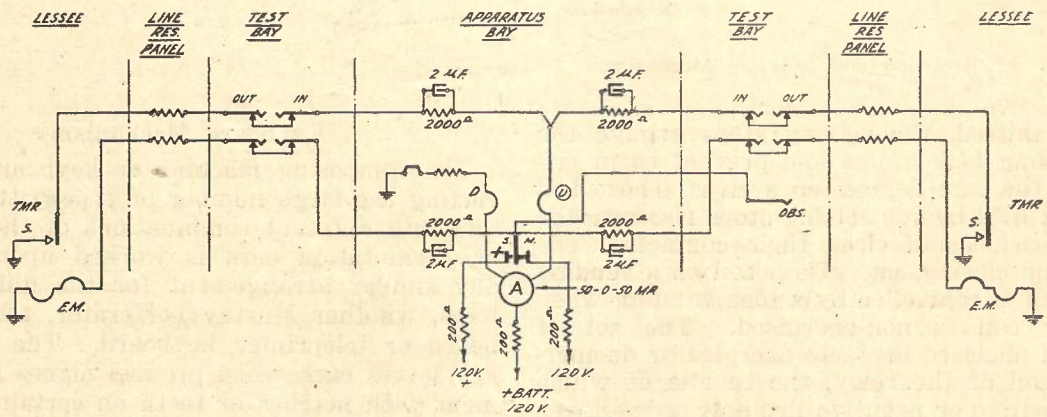


Fig. 5. Standard Teleprinter Local Network

depression of a key allows certain comb bars, which are free to move longitudinally, to be displaced in accordance with the code. A displaced comb bar corresponds to a marking signal, and a bar which has not been moved corresponds to a spacing signal. The position of each comb bar determines whether a spacing or marking signal shall be transmitted. In addition to the current impulses forming the particular combination, a "start" impulse precedes the code combination and operates the electromagnet controlling the printer at the distant terminal so that the receiving clutch mechanism can be operated. The "stop" impulse is a marking impulse and the electromagnet armature is moved to the marking side and disengages the receiving cam shaft.

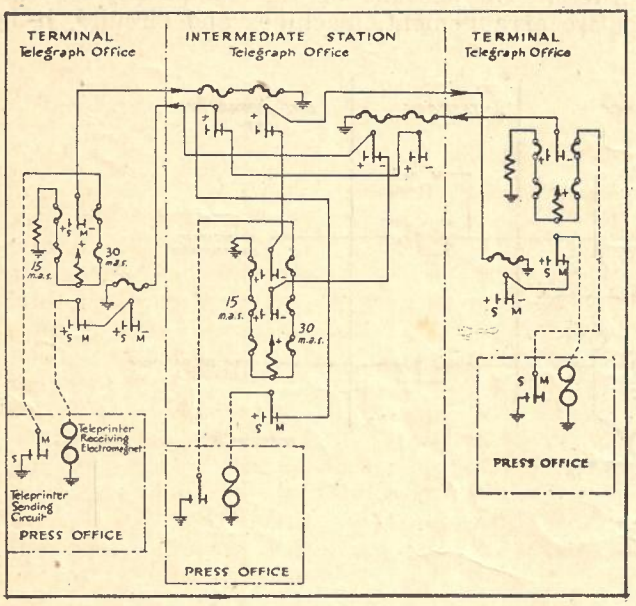


Fig. 6. Circuit for
Multi Transmission and Reception

Fig. 2 shows in simplified form the keyboard mechanism, five code bars, selecting levers and other mechanism including the transmitting contacts and tongue.

Fig. 3 shows the receiving mechanism in simplified perspective. The receiving machine includes, with other devices, the translating and the selecting mechanism. The incoming signals operate the polarised electromagnet and the movements of the armature are employed to:— (a) Set in motion the selecting and printing mechanism; (b) select the required character to be printed; (c) bring the mechanism to rest at the end of a message.

A steady current from the line holds the armature of the electromagnet against the "marking" stop. The start impulse being in a "spacing" direction moves the armature to the left. This actuates the automatic starting switch and the trip shaft is rotated. The receiving cam pawl abutment removes the ratchet pawls from engagement with the ratchet on the receiving cam sleeve which commences to rotate. As the receiving cam makes one complete revolution, the traversing link carries the finger setting pin first from centre to left and then back to the right, and finally to the central position again. The movement to the left causes the comb setting fingers to be withdrawn from the position held in the previous character. As the traversing link moves to the right with the finger setting pin, the setting blade also operates. This causes the finger setting blade to move inwards and outwards. Depending on whether the setting blade is deflected for a spacing signal or is not deflected for a marking signal, the setting blade strikes the setting pin as it is brought successively opposite each of the comb setting fingers. These movements are so timed that the operation of the finger setting blade occurs simultaneously with the reception of each signal character. The reception of each signal in a marking direction results in the displacement of a comb setting finger, while for a spacing signal the corresponding comb setting finger is not moved. In this way the combination set up on the transmitter comb bars is reproduced on the comb setting fingers at the receiving end.

The translating mechanism consists of five combination disc combs against which a number of selector bell-cranks press. The comb setting fingers are designed to pass on the code combination by means of a corresponding setting of the disc combs. The slots of the discs are placed so that for every setting of the combination discs one selector bell crank will be able to drop into a set of slots in alignment. The type wheel driven by a friction clutch is fitted with a stop arm which can be caught by any bell crank that has become placed in a combination set of slots. When the type wheel has come to rest at the required position, the receiving cam actuates a printing hammer which operates to print the required letter.

Electrical Considerations

The types of teleprinter service which the Postmaster-General's Department is prepared to provide for lessees are:—

1. Printergram service.
2. Leased point to point service within local networks.
3. Leased point to point service between distant networks.
4. Multi transmission and reception such as newspaper services.
5. Multi single way transmission such as stock ticker services.

The internal connections of the teleprinter are shown in Fig. 4, and the communication circuits which have been standardised are shown

schematically. Fig. 5 shows the standard teleprinter point to point local network, and Fig. 7 shows the circuit for distant service. In the latter case the channel used can either be a duplexed physical or a voice frequency channel. Owing to the necessity of having a home record of all transmitted material, the services provided are on a simplex basis, i.e., the transmission can only be effected in one direction at a time. If duplex or simultaneous both way transmission is desired, two receiving machines would be required at each terminal. The only equipment that is provided at the premises of the lessee is the teleprinter machine and the operating table. The relay equipment and testing and monitoring apparatus is located at the telegraph office, and all circuit testing is conducted from the central point. These tests comprise:—(a) Local run of

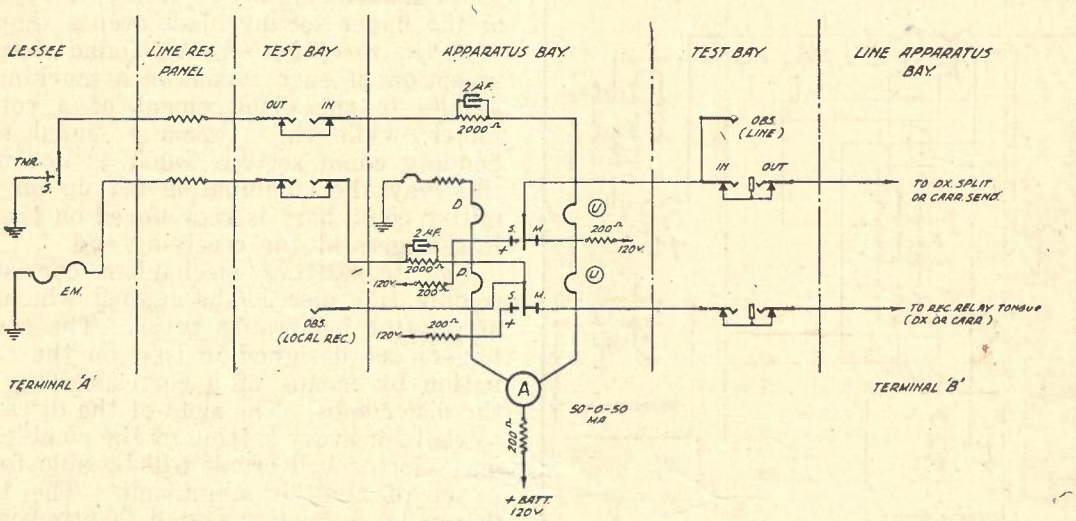


Fig. 7. Teleprinter Circuit for Distant Service

the observation teleprinter set; (b) teleprinter speaking test between the controlling office and the local lessee's office; (c) teleprinter speaking test between the controlling office and the distant telegraph office; (d) teleprinter speaking test between the distant telegraph office and the distant lessee's set; (e) observation of actual working in either direction between the local lessee's office and the lessee's office at the distant terminal.

It will be noticed that transmission from a lessee's machine is single current on the loop to the telegraph office, and the machine transmitting tongue, when spacing, merely closes circuit by connecting earth from the spacing contact. A condition of no current exists on the marking contact of the transmitter. This arrangement is to obviate providing positive and negative signalling battery supplies at the lessee's premises, and all teleprinter services are operated from centralised relay equipment and common battery supplies of the office. The location of teleprinter control equipment in the telegraph apparatus room instead of locating each set of relay apparatus at the subscribers' premises is the better practice, as the services are able to be placed under observation and monitored as a regular routine and maintenance effort is coordinated. On distant services, double current working obtains on physical lines, and on carrier loops double current operation obtains on the loops to the voice frequency or other carrier equipment.

Fig. 6 shows the circuit adopted for multi transmission and reception. In this type of service the transmitted matter from one machine will appear on all the other machines in the circuit and any machine may transmit to the others. On account of the complexity of the entire arrangement, machines and circuits, it is very desirable to have single way double current transmission on separate go and return lines. The confusion that would result to all stations under any out of balance condition of duplexed sections would nullify the usefulness of a long distance instantaneous press circuit of this nature. Fig. 8 shows the circuit of the stock ticker service where transmission from the central machine is simultaneously received.

Machine Transmission

Telegraphy has become, in recent years, a more measurable art, and several types of distortion measuring sets have been designed. A unit of transmission, the Baud, has been adopted internationally. The telegraphic speed of transmission of one unit of elementary signal per second is termed a baud. A reference to a multiplex plateau will make the definition more simple. The number of unit signals sent or segments swept, multiplied by the number of turns per second

equals the speed in bauds. Assuming a quadruple multiplex at a speed of 300 r.p.m., the 22 segments $\times$ 5 = 110 bauds.

For Wheatstone working.—Bauds = the number of direction holes per sec. multiplied by 2.

For start-stop working.—Bauds = the number of turns per sec. multiplied by the number of transmissions necessary for a character.

A model 7C Teleprinter run at 400 r.p.m. =
$400 \times 7 \div 60 = 46.6$ bauds;
if run at 432 r.p.m. = 50 bauds.

The following data apply to a model 7C Teleprinter:—
Rotation per min., 400 r.p.m. (428.6 r.p.m. receiver).
Duration in seconds of a rotation, 0.15 sec.
Words per min., 400/6 = 66.
Number of cam elements, 7 (sender), 6½ (receiver).
Duration in seconds of a current element, 0.02.

ment of contacts, unbalanced battery voltages, hysteresis in the relay cores, etc. In composited systems some characteristic distortion is introduced by the low pass filters.

Distortion of signals in other than machine systems using the five-unit code can often be overcome by the use of the Gulstad relay, which device supplements the weak portions of the signals that have become attenuated owing to leakage or other causes. In the Wheatstone system, if the receiver is running faster than the transmitter, the tape signals become merely elongated. If some impulses are distorted or slightly delayed in relation to the other impulses, no great inconvenience is occasioned and the telegraphist can usually interpret the poor

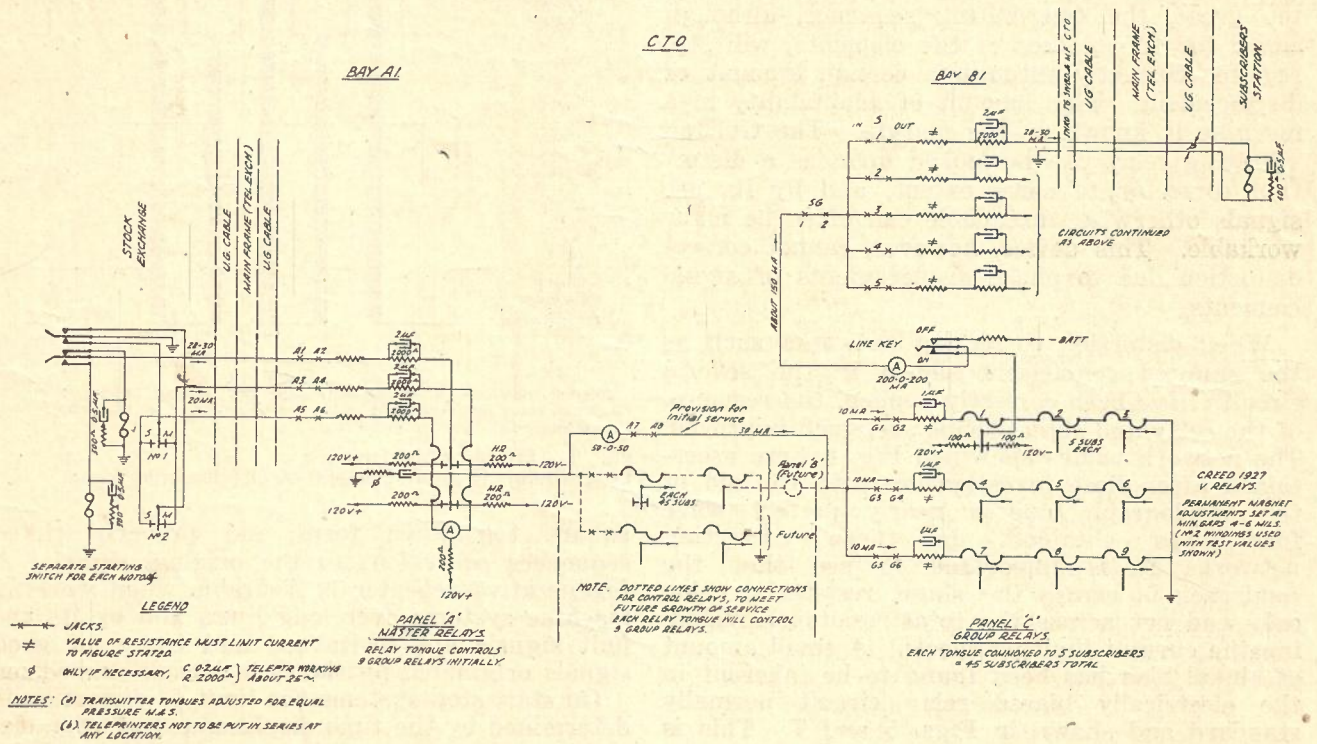


Fig. 8. Schematic of Stock Exchange Ticker Service.

Distortion

Distortion in telegraph working is the general term applied when the received impulse wave form is so ill-shaped that it bears little resemblance to the wave shape of the original signals. Distortion in telegraph circuits can be caused by the transmitter adjustments, by the line or channel characteristics, and by the mechanism of the receiving equipment. Total distortion includes characteristic or regular distortion due to attenuation and phase distortion, irregularities due to inductive disturbances from other lines, and bias distortion due to the apparatus. The latter may be due to many causes such as incorrect adjustment of contacts, unbalanced battery voltages, hysteresis in the relay cores, etc. In composited systems some characteristic distortion is introduced by the low pass filters.

Distortion of signals in other than machine systems using the five-unit code can often be overcome by the use of the Gulstad relay, which device supplements the weak portions of the signals that have become attenuated owing to leakage or other causes. In the Wheatstone system, if the receiver is running faster than the transmitter, the tape signals become merely elongated. If some impulses are distorted or slightly delayed in relation to the other impulses, no great inconvenience is occasioned and the telegraphist can usually interpret the poor record. In the case of the five-unit code where a train of code impulses for one character are sent in a period of time equal to one revolution of a device or cam, any great difference of speed of the receiving machine compared with the sender would result in the first, second, third, fourth or fifth impulse being received on other than the first, second, third, fourth or fifth portion of the distributing device. If some of the signal elements in a train are phase distorted or slightly displaced in time sequence in relation to the others, wrong selections, and therefore characters, are almost sure to result. Similarly,

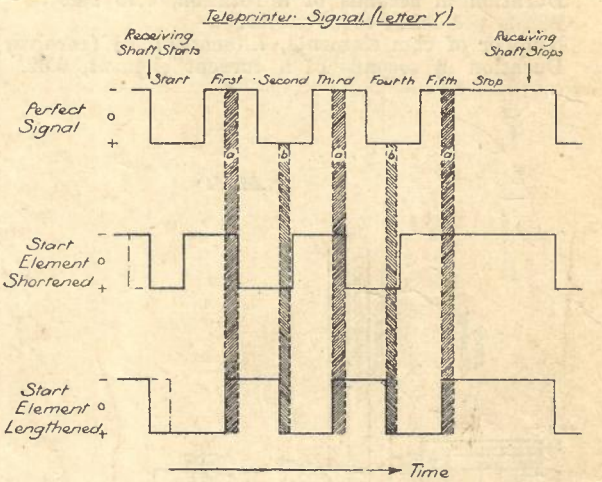
if the start signal be shortened or lengthened in time owing to characteristic or other distortion, the first and following code impulses in the train may be too early or too late for registration on the correct code setting and translating device. It will be seen that the bad effects of distortion due to any cause are much more serious in five-unit code transmission where a train of elements form a character, and in start-stop systems the most critical element is the start signal. Telegraph machines cannot assist in any way in the interpretation of a bad signal train, and must print a wrong character if distorted elements are received. The teleprinter receiving mechanism is so designed and timed that the centres only of element impulses are selected or used, and if the distortion or displacement is not too great, the distributing sequence, although timed for the centres of the elements, will still register correctly through a certain amount of displacement. This amount of adaptability in a machine is known as the margin. The Gulstad vibrating relay can be looked upon as a distortion corrector to some extent, and by its use signals otherwise unreadable can often be made workable. This device, however, cannot correct distortion due to phase displacements of signal elements.

When distortion correcting networks such as the shunted condensers shown in the several circuits have been correctly applied, the response of the relay and signal shape are much improved. The network values shown in Fig. 8 were ascertained after close investigation with the aid of the oscillograph, and a nearly perfect wave form was obtained. In these correcting networks it is important to see that the condenser is across the shunt resistance value only and not across the total resistance including the current limiting spools. A small amount of signal bias has been found to be inherent in the electrically biased relay circuit normally standard and shown in Figs. 5 and 7. This is probably due to unequal energising or the rate of growth of current in the spacing wiring at the instant of change over of the transmitter tongue. In the rest position, a current of, say, 10 m.a.s. obtains in the marking winding and no current in the spacing winding. When a start impulse or spacing current is sent, the corresponding spacing value is, say, 20 m.a.s., or double the value in the bias or marking winding. The spacing coil then assumes control and the tongue moves across to the spacing contact.

In order to eliminate bias as far as possible in the stock ticker transmitter circuit, the conditions were made as shown in Fig. 8, which necessitates three wires for the connecting lines from the lessee's office.

Repeaters

An ordinary telegraph repeater cannot repeat signals as perfectly formed as those transmitted by the original transmitter. Apart from distortion of wave shape on the signals received at the repeater station, a further modification of shape is produced by the repeater. The ordinary repeater therefore passes on signals of greater energy but of a wave form not superior to that received. Regenerative repeaters, on the other hand, have been designed in which the received signals are stored or re-set up in such a way that they are retransmitted in more or less



Shaded portions a indicate the periods during which marking elements must be registered, and shaded portions b the corresponding periods for spacing elements.

Fig. 9. Effect of Shortening or Lengthening the Start Element of a Teleprinter Signal.

square top wave form and properly timed sequences equivalent to the original signal. A regenerative repeater is desirable when working machine systems over long lines, and by its use unit signals are revitalised and trains of good signals originated by the poor signals passed on.

On start-stop systems the limit of distortion is determined by the time displacement of code elements with regard to the commencement of the start signal which precedes them, i.e., distortion is defined in terms of the error in timing of the received elements. Fig. 9 shows the effect of shortening or lengthening the start element of a teleprinter signal. It will be seen that altering the length of the start signal is equivalent to displacing all code elements with respect to the selecting mechanism of the machine.

The grade of service being given on the stock ticker service is such that an average of only 1.4 minutes are lost per machine per week. During the recent test matches, teleprinters were used from the cricket ground to the cable company and also to the other chief telegraph offices. The machines stood up to the heavy load very well, not one failure occurring.

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