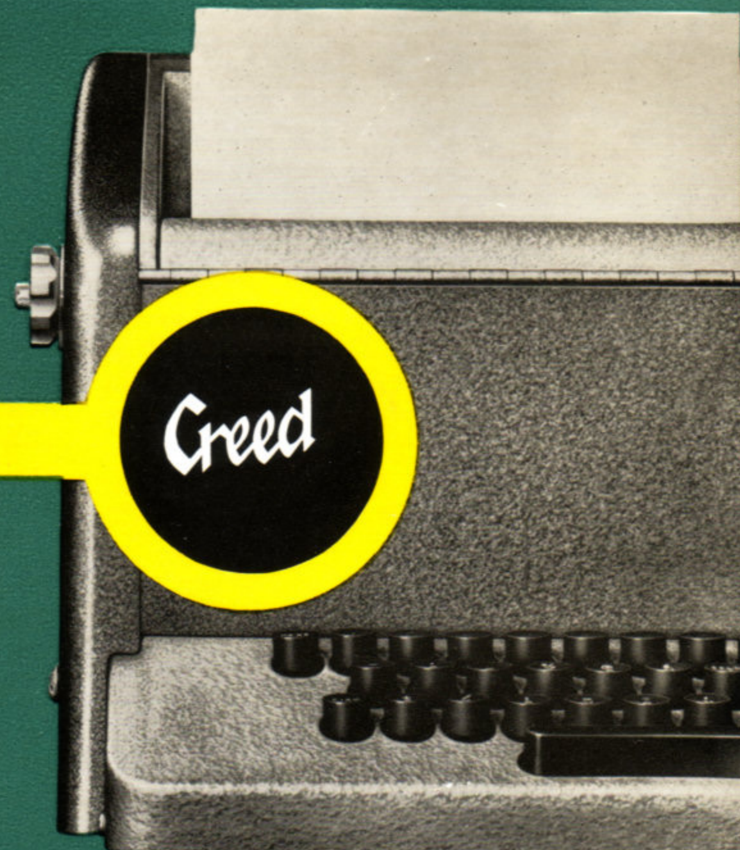
an introduction to Creed



TELEPRINTERS

and Punched Tape Equipment

COMMUNICATION · DATA PROCESSING · AUTOMATION

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an
introduction
to

Creed

TELEPRINTERS and PUNCHED TAPE EQUIPMENT

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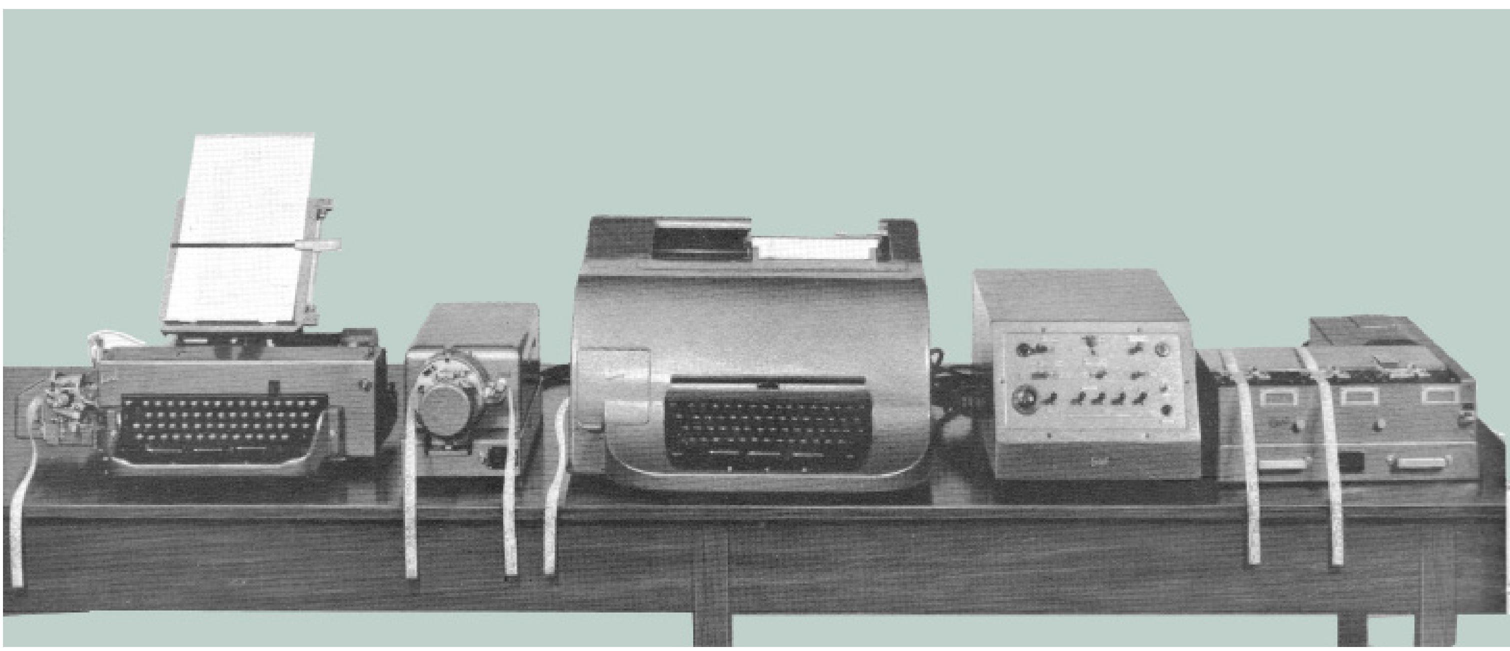


INTRODUCTION

Creed Teleprinters and Punched Tape equipment were originally developed for use in the telegraph communication field and they have been increasingly used ever since in telegraph systems all over the world.

During recent years, however, their use has been extended beyond this traditional field to a rapidly growing number of non-telegraphic applications such as the provision of input and output facilities for digital computers and the increased automatisation of existing systems such as punched card accounting and mechanised addressing.

As a result of this sudden increase in the number of applications that are being found for Teleprinters and Punched Tape, considerable interest is being shown in this equipment by engineers and others who wish to discover whether it can be applied to their own special problems but who lack sufficient knowledge of the basic principles involved to permit them to do this.

This bulletin has been written principally for such readers. It contains a brief, non-technical introduction to the general principles Underlying the operation of Creed Teleprinters and Punched Tape equipment and provides a number of examples of non-telegraphic applications.

It must be emphasised that this bulletin does not describe all the non-telegraphic applications that have been made to date of this equipment, nor does it contain any engineering details of circuits or machines. Readers requiring such details, or who wish to know whether the equipment can be adapted to their requirements, are invited to write to Creed & Company.

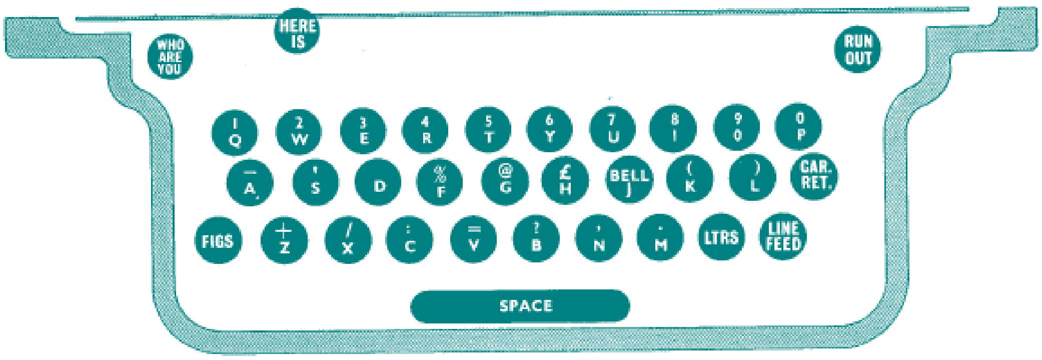


Fig. 1. Typical 3-Row Keyboard layout

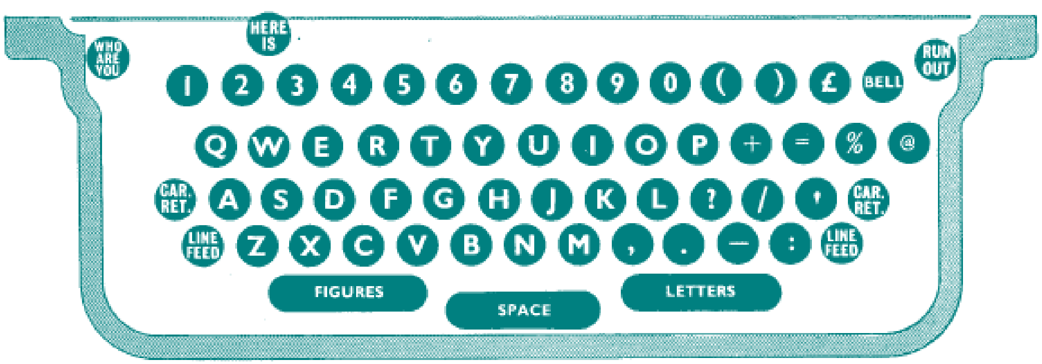


Fig. 2. Typical 4-Row Keyboard layout (Single Character Per Key)

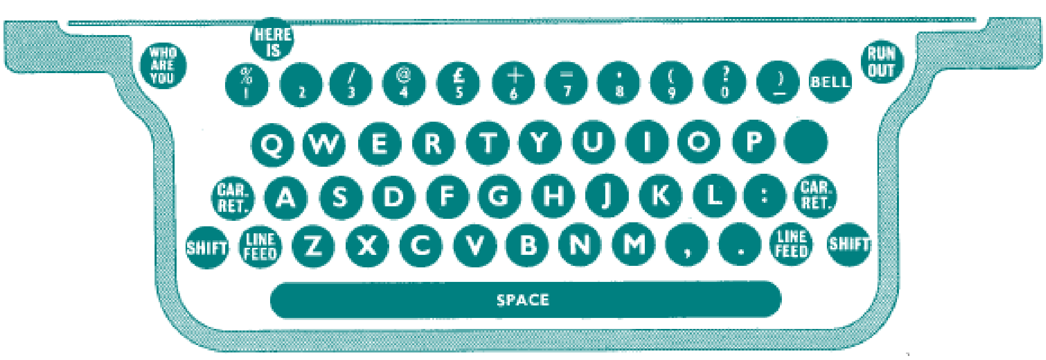


Fig. 3. Typical Commercial Typewriter Keyboard layout

Part I: Teleprinters

Definitions

Any system for transmitting and receiving messages electrically over a distance in the form of coded signals is called a *telegraph system*.

If the messages are automatically printed by the receiving apparatus, the system is then referred to as a *printing telegraph system*.

The *teleprinter* is the basic piece of equipment of the Creed printing telegraph system. It consists of two parts : a keyboard transmitter and a receiver.

The *keyboard transmitter* consists of a keyboard, similar in appearance and layout to a typewriter keyboard, for originating the message, and a transmitter for converting the operator's key depressions into suitably coded electrical signals which it transmits to the line or other medium of transmission.

The *receiver* is a device for registering the coded signals that are received from the distant transmitter and converting them into a printed message on a page or tape.

Intelligence

The intelligence transmitted consists of characters, numerals, signs and functions. The most commonly used items of intelligence are shown in the three typical keyboard layouts illustrated in Figs. 1-3.

The *characters* in all three layouts are the twenty-six letters of the English alphabet. While this is the most common arrangement, layouts for other alphabets with more or less than twentysix letters are available.

Similarly, although the *numerals* in these layouts are confined to 0 and 1-9, these may be augmented by fractions.

The *signs*, such as '%', '@' and '?', may also be varied to suit special requirements, e.g. for weather charts.

Seven *functions* are shown, viz. 'Line Feed', 'Carriage Return', 'Who-are-You ?', 'Bell', 'Space', 'Letters' and 'Figures'. The purpose of these functions is as follows :

(1) *Line Feed*. The transmission of this function causes the paper on the receiving teleprinter to be fed up to the next line. (If the received message is printed on tape, the 'Line Feed' function is not, of course, used).

(2) *Carriage Return*. This function causes the carriage on the receiving teleprinter, to return to the beginning of its travel so that the printing starts again at the beginning of a line. (Again, with tape printing, this is not used).

(3) *Who-are-You ?* This function causes the distant teleprinter keyboard transmitter to send back automatically to the calling teleprinter, where it is printed, a series of characters and/or numerals informing the calling operator of the identity of the distant station. This assures the calling operator :

(a) that he is connected to the right station ;
(b) that the called teleprinter is operating even if unattended ; and
(c) if operated at the end of a message, that the whole message has been received.

(4) *Bell.* The transmission of this function causes a bell to ring (or produces some other

COMB^N Nº	LETTERS CASE	FIGURES CASE	START	CODE ELEMENTS 1	2	3	4	5	STOP
1	A	–	□	■	■	□	□	□	■
2	B	?	□	■	□	□	■	■	■
3	C	:	□	□	■	■	■	□	■
4	D	WHO ARE YOU?	□	■	□	□	■	□	■
5	E	3	□	■	□	□	□	□	■
6	F	OPTIONAL	□	■	□	■	■	□	■
7	G	OPTIONAL	□	□	■	□	■	■	■
8	H	OPTIONAL	□	□	□	■	□	■	■
9	I	8	□	□	■	■	□	□	■
10	J	BELL	□	■	■	□	■	□	■
11	K	(	□	■	■	■	■	□	■
12	L	)	□	□	■	□	□	■	■
13	M	.	□	□	□	■	■	■	■
14	N	,	□	□	□	■	■	□	■
15	O	9	□	□	□	□	■	■	■
16	P	0	□	□	■	■	□	■	■
17	Q	1	□	■	■	■	□	■	■
18	R	4	□	□	■	□	■	□	■
19	S	'	□	■	□	■	□	□	■
20	T	5	□	□	□	□	□	■	■
21	U	7	□	■	■	■	□	□	■
22	V	=	□	□	■	■	■	■	■
23	W	2	□	■	■	□	□	■	■
24	X	/	□	■	□	■	■	■	■
25	Y	6	□	■	□	■	□	■	■
26	Z	+	□	■	□	□	□	■	■
27	CARRIAGE RETURN		□	□	□	□	■	□	■
28	LINE FEED		□	□	■	□	□	□	■
29	LETTERS		□	■	■	■	■	■	■
30	FIGURES		□	■	■	□	■	■	■
31	SPACE		□	□	□	■	□	□	■
32	ALL SPACING		□	□	□	□	□	□	■

MARK ELEMENT ■
SPACE ELEMENT □

Fig. 4. Start-Stop Code

warning indication) at the called station to attract the operator's attention.

(5) *Space*. This is similar to the normal spacing function on a typewriter. Its transmission results in the carriage on the receiving teleprinter feeding along one space without printing.

(6) Letters and

(7) *Figures*. These functions have a purpose which will be explained in the next section.

In the keyboard layouts in Figs. 1-3, three keys ('Shift', 'Run Out' and 'Here is') have not so far been referred to, since they are not strictly speaking items of intelligence, i.e. no code signal is allocated to them. Their purpose is as follows :

(l) *Shift Key.* This key, which is used only on the layout illustrated in, Fig. 3, serves the same purpose as the shift key on a typewriter, i.e. by depressing it the operator gains access to the 'upper case' signs on the top row of keys.

(2) *Run-Out Key.* The depression of this key results in the last signal sent being repeatedly transmitted for as long as the key remains depressed.

(3) *'Here is' Key*. The depression of this key causes the keyboard transmitter to send automatically the calling station's identification code signal to the called station.

Teleprinter Code

The code used for the transmission of intelligence from one teleprinter to another is a 5-unit, 2-element (binary) code which allows a total of 2^5, i.e. thirty-two combinations. The method of allocating these combinations to the various items of intelligence has been the subject of various conferences held by the C.C.I.T.T. (International Telegraph and Telephone Consultative Committee), a body which represents most of the main telegraph interests in the world and exists to promote, among other things, the growth of common practices in telegraphy. The method of code allocation indicated in Fig. 4 is the C.C.I.T.T. International Code No. 2, which is the one at present in general use.

It will be noticed that the two kinds of elements of the code are called 'mark' and 'space' elements. These terms were derived from telegraph systems employing the Morse Code, where the dots and dashes were referred to as 'marks' and the spaces between the dots and dashes simply as 'spaces'. In connection with the 5-unit code these meanings are, of course, irrelevant, but the terms have been adopted as convenient labels for distinguishing between the two kinds of elements of the code. A 'mark' element may be defined, therefore, in terms of the International Code as any element of the code represented by a solid square in Fig. 4 ; similarly, a 'space' element is any element of the code represented by an open square.

It will also be noticed that there are more items of intelligence in the International Code than there are 5-unit code combinations. It might seem at first sight that this would preclude the use of a 5-unit code, as the simplest and most natural method of coding is to allocate one combination to each item of intelligence. In fact, however, the intelligence carrying-capacity of the 5-unit code can be nearly doubled by allocating two combinations to each item of intelligence. This method of coding results in a more complicated keyboard operating procedure and some loss in transmission time but, by a device described below, most of the additional complication and loss of transmission time can be eliminated. The resulting system is simpler than could be obtained by using a 6-unit code.

Following the principle, therefore, of allocating two combinations to each item of intelligence, the required code-pairs are made by using combinations 29 or 30 as the first member of each pair, and one of the remaining combinations as the second member. (The 'All Spacing' combination is not generally used, for reasons that will be given later). Thus, the code-pairs fall naturally into two groups : those having combination 29 as their first member and those having combination 30 as their first member.

Before allocating these code-pairs to the different items of intelligence, the items are similarly divided into two groups, called 'cases'. (The word 'case' as used here has no connection with its use in typography or with the upper and lower cases on teleprinter or typewriter keyboards). The twenty-six letters of the alphabet are put into one case, called the 'Letters' case ; the numerals, signs, optional items and two of the functions are placed in the other, 'Figures' case ; and the three remaining functions, 'Carriage Return', 'Line Feed' and 'Space', are assigned to both cases.

The items of intelligence in the 'Letters' case are now coded using the group of code-pairs having combination 29 as their first member. This combination is, consequently, called the 'Letters' combination. Similarly, the items of intelligence in the 'Figures' case are coded using the code-pairs having combination 30 as their first member, and this is called the 'Figures' combination. The three functions allocated to both cases are coded by the code combinations given in Fig. 4 preceded by either a 'Letters' or a 'Figures' combination, i.e. each function may be regarded as being coded by either one of two code-pairs.

This system of coding, if used without further modification, would require the depression of a 'Letters' or 'Figures' key before each character key. This would result in a complicated and tedious keyboard operating procedure and produce a very low speed of message transmission.

To avoid this situation, advantage is taken of the fact that with the method adopted in the International Code of grouping all the letters of the alphabet into one case and the remaining items of intelligence into the other (except, of course, the three functions in both cases), most messages contain very few *changes of case*. This is done by designing the receiver in such a way that the 'Letters' and 'Figures' combinations have to be transmitted *only when a change of case occurs*. For example, if a 'Letters' combination is transmitted, the receiver translates all combinations received after this and before the reception of the next 'Figures' combination, into the 'Letters' case.

The 'Letters' and 'Figures' combinations, because they possess this case-changing function, are usually referred to as 'case-change' or 'case-shift' combinations, and the corresponding keys are similarly referred to as 'case-shift' keys.

It has been mentioned that the Carriage Return, Line Feed and Space functions are in both cases. The depression of the keys corresponding to these functions results in the receiver performing the functions irrespective of the case to which it is preset. The object of this is, once more, to keep the number of depressions of the 'Letters' and 'Figures' keys to a minimum.

Start-Stop Principle

Each of the code combinations in the International Code (see Fig. 4) is preceded by a spacing element and succeeded by a marking element. These are known as the 'Start' element and 'Stop' element respectively.

A fundamental problem in the design of telegraph apparatus is that of ensuring that the transmitter and receiver remain in synchronism. This problem has been solved in a number of different ways, e.g. in the Baudot system, by the use of special correcting pulses. The method used in the teleprinter, which is the simplest and most widely used, is that of running the receiving apparatus slightly faster than the transmitting apparatus, and transmitting special 'Start' and 'Stop' signals at the beginning and end of each code transmission. The receiving apparatus is thus started and stopped by the sending apparatus for each character transmission. Any difference in phase between the two machines caused by a slight difference in the speed of their motors is thereby prevented from accumulating and synchronism within the required degree of accuracy is, accordingly, maintained.

The advantage of this method of achieving synchronism is that the transmitter and receiver motors may differ slightly in speed without interfering in any way with transmission. This means that a simple mechanical motor governor is all that is required to maintain synchronism.

The Start-Stop principle of synchronisation is so fundamental to the design of telegraph apparatus that printing telegraph machines employing this principle are generally referred to as 'Start-Stop' Printing Telegraph machines.

Telegraph Signals

A result of using the Start-Stop principle is that the time required for the transmission of the seven elements for each code combination must be longer than the time for one cycle of operations for the receiving apparatus.

On the standard Creed teleprinter, this is done by making the time for a complete seven element code transmission equal to 7½ units in length (a 'unit' being the time of transmission for the shortest signal) and the cycle of operation of the receiver equal to 6½ units. This allows a one unit rest for the receiving apparatus between the reception of each code combination.

The 7½ units for each seven-element code transmission are shared out between the seven elements by allocating one unit to the 'Start' element, one unit to each of the code elements and 1½ units to the 'Stop' element.

The use of 7½-unit transmission with 6½-unit reception instead of, say, 7-unit transmission with 6½-unit reception or 7½-unit transmission with 7-unit reception is, to a large extent, arbitrary. As a result, there has been some variation in the systems adopted by different countries at different times. For example, the original Creed Teleprinter (Model 7A), which was used by the British Post Office, was designed for 7½-unit transmission and 7-unit reception. In 1932, the C.C.I.T. standardised on 7-unit transmission. The British Post Office, which had a large number of 7½-unit transmitters already in use, decided to retain 72-unit transmission but go over to 62-unit reception to be able to receive from machines using the C.C.I.T. transmitting standard. Creed, therefore, brought out two new models of the 7 Teleprinter : the 7B to suit the B.P.O. method of working and the 7C to suit customers working to the C.C.I.T. recommendation.

method of working and the 7C to suit customers working to the C.C.I.T. recommendation.

Recently, the C.C.I.T. recommended that not less than 7.4 units shall be used for transmission and receivers must be able to work either to 7-unit or 7½-unit transmission. The Creed Model 7B Teleprinter meets these requirements and has been, for some time, the standard Model 7 teleprinter, the 7A being out of production and the 7C being manufactured only in small quantities. The more recently introduced Creed Model 54 Teleprinter illustrated on page 4 is identical in these respects to the Model 7B Teleprinter.

Telegraph Speed

The unit of telegraph speed is called the 'baud', after the famous French telegraph inventor Baudot. It is equal to the number of shortest telegraph signals, i.e. units, per second.
The usual speed for a teleprinter is 50 bauds, which makes the unit equal to 20 milliseconds. With 72-unit transmission, the 'Start' signal and the five code signals are, therefore, each 20 milliseconds in length while the 'Stop' signal is 30 milliseconds, and the transmission time for a complete 7½-unit transmission is 150 milliseconds.

Another way of measuring telegraph speed, which is very useful, is in words per minute. In order to obtain a word-measure, five letters and a space are taken to be the average length of a word in English, i.e. six code transmissions. A telegraph speed of 50 bauds, using 72-unit transmission, is thus equivalent to

$$\frac{1000}{150} \text{ X } \frac{60}{6} = 66\text{-}2/3 \text{ words/min.}$$

OUTLINE DESCRIPTION OF A TELEPRINTER

The basic elements of a simple point-to-point teleprinter system are represented in Fig. 5. The transmitter consists essentially of a metal tongue T which, when a key is depressed, is caused to move between two contacts M (marking) and S (spacing) in a manner determined by the code combination of the key depressed. Voltages of opposite polarity are connected to the

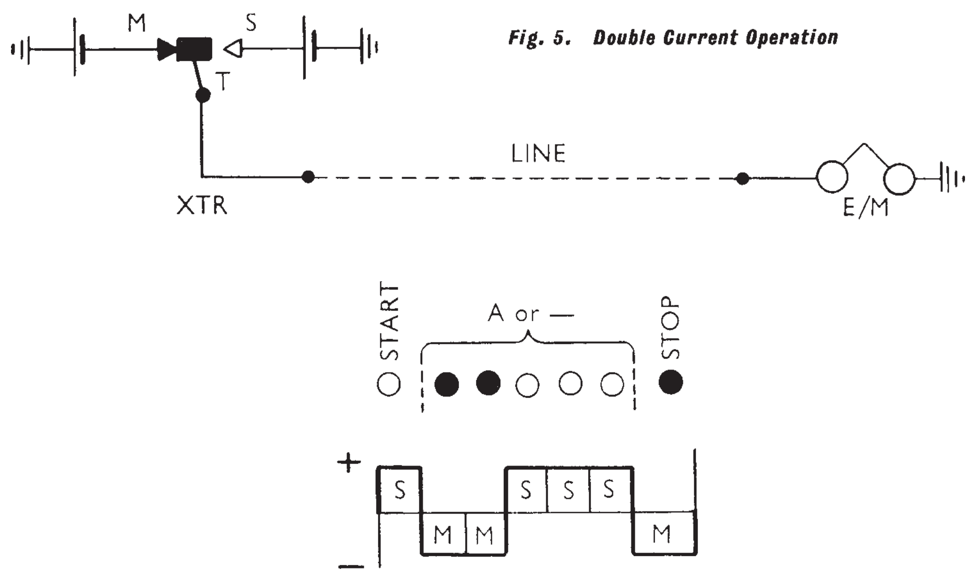
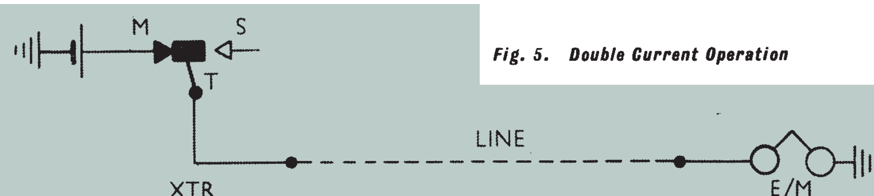


Fig. 5. Double Current Operation



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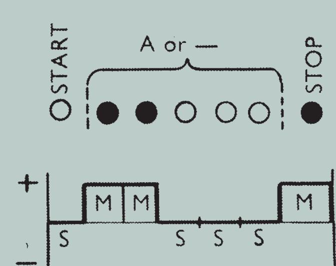


Fig. 6. Single Current Operation

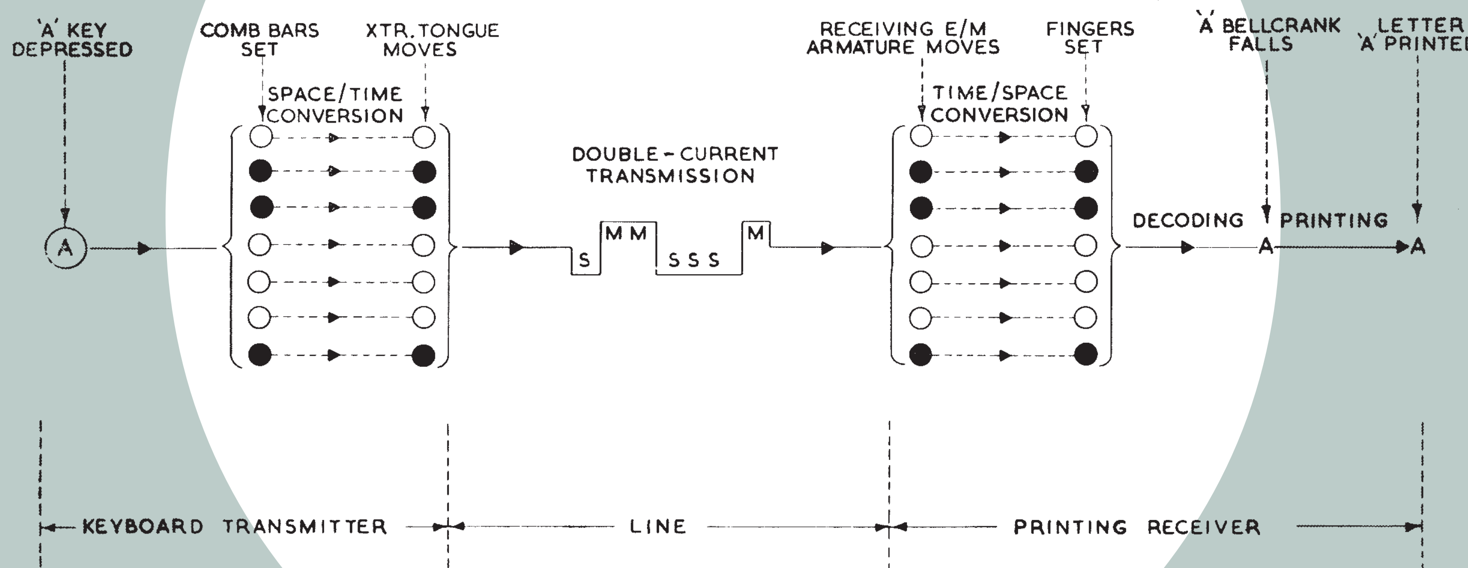


Fig. 7. Transmission of letter 'A' for the Model 54 Teleprinter

two contacts and the tongue is connected to the line.

The basic element of the receiver consists merely of an electromagnet, one side of which is connected to line and the other side to earth.

Thus, when a key is depressed, a sequence of square-wave pulses (ignoring distortions caused by the line constants and the electromagnet inductance) is transmitted to the electromagnet, the armature of which is caused to reproduce the movements of the transmitter tongue. The re mainder of the receiver is a device for 'reading' these armature movements and printing the characters or performing the functions corresponding to the code combinations read.

The method of transmission represented in Fig. 5, in which the pulses of transmitted voltage are of opposite polarity, is called 'double-current' operation. Although in the figure the marking voltages are negative and the spacing positive, there is no rule that is universally followed. The B.P.O., for example, adopt the convention in Fig. 5, whereas America and the continental countries adopt the reverse convention.

Fig. 6 illustrates the 'single-current' method of operation, in which voltage is applied only to one contact. In this system, a spring is used to return the electromagnet armature when there is no current flowing through the electromagnet. Once again, no set rule is followed in deciding whether the voltage should be applied to the marking or spacing contact or whether this should be positive or negative.

Stages of Transmission

There are a number of well-defined stages and processes between the depression of a key and the impression of the selected character on the paper in the distant printer. These are shown schematically in Fig. 7 which, for clarity, represents the stages for the transmission of a particular letter-A, for the Model 54 Teleprinter.

The depression of the letter 'A' key on the keyboard sets up the code corresponding to the letter 'A' on a set of combination bars running underneath all the keys, by displacing marking bars in one direction and spacing bars in the other. The depression of the key simultaneously releases a transmitter camshaft which is geared to the teleprinter motor. This revolves and automatically 'reads off' the code from the bars, converting it into a sequence of movements of the transmitter tongue between its two contacts. If double-current operation is employed, signals of opposite polarity are thereby transmitted to the line.

At the distant teleprinter these signals cause the electromagnet armature to move in the same manner as the transmitting tongue. These movements are 'read off' once more, this time by a mechanism controlled by the receiving camshaft, and the code is stored as a spatial arrangement of five vertical fingers.

Corresponding to each of the code-carrying keys on the keyboard there is a bellcrank in the printer. A decoding mechanism automatically translates the code setting on the five vertical fingers into the displacement of the 'A' bellcrank. This bellcrank interrupts the path of a re volving typehead and arrests this so that the letter 'A' is opposite the printing point. A typehammer, controlled from the receiving camshaft, then prints the letter 'A'.

Keyboard

The teleprinter keyboard consists of the following parts :

(1) An assembly of keys (see Figs. 1-3).

(2) A number of saw-toothed combination bars running under the keys. Five of these are used to set up the code corresponding to the key depressed in the manner described above. A sixth bar is used to trip the transmitter camshaft when moved endwise by the depression of a key and, on some keyboards, a seventh bar, which is moved to the left by the depression of the 'Figures' key and to the right by the 'Letters' key, is used to lock all keys in the opposite case, to prevent their inadvertent depression. Keyboards having this seventh bar are said to be fitted with a 'shift-lock' facility.

(3) A *transmitting mechanism* for automatically 'reading' the code combinations set up on the five code combination bars and converting this into the movement of the transmitter tongue between the marking and spacing contacts.

(4) A *trip mechanism*, operated by the trip bar when any key is depressed, for releasing the transmitter at the beginning of a code transmission and arresting it at the end.

(5) An *answer-back unit* (optional facility) which is operated by the receiver when a 'Whoare-You?' signal is received by it. It first locks the keyboard against manual operation and then automatically takes control of the code and trip combination bars, transmitting through them the station identification code signal which is stored in the unit on a number of metal wards.

(6) An *'End-of-Line Indicator'* unit (optional facility). This is a counting device which records the number of key depressions after each operation of the Carriage-Return key. When fifty-five key depressions have been recorded, the device closes a pair of contacts and lights a warning lamp on the front of the teleprinter. The ensuing operation of the Carriage-Return key resets the mechanism. It is used when transmitting without a local record to a page teleprinter to provide a visual warning to the sending operator that the page attachment on the distant teleprinter is now approaching the end of a line and he must therefore depress his Carriage-Return key.

(7) An *automatic Send-Receive switch*. This switch is similar to the transmitter armature and consists of a metal tongue operating between two metal contacts. When the key board is at rest, it is held against the Receive contact. Immediately after the transmitting mechanism is released, i.e. before any intelligence is transmitted, it is moved automatically by a cam on the transmitter shaft to the 'Send' contact. At the end of each cycle of operations, it is returned to the 'Receive 'contact once more.

Receiver

The receiver consists of the following main components :

(1) A governed, 3,000 r.p.m., fractional horse-power motor. This provides power for the keyboard transmitter as well as the receiver.

(2) A receiving *electromagnet* to reproduce the movements of the keyboard transmitting tongue.

(3) A *cam unit*, the mechanism of which is released and arrested by the 'Start' and 'Stop' signals respectively. When released it 'reads' the electromagnet armature movements corresponding to the incoming code combination and stores the combination on five vertical fingers. It also controls the operation of all other units (see below).

(4) A *combination head unit*. This unit, which is cylindrical in shape, contains one bell crank for each item of intelligence arranged around its curved surface. It is controlled by the cam unit and converts the intelligence set up on the five vertical fingers into the operation of the corresponding bellcrank. A case-shift mechanism is included which operates on receipt of the 'Letters' and 'Figures' combinations. This determines which of the two bellcranks corresponding to each code combination set up on the fingers is operated, e.g. if a 'Letters' case-shift signal is received, the case-shift mechanism is preset so that the subsequent receipt of the combination MMSSS leads to the operation of the 'A' bellcrank (see Fig. 4) and not to the operation of the '-' bellcrank.

(5) A *typehead unit* which is powered independently of the cam unit from the motor. This unit is also cylindrical in shape and rotates on the rear end of the combination head unit. When a bellcrank operates, the typehead is arrested by it and presents the proper type opposite the printing point.

(6) A *typehammer unit* operated by the cam unit which pushes forward the presented type against the paper and so prints the received item of intelligence.

(7) A *control lever unit* containing a number of levers controlled by the operations of the functional bellcranks in the combination head and controlling, in turn, the mechanism associated with the paper carriage functions described below.

(8) A *page or tape attachment unit*. A page attachment unit consists of a paper carriage for mounting a roll of paper, and a number of mechanisms powered by the cam unit and controlled by the control lever unit for performing the following functions :

(a) *'Letter feeding'*, i.e. feeding the carriage along past the printing point on receipt of any combination other than a functional combination.

(b) *'Line Feeding'*, i.e. feeding the paper up one or two lines (this may be predetermined by a manual setting) on receipt of a 'Line Feed' combination.

(c) *'Carriage-Re turn'*, i.e. returning the carriage to the beginning of a line on receipt of a 'Carriage-Return' combination.

(d) *Ringing a bell* as the carriage nears the end of a line.

(9) A *ribbon feed mechanism* for automatically feeding and reversing the feed of the ink ribbon. A ribbon jumper is provided to lower the ribbon from in front of the printing between operations of the typehammer.

(10) An *answer-back trip mechanism*. This mechanism is controlled by the 'Who-are-You T bellcrank on the combination head unit. When this bellcrank operates, the mechanism, which is connected to the answer-back unit on the keyboard, trips this unit, thereby causing it to transmit the station identification code signal to the distant teleprinter.

(11) An *orientation device*. This device is connected between the receiving electromagnet armature and the cam unit and provides a means of adjusting the phase of the cycle of operations of the receiving mechanism to that of the incoming code signals, thereby increasing the tolerance of the receiver to distortion in these signals.

(12) A *'period of operation'* counter (optional facility). This mechanism records the number of cycles of operation performed by the receiving mechanism and provides an indication of when to service the teleprinter.

NEW MODEL *Seventy-Five* TELEPRINTER

N. B. The above outline descriptions of a teleprinter keyboard and receiver apply to the Creed Model 54 Teleprinter. The facilities provided on the new Creed Model *Seventy-Five* Teleprinter are identical to those listed above, but the mechanical details are in many respects quite dissimilar. Separate publications are available on request dealing with the new Model *Seventy-Five* Teleprinter.

Part II: Punched Tape Equipment

Creed punched tape equipment was originally designed, and is still mainly used, as an important means of increasing the efficiency of telegraph transmission systems. Automatic tape transmission has been used for many years to give fuller utilisation of line or channel time and, since the war, tape relay systems have been installed in many parts of the world.

Recently, however, this equipment has found a rapidly growing number of applications in non-telegraphic fields such as data recording, process control and the provision of input and output facilities for digital computers. What was once a method of automatically transmitting messages is now becoming a comprehensive technique for automatically recording, storing and processing information of all kinds.

The punched tape system is obviously analogous to punched card systems, but it has important advantages over the latter in providing a continuous record of information in place of the discrete record produced by a punched card and, by the ease with which it may be used for auto matic data recording, in eliminating the necessity for transcribing written information into punched card form.

Knowledge of the punched tape technique and the somewhat specialised machines used in conjunction with it has hitherto been largely confined to telegraph engineers. The principal purpose of the following sections is to give a brief, non-technical description both of the technique and the machines used with it, for those who are not telegraph specialists but wish to discover whether punched tape can solve their information-handling problems.

The following sections are necessarily neither detailed nor complete, but the reader is invited to write to Creed & Company for further information on any of the points covered, and on any other points concerning the punched tape system.

Kinds of Punched Tape

Three kinds of punched tape are in common use : the 'fully punched tape' illustrated in Figs. 8 and 9, the 'chadless tape' illustrated in Fig. 10, and the 'fully punched and printed tape' shown in Fig. 11.

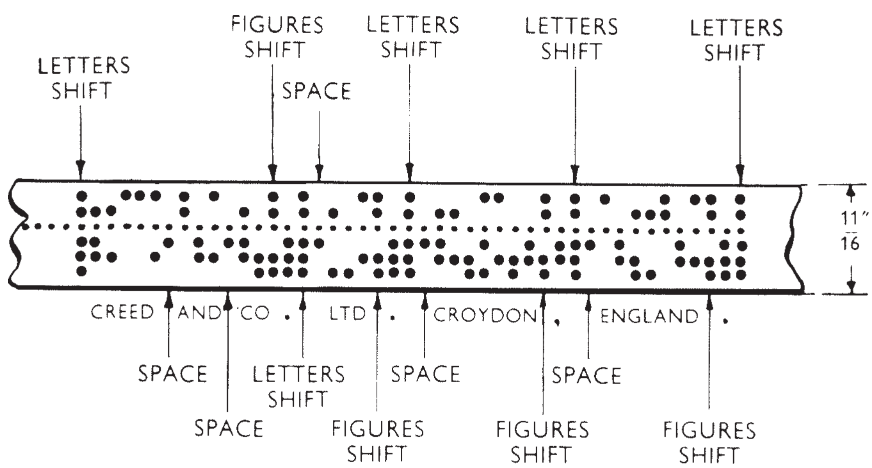


Fig. 8. Coding

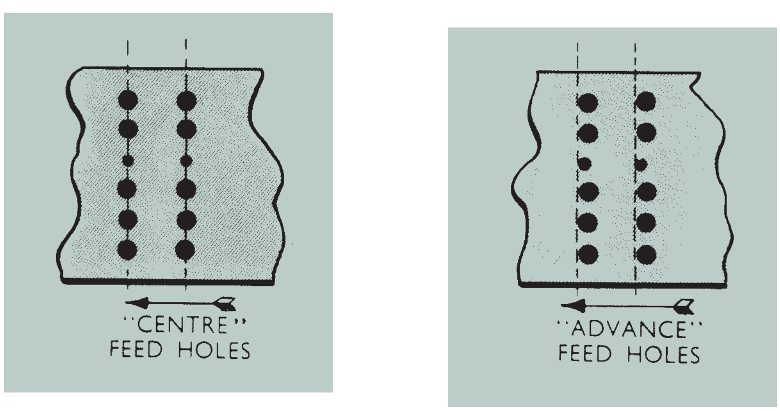


Fig. 9.

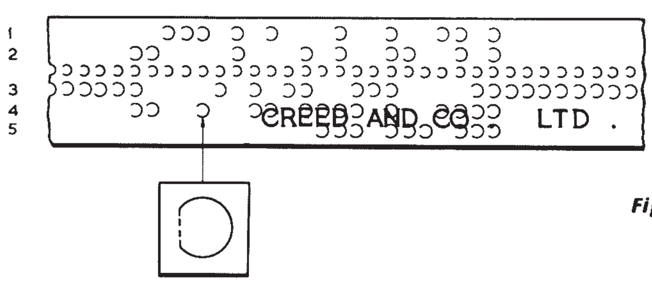


Fig. 10. Chadless Tape

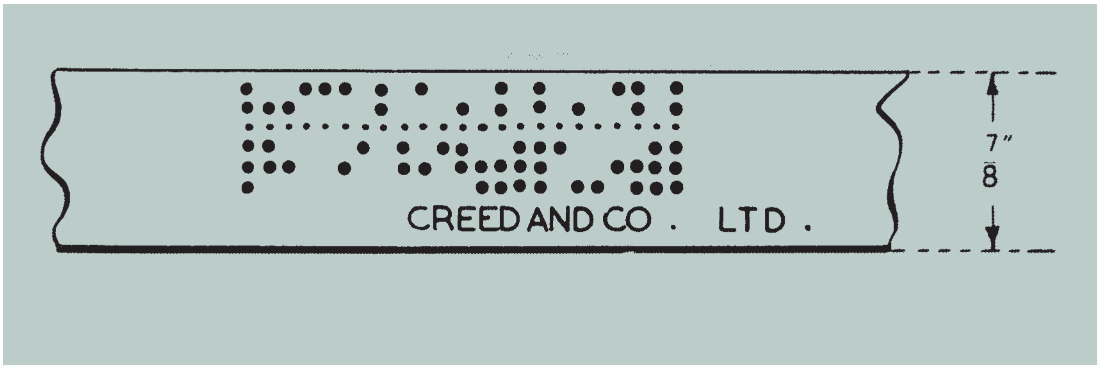
The *fully punched tape* used in Creed equipment is 11/16 in. or 7/8 in. wide and is supplied in reels of 340 yards long, the former accommodating 5-unit and the latter 6- or 7-unit code combinations. The code is punched across the tape, ‘marks’ being represented by punched holes and ‘spaces’ by leaving the tape unperforated. Between the second and third code holes, on 11/16 in. wide tape and the third and fourth code holes on 7/8 in. wide tape, a smaller feed hole is punched to enable the tape to be drawn through the equipment by a sprocket wheel. These feed holes are usually in line with the code holes (see Fig. 9), but they may, if required, be punched slightly in advance of the code holes to provide a ready means of identifying the correct direction in which to read the tape. These two methods of perforating the feed holes are referred to as `centre' feed punching and `advance' feed punching respectively.

‘Chadless’ tape is used when a printed record of the message is required on the tape in addition to the punched record, without increasing the width of the tape. This is achieved by only partially perforating the tape, leaving the 'chads' as hinged lids which are bent back flush with the surface of the tape and printing the message over the fourth and fifth code tracks. It will be noticed from Fig. 10 that the printing lags eight feed hole pitches behind the perforations. This is unavoidable as the printing and perforating points with this kind of tape must of necessity be separated. As a result, it is important, when using 'chadless' tape, to make allowance for this separation when tearing or cutting the tape. Also, when fitting the tape into a transmitter, the first printed character must be preceded by at least eight sets of code perforations in order to transmit the entire message.

The *‘fully punched and printed’* tape illustrated in Fig. 11 embodies an alternative method of combining printed with perforated information on the same tape. The printing is in this case placed underneath the perforations, a 7 /8 in. wide tape being employed to achieve this.

In all three of the kinds of tape described above, it is important to ensure that the spacing between successive sets of punched holes is uniform and equals 1/10 in. with an accuracy of ±1½ feed hole pitch in ten inches of tape.

Mention should be made here of the fact that tapes are available in a variety of colours. Colour coding of tapes is widely used to distinguish their different functions, where there is any danger of mistakes occurring.



Methods of Coding Information on Punched Tape

Telegraph intelligence is coded in punched tape according to the International Start-Stop Code No. 2, given in Fig. 4. This follows from the fact that telegraph signals are used for communication. The 'Start' and 'Stop' signals are not perforated in the tape as these are inserted automatically by the transmitter.

If 'chadless' tape is used, it is customary to include signs for the functional combinations (see Fig. 12) so that every perforated combination is represented by a printed sign ; this simplifies the reading of the tape.

Non-telegraphic information may be coded in many different ways. There are no standard methods except in certain specialised fields, e.g. meteorology, and the method adopted will depend on the particular application for which it is required. The three main kinds of non-telegraphic application are the provision of computer input facilities, the automatic recording of data for subsequent analysis by a computer and the automatic control by punched tape of a sequence of operations or processes. As the same principles of coding are employed in the last two applications, the following brief discussion will be confined to computer codes and automatic data recording codes, the latter being dealt with first.

In the discussion of telegraph theory given in Section A, the unit of intelligence was called an 'item' of intelligence and the usual method of allocating a 5-unit combination to each item of intelligence was described. In discussing the wider field of data recording, the more general term 'information' will be used in place of 'intelligence' and the unit of information will be called an 'item' of information. An item of information may be any state or condition of a process under investigation, a meter reading, a specific lapse of time, a distance or any definite value of a variable quantity.

In telegraphy, the coding of intelligence is relatively simple because the items of intelligence comprising the message are transmitted and received serially, i.e. no two items of intelligence are required to be transmitted or received simultaneously. In punched tape recording of nontelegraphic information this is not always the case. Whereas the coding of the movement of an instrument pointer approximates to the telegraph case, since the pointer cannot point to two divisions of the scale at the same time, the coding of a number of different states of a process, some of which may occur at the same time, is more complicated.

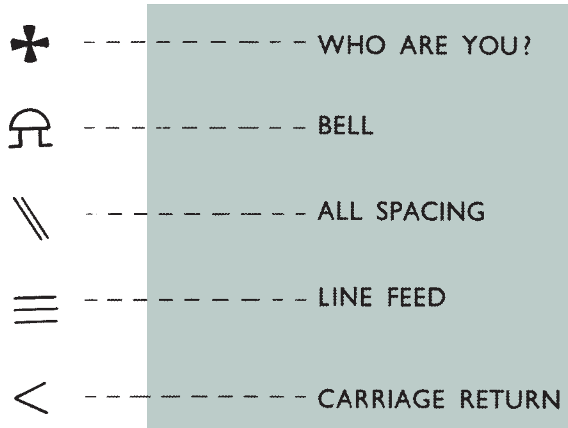


Fig. 12. Functional Signs

It will simplify the discussion to introduce the following technical terms :

Disjunctive information : this consists of items of information no two of which can occur at the same time.

Conjunctive information : this is made up of items of information any of which may occur at the same time.

Mixed information : this consists of both disjunctive and conjunctive items of information.

(It follows from these definitions that telegraph intelligence is of the disjunctive kind).

To take first the coding of disjunctive information. As there are thirty-two combinations available with the 5-unit code, thirty-two distinct items of information can be coded if one item of information is allocated to each code combination. Thus, the scale of an instrument could be divided into thirty-two parts and each division of the scale represented by one combination. If greater accuracy is required, two successive combinations can be allocated to each item of information and one combination reserved to discriminate between the combination pairs (e.g. the 'all-spacing' combination). This would give 31^2 or 961 divisions.

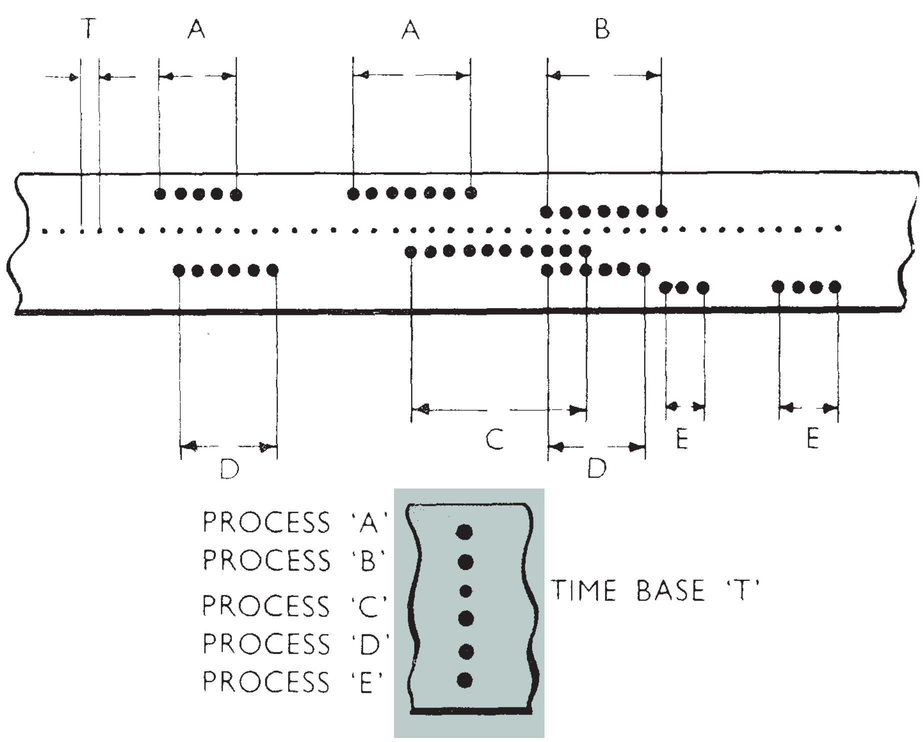


Fig. 13. Conjunctive Coding First Method

The capacity of the 5-unit code for coding *conjunctive information* is more restricted. Using the most straightforward method of coding, only five conjunctive items of information can be coded. This is effected by representing each item of information by a series of punched holes in one of the five code tracks (see Fig. 13). A sixth item of information, if this is a continually repeated item such as a fixed lapse of time or a fixed distance, can be represented by using the feed holes for the purpose. Various methods may be employed to increase the number of conjunctive items of information that may be coded. For example, nine sources of information may be coded by using four of the code tracks for eight items of information, the items being punched in two successive groups of four, and the feed holes used to represent time or distance as before. The fifth track is reserved for discriminating between the first and second group (see Fig. l4). This method of coding may be extended to code 13, 17, etc. items of information, with a corresponding reduction in the speed of recording as the number of items increases.

To code *mixed information*, the most straightforward method is to separate the informa-

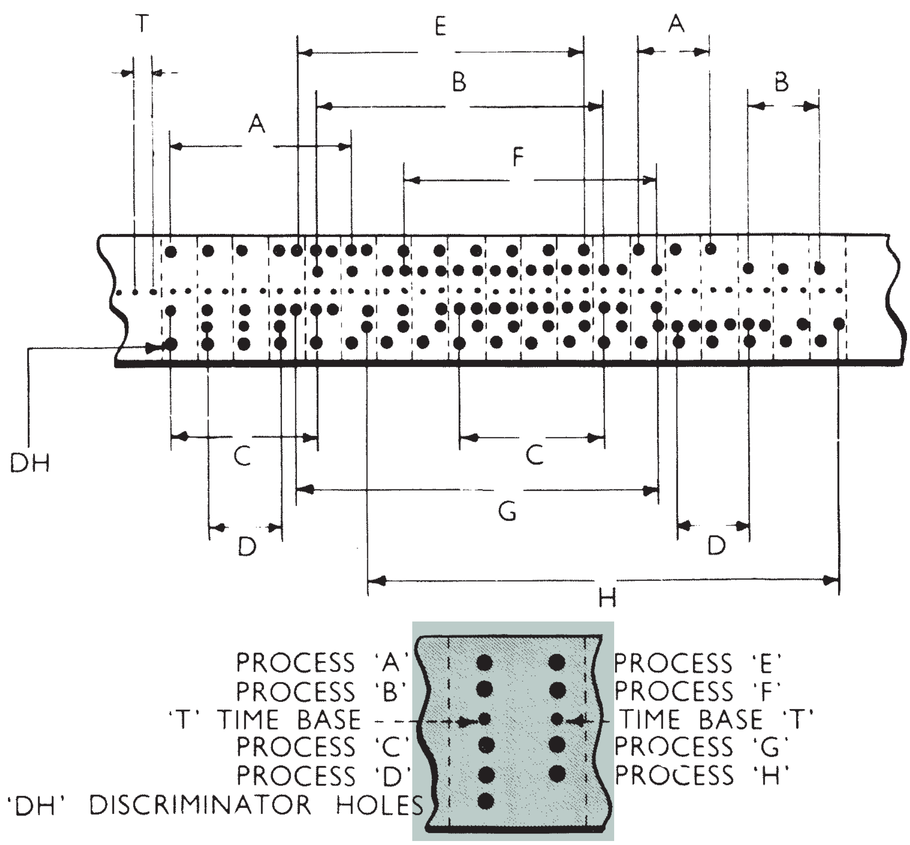


Fig. 14. Conjunctive Coding Second Method

To code *mixed information*, the most straightforward method is to separate the information into its disjunctive and conjunctive parts and use a mixture of the coding procedures already described for these kinds of information. Thus, the first two tracks could be utilised for coding three disjunctive items of information using a 2-unit code, and the remaining three tracks utilised for three conjunctive items of information. The feed holes could be used, as before, to represent time or distance. (See Fig. 15).

In the foregoing discussion only a small selection of the possible methods of coding information for automatic data recording systems has been given, and these have all been based on the use of 5-unit tape. Considerably more information may be coded by the recently introduced 6- and 7-unit versions of the Model 25 Reperforator (see p. 38). The principles of coding on this new reperforator, however, are the same as those given above.

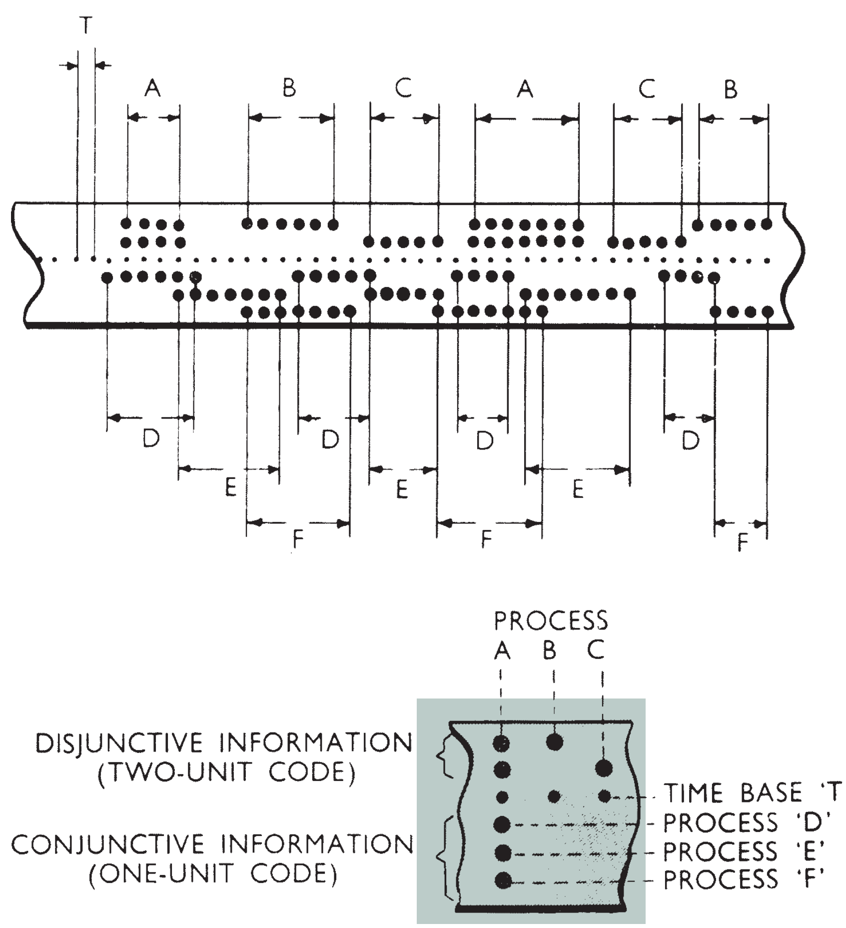


Fig. 15. Mixed Coding

FIGURES CASE	LETTERS CASE	TAPE 5 4 3 2 1	BINARY VALUE	DECIMAL VALUE
FIGURES SHIFT		·	0	0
1	A	· ●	1	1
2	B	· ●	10	2
*	C	· ● ●	11	3
4	D	● ·	100	4
(	E	● · ●	101	5
)	F	● · ●	110	6
7	G	● · ● ●	111	7
8	H	● ·	1000	8
≠	I	● · ●	1001	9
=	J	● · ●	1010	10
−	K	● · ● ●	1011	11
ʋ	L	● ● ·	1100	12
L.F.	M	● ● · ●	1101	13
SP	N	● ● · ●	1110	14
,	O	● ● · ● ●	1111	15
0	P	● ·	10000	16
>	Q	● · ●	10001	17
≥	R	● · ●	10010	18
3	S	● · ● ●	10011	19
→	T	● ● ·	10100	20
5	U	● ● · ●	10101	21
6	V	● ● · ●	10110	22
/	W	● ● · ● ●	10111	23
X	X	● ● ·	11000	24
9	Y	● ● · ●	11001	25
+	Z	● ● · ●	11010	26
LETTERS SHIFT		● ● · ● ●	11011	27
•	•	● ● ● ·	11100	28
ɲ	?	● ● ● · ●	11101	29
C.R.	£	● ● ● · ●	11110	30
✗	✗	● ● ● · ● ●	11111	31

Fig. 16. A computer input-output code

Computer codes, like the ordinary teleprinter code, follow the principle of disjunctive coding, but the items of information are allocated to the different code combinations in such a way as to simplify the detection of errors and to satisfy other operating requirements.

A detailed discussion of this subject cannot be given here, but the main requirements for a good computer code can be seen from a study of Fig. 16, which gives the code employed by a leading computer manufacturer.

It will be noticed in the first place that the combinations are listed in order of their equivalent numerical values, 'holes' being taken to represent the 1's and 'no-holes' the 0's of binary numbers. The convention is adopted that the first teleprinter element of each code combination corresponds to the least significant digit of the associated binary number. Thus, the combination MSMMS corresponds to the binary number 01101.

The letters case contains the alphabet, full-stop, question mark, pounds sign and erase sign. The figures case contains the decimal digits, a number of arithmetical symbols, a range of programming symbols, the full-stop-which is used for the decimal point-the erase sign and space. The figures and letters case-shift functions appear in both cases as with the International Alphabet No. 2 (see Fig. 4) and for the same reasons.

The allocation of code combinations to these 61 characters and functions is carried out in the following way :

(1) The twenty-six letters of the alphabet are coded by assigning to them the combinations whose numerical equivalents correspond to their positions in the alphabet. Thus, 'V' which is the twenty-second letter of the alphabet, is coded by 10110 (i.e. SMMSM), the binary equivalent of 22. The object of this is to simplify alphabetical sorting.

(2) The decimal digits, together with the most important arithmetical symbols and teleprinter functions, are coded by combinations having an odd number of holes. This provides a very useful safeguard against the most common teleprinter faults, viz. the substitution of a mark for a space ('extra') and of a space for a mark ('failure'). When either of these faults occurs in a combination having an odd number of holes, it always turns into one with an even number. Hence, the items of information whose combinations have an odd number of holes cannot be changed into other items of the group, but only into some other more easily detected items.

This odd-parity condition leaves scope for imposing a further condition on the allocation of code combinations to the decimal digits. Since there are only ten decimal digits, they may be coded by the first four significant digits of the corresponding binary numbers, the fifth significant digit being disregarded. Thus '0' is coded by '0000', '1' by '00001', '2' by '00010', '3' by '10011' and so on. When such combinations pass into the computer, they are first checked for odd-parity and then the fifth significant digit is ignored.

(3) Erase is coded by five holes, i.e. the all-marking combination. Punching errors are eradicated by overpunching with the erase combination. When this combination is fed into the computer, it is ignored.

(4) The figure-shift signal is coded by blank tape, i.e. by an all-spacing combination, so that on input the blank tape before the perforations automatically sets the computer into an assigned condition.

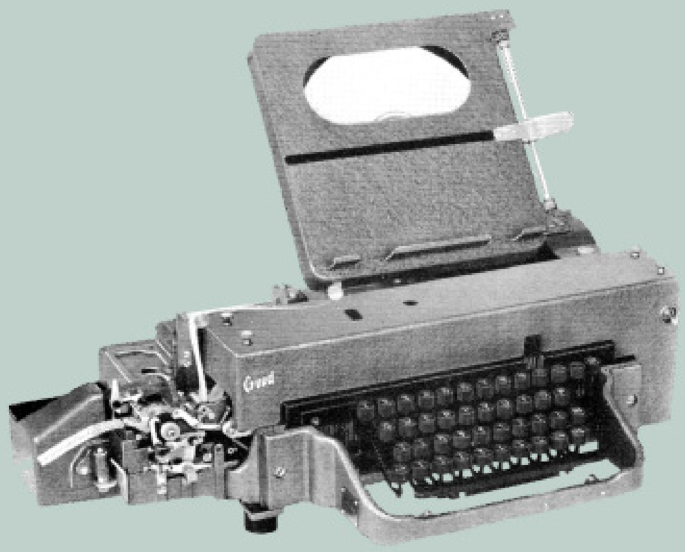


Fig. 17. Model 7P/N Keyboard Perforator

KEYBOARD PERFORATORS

A keyboard perforator is an instrument for manually preparing punched tape.

There are two main methods of doing this:

(1) On a Model 7P/N Keyboard Perforator (See Fig. 17), which produces 11/16 in. wide, fully perforated tape. The maximum speed obtainable is 140 words per minute, i.e. 14 characters per second, but no print-out is provided.

(2) On a Model 54 Teleprinter fitted with a perforating attachment (See Fig. 24). This also produces 5-unit, 11/16 in. wide, fully-perforated tape under the control of a 3-row or 4-row teleprinter pattern keyboard. The speed of punching is less than in the previous method, viz. 66 words per minute or 6-2/3 characters per second, but in this case a printed page record is provided, thereby enabling a relatively unskilled operator to prepare tape.

The *Model 7P/N Keyboard Perforator* consists of a keyboard identical in design to a normal teleprinter keyboard, a perforator unit controlled by the keyboard, a tape roll holder and a motor to power the perforator unit.

The principle of operation is, very briefly, as follows : the depression of a key sets up the corresponding code on five combination bars which extend under all the keybars. The combination bars have saw teeth cut in their upper edges in such a way that marking bars are moved in one direction and spacing bars in the other. The combination bars control five anvil bars on the perforator unit situated beneath five vertical tape punches, marking anvil bars being positioned under the corresponding punches and spacing anvil bars being moved clear of their punches.

The tape emerges from a tape roll holder and is guided by rollers to the perforator unit, where it passes over the top of the five code punches and a sixth feed hole punch. Thence it passes over a toothed sprocket wheel which engages in the feed holes in the tape and draws the tape forward once in each cycle of operations.

The tape, tape punches and sprocket wheel are caused to move downwards and then upwards again, once for every key depression, by a cam which is powered by the motor and released indirectly by the key depressed. During the downward movement, the punches above the marking anvil bars are arrested by the anvil bars and perforate the tape, whereas the punches above the spacing anvil bars miss the bars and no perforation takes place. A sixth anvil bar, fixed in position under the feed hole punch, causes a feed hole to be punched for every key depression. The tape is then fed forward by the sprocket wheel as the punch assembly is raised to the rest position.

The following facilities are also provided on the keyboard perforator :

(1) *Back Space Key.* This key is fitted to the perforator unit and is provided to enable the operator to correct any errors he has made in preparing the tape. The method of doingthis is as follows : when one or more faulty combinations are perforated in the tape, the operator repeatedly depresses the Back Space key until the leading faulty combination is over the punches of the perforator unit. The 'Letters' case-shift key is then repeatedly depressed or, alternatively, the 'Letters' case-shift key is depressed once and the 'RunOut' key is held down, until all the erroneous combinations have been over-punched with the all-marking combination. The correct message is then punched after the last all-marking combination.

When the tape is subsequently put into an automatic transmitter and the message transmitted to a distant receiver, the all-marking combinations will be registered by the receiver merely as 'Letters' case-shift signals, nothing being printed and the carriage feed being suppressed, i.e. no sign of the erroneous combinations will appear in the received message.

(2) *End-of-Line Indicator*. An End-of-Line Indicator is fitted to the keyboard perforator for use when tape is prepared which will be subsequently used to control an automatic transmitter transmitting to a page receiver. An automatic warning is given to indicate to the operator when to depress the Carriage Return key. This warning is given by a 6-volt lamp which can be seen through a plain transparent window in the top of the machine cover immediately below the message desk. The lamp lights up when a counter unit on the keyboard completes an electric circuit, after recording fifty-five key-depressions from the previous depression of the Carriage Return key. (The standard teleprinter page receiver prints sixty-nine characters on a line). A further depression of the key then resets the counter mechanism and extinguishes the light.

The Model 54 Teleprinter method of preparing tape depends on the use of a perforating attachment, almost identical to that used on the Model 7P/N Keyboard Perforator, which is fitted on the left-hand end of the teleprinter keyboard. (see Fig. 24). This attachment is not controlled directly from the keyboard, however, but indirectly from the receiver. This permits it to be used as a reperforator, i.e. to be used for punching tapes from signals passed to the receiver from an external automatic transmitter.

A switch is provided on the perforator unit to enable the operator to switch the attachment in or out of use as desired.

A Back Space Key is also provided to give the error correction facility already described above in connection with the Model 7P/N Keyboard Perforator.

End-of-line indication is, in this case, provided by an end-of-line switch on the carriage, which may be arranged to ring a bell or light a lamp as the carriage nears the end of a line. The light is extinguished as the carriage returns to the beginning of the next line.

TAPE READERS
(AUTOMATIC TAPE TRANSMITTERS)

A teleprinter tape reader or automatic tape transmitter is an instrument for translating the 5-unit code combinations perforated in a tape, of either the fully-punched or `chadless' kind, into single- or double-current electrical signals.

There are various kinds of tape readers, each designed to perform some specific functions. They may be classified as follows :

(1) Single-head, single-wire tape readers.
(2) Single-head, multiple-wire tape readers.
(3) Multiple-head, single-wire tape readers.
(4) Multiple-head, multiple-wire tape readers.

Single-head tape readers are so-called because they consist of a single tape-reading head and driving motor mounted together on a base.

Multiple-head tape readers consist of more than one tape reading head ganged together on a common base and driven by a common motor.

Single-wire tape readers translate the code combinations in the tape into a single train of electrical impulses for transmission on a single wire. They automatically insert the 'Start' and `Stop' impulses at the beginning and end respectively of each 5-unit code combination.

Multi-wire tape readers translate the 5-unit code combinations in the tape into five separate trains of impulses, one for each code element, the five impulses for each combination being transmitted simultaneously on a five-wire output. Additional wires are used for circuit control purposes, e.g. for tripping the transmitter, providing a return path, etc.

In general, single-wire tape readers are used in telegraphic applications, e.g. tape relay systems, whereas multiple-wire tape readers are used as inputs to digital computers and for other non-telegraphic purposes.

The normal speed of transmission for all these tape readers is 50 bauds, i.e. 66 or 72 w.p.m. for 7½ and 7-unit transmission respectively. The multi-wire tape readers can readily be adapted, however, for much higher speeds of transmission.

Single-head, Single-wire Tape Readers

The standard Creed single-head, single-wire tape reader (Model 6S/5) consists of a tape reading head, tape control unit and a motor mounted together on a 15" X 72" base. (See Fig. 18).

The *tape reading head* consists of a striker type transmitting mechanism for sensing the punched holes in

Fig. 18. Model 6S/5 Tape Reader

the tape and converting these into a sequence of electrical impulses (with the 'Start' and 'Stop' impulses automatically inserted), and a step-by-step mechanism for feeding the tape. The head accepts standard $^{11}/_{16}$ in. tape, fully-perforated or `chadless', and of the 'advanced' or 'centre' feed hole type. It may also be adjusted to take $^{7}/_{8}$ in. wide tape as shown in Fig. 11.

The tape control mechanism is a device for automatically stopping the tape feed mechanism when the tape becomes taut, in order to prevent tape mutilation or breakage. The tape feed automatically starts again when the tape slackens.

The motor is a 1,500 r.p.m. governed motor.

Two special facilities can be fitted to the tape reader :

(1) *Tape-Out Contacts.* These are utilised to give a visual or aural warning when the end of the tape has passed through the tape reader head.

(2) *Magnetic Clutch Control*. This is a device for permitting the tape reader clutch, and hence the trip of the punching cycle, to be remotely controlled. Tape readers fitted with this device are given the model number 6S/5M.

Single-head, Multi-wire Tape Readers

Two single-head, multi-wire readers are in production :

(1) The Model 92 high-speed five-wire tape reader which is electromagnetically operated.

(2) A motor operated tape reader.

The *Model 92 Tape Reader* (See Fig. 19) reads standard $^{11}/_{16}$ in. wide, 5-unit, fully-punched tape with advanced or centre feed holes, at speeds up to 20 characters per second, and provides either a single- or double-current five-wire output.

The tape is controlled by an electromagnet which is pulsed from an external source. The electromagnet armature, when it operates, feeds round a ratchet which, in turn, rotates a sprocket feed wheel by one tooth. The five reading peckers trail over the tape as it moves forward, rising rapidly into the holes of the tape when they present themselves. An extension on the underside of each pecker moves a metal tongue between two contacts, thereby converting the punched code into electrical signals.

This mode of operation (electromagnetically controlled tape feed with trailing peckers) has the advantage that no motor is required.

The tape reader is, in consequence, simple, light (7 lbs. approx.) and small (6" x 8 $^{9}/_{16}$" x 33").

An additional contact is fitted to the armature of the electromagnet which makes when the tape feed takes place.

This can be used to indicate to the external control that the tape has moved forward to the next character and that the code is being read.

'Tape Out' contacts are provided which automatically stop the tape reading operation

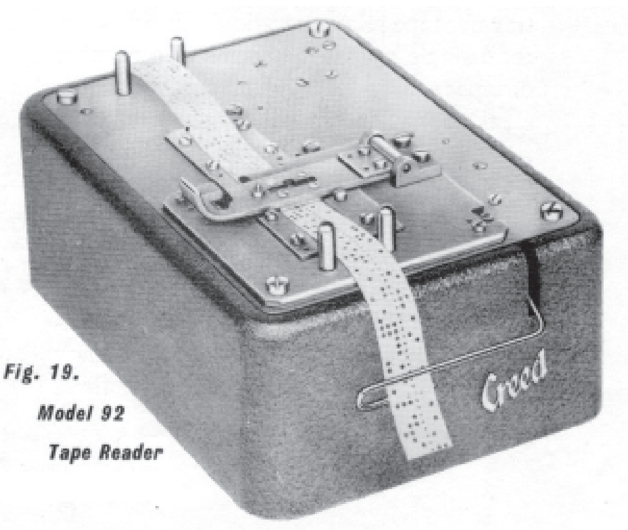


Fig. 19. Model 92 Tape Reader

when the tape has passed the sensing point ; also, 'Taut Tape' contacts are fitted which arrest the feeding mechanism if the tape becomes taut, in order to prevent mutilation or breakage. The tape feed is automatically resumed when the tape slackens.

The *motor operated five-wire tape reader* is designed to provide a 5-wire output at 50 or 100 bauds and uses 7.42 unit transmission, i.e. its maximum speed of operation is 13½ characters per second. It is suitable for fully-perforated or 'chadless' tape with `centre' or `advanced' feed holes.

The tape reader consists of a tape reading head and a driving motor, mounted on a common base. The tape reading head consists essentially of a driving gear, a driven cam sleeve, an electromagnetically controlled ratchet-clutch for tripping and arresting the sleeve, a number of cam operated levers, and a bank of seven electrically independent contacts. Five of these contacts are under the control of the code sensing peckers, the marking contacts being arranged to close when the corresponding sensing peckers pass through a hole in the tape. The closing of the marking contacts takes place simultaneously, so that the marking pulses of each code combination are likewise transmitted simultaneously on the corresponding output wires. A sixth contact lever is closed by a lever working off a cam of the cam sleeve and transmits a trip signal for each code combination on a separate output wire. The seventh contact is similarly operated; when the tape runs out, to provide a signal to indicate this condition.

On the 50-baud model of the reader, the cam sleeve makes a complete revolution for each code transmission. The increased speed of the 100-baud model is obtained by employing a half-revolution cam sleeve. This permits the motor and driving gears to be identical in the two cases.

For special applications, this reader may be fitted with a mechanism for reversing the feed of the tape under the control of an electromagnet-type switch.

Multiple-head, Single-wire Tape Readers

For many applications, e.g. manual transfer tape relay operation, it is necessary for a single operator to control a number of tape reading heads. To secure maximum efficiency in this, it is advantageous to 'gang' several tape reading heads together, i.e. mount them in close proximity together on the same base and drive them by the same motor. This practice also effects important economies in space and components.

The multiple-head tape readers manufactured by Creed & Company are 3-gang tape readers, i.e. they consist of three tape reading heads ganged

Fig. 20. Model 71 3-Gang Multiple Tape Reader

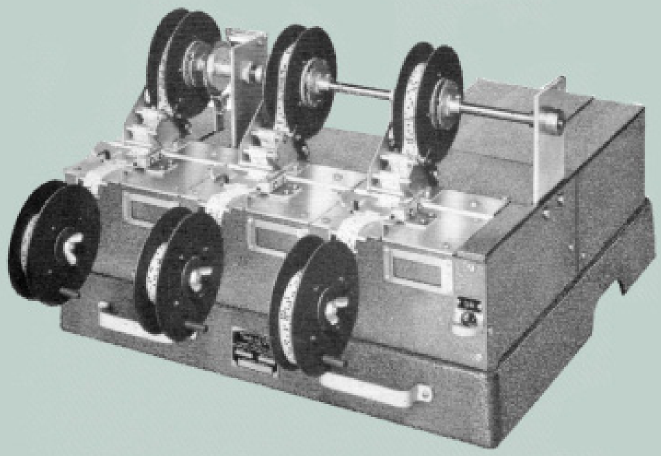


Fig. 21. Model 72 Multiple Number Tape Reader

together on a common base and driven by a common motor.

In tape relay operation, two kinds of tape reading heads are required, viz., message transmitting heads and message serial number transmitting heads, and Fig. 21. Model 72 Multiple Number Tape Reader it is also advantageous, for the reasons given above, to gang these two kinds of head together in various combinations.

The standard combinations used and their Creed model numbers are as follows :

71 D-comprising three message transmitting heads. See Fig. 20.

7213-comprising three number transmitting heads. See Fig. 21.

7413-comprising two message and one number transmitting heads. See Fig. 22.

These models of the Creed multiple-head, single-wire tape reader are known generically as the 'Creed 3-gang Multiple Tape Reader'.

In addition to the three tape reading heads and motor, each machine comprises a relay unit, mounted to the rear of the main base, the contents of which may be varied to suit particular circuit requirements.

The *message transmitting heads* are similar in design to the multiple-wire tape reading heads described in the last section. The five code contacts, however, are connected in parallel instead of being independent and the cams controlling these contacts are arranged sequentially to provide a sequential single-wire output. The trip contacts are replaced by Start-Stop contacts which automatically insert the Start and Stop signals at the beginning and end of the code signals. The speed of transmission is 50 bauds, employing 7.42 units per character, and the heads are suitable for either $^{11}/_{16}$ in. wide fully-perforated or 'chadless' tape with either 'centre' or 'advance' feed holes. Modified versions are also available which accept $^{7}/_{8}$ in. wide tape. A single-current output is produced, but this can be converted to double-current, if required, by including a polarised relay in the relay unit.

Each message transmitting unit is fitted with a Start Key, which is manually operated to prepare the unit for transmission. To do this, the Start Key is first depressed. This frees the tape wheel so that the tape may be placed in position without raising the tape retaining plate and, simultaneously, breaks a pair of start contacts. The key is then released again, thereby closing the start contacts which, according to the state of the circuit, either initiates the transmission or presets the unit for subsequent transmission.

Each unit is also fitted with tape-out contacts controlled by a tape-out pecker. These are provided to detect the end of a message, the contacts being arranged to open when the tape runs out. They are closed automatically when the Start Key is depressed and remain closed when the key is raised again.

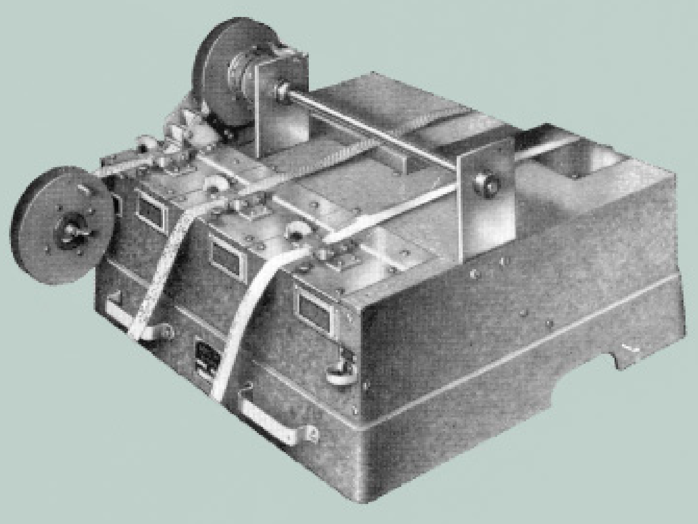


Fig. 22. Model 74 Multiple Message and Number Tape Reader

The number transmitting heads are closely similar to the message transmitting heads. The main differences are as follows :

(1) *'Letters' sensing Contacts.* The contacts which are used on the message transmitting unit as tape-out contacts have the function, on number transmitting units, of registering the `Letters' combination, which is perforated in the numbering tape immediately after each serial number. These contacts, when fitted to number transmitting units are, therefore, referred to as 'Letters Sensing Contacts' and have the function of registering the end of a serial number transmission.

The tape sensing mechanism which controls these contacts may be modified to make the contacts register the presence of any combination in the tape. This is of special use in certain non-telegraphic applications of the multiple tape reader.

(2) *Serial Number Suppression*. The start key on number transmitting units is slightly modified in order to provide for the facility of suppressing the transmission of serial numbers by depressing and latching the start key.

(3) *Numbering Tape.* The number transmitter is equipped externally with a tape storage reel to carry the numbering tape, and a take-up reel to store used tape in readiness for re-winding. This tape may be either a normal tape or a special hard-wearing tape which is suitable for repeated use.

Multiple-head, Multiple-wire Tape Readers

Multiple-wire tape reading heads of the kind described on page 32 may be ganged together on standard Creed 3-gang bases, to economise in space and components.

This arrangement may also be used to read information in 10- or 15-unit code on two and three tapes `in parallel' respectively.

PERFORATOR-READERS

A perforator-reader is a combined instrument consisting of a keyboard perforator (see Fig. 17) and a single-head, single-wire automatic tape reader (see Fig. 18) mounted on the same base and driven by a common motor. The standard Creed perforator-reader is a combination of the 7P/N Keyboard Perforator and the 6S/5 Automatic Tape Reader and is known as the Model 67P/N Perforator-Reader.

The tape issuing from the keyboard perforator part of the instrument is fed directly into the tape reading head via a tape control unit. This automatically stops the revolution of the reader camshaft and the feed of the tape in the tape reading head when the tape becomes taut after the operator stops typing, and thus prevents the tape from breaking.

The various facilities separately described on pages 28 and 30 are all retained on this combined instrument.

REPERFORATORS

A reperforator is an instrument for automatically converting coded electrical impulses into perforations in a tape. It thus has an opposite function to that of an automatic tape reader.

This reversal of function and the fact that automatic tape readers and reperforators are usually required to interoperate, determine the main characteristics of reperforators. Thus, corresponding to the fact that automatic tape readers may have single- or multiple-wire outputs, reperforators may have single- or multiple-wire inputs. Again, corresponding to the fact that automatic tape readers may accept fully-perforated, ‘chadless’, or ‘printed and fully-perforated’ tape, so there are reperforators to produce the three kinds of tape. In the latter case there is, however, a difference. Whereas the same automatic transmitter may be adapted to accept the three kinds of tape, different Creed reperforators are required to produce them.

The types of reperforators available for use with Creed punched tape equipment may, accordingly, be classified as follows :

(1) Single-wire, non-printing reperforators (for fully-perforated tape).
(2) Single-wire, printing reperforators (for `chadless' tape or `printed and fully-perforated' tape).
(3) Multiple-wire, non-printing reperfoartors (for fully-perforated tape).

As a rough general rule, the single-wire reperforators are used in telegraphic applications with single-wire automatic tape readers, whereas the multiple-wire reperforators are used in non-telegraphic applications with the corresponding type of automatic tape reader.

Single-wire, Non-Printing Reperforators

Two models of this kind of reperforator are in current production :

(1) Model 7TR/3, which is a selfcontained machine. (See Fig. 23).
(2) An attachment which may be added to either of the standard Creed teleprinters (Models 7 and 54). This attachment converts these teleprinters to reperforators of the kind under discussion. It also, however, permits them to be used as keyboard perforators for preparing punched tape with a local printed record of the perforations. (See Fig. 24).

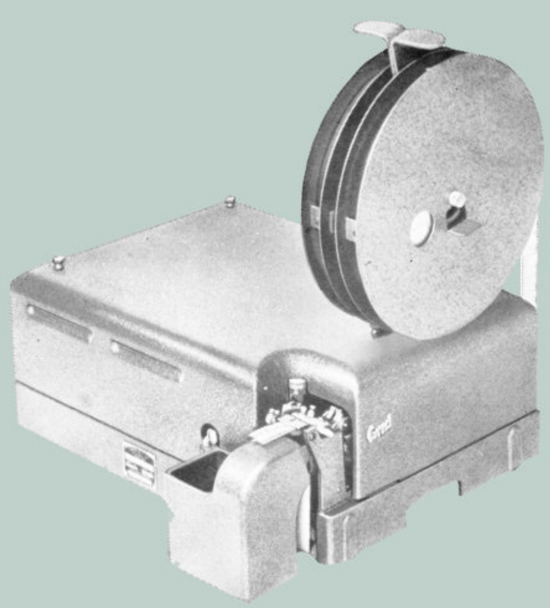


Fig. 23. Model 7TR/3 Non-Printing Reperforator

The Model 7TR/3 Reperforator is designed to punch tape from a single-wire input from either 7- or 72-unit transmitters, the standard operating speed of the machine being 50 bauds.

The reperforator consists of a receiving electromagnet, the armature of which registers the incoming signals as in a teleprinter, coupled to a teleprinter-type selector mechanism. The Start and Stop signals trip and arrest a cam sleeve which controls the selector and punching processes. The code signals, instead of being converted into a code setting of five vertical fingers, as in a teleprinter receiver, are converted into a setting on five punching levers, marking levers being set to engage their punches and spacing levers to miss their punches when the punching levers are operated by a lever working on one of the tracks of the cam sleeve. The tape is fed forward by a step-by-step mechanism in the usual manner. The power for these operations is derived through a number of reduction gears from a governed motor.

The reperforator is equipped with the following special features :

(1) *Run-Out Key*. This is provided to permit the tape to be fed through the punch block continuously under power.

(2) *Automatic Starter*. To permit the reperforator to be left unattended, it is fitted with a unit which automatically starts the motor on receipt of a Start signal and stops it again if no signal is received for a period of 1/2 to 1 1/4 minutes after the end of the transmission.

(3) *Tape Roll Holder*. This can be provided to accommodate either one or two tape rolls, ac cording to whether one or two tapes are to be punched.

The Reperforating Attachment consists of a perforator unit that is almost identical to the perforator unit on the keyboard perforator described on page 28, a tape roll holder and cuttings chute and two perforator control mechanisms.

One of these control mechanismsthe selector control mechanism-consists of a set of -five Bowden cables with plungers at each end. These cables transfer the code combinations set up on the receiver comb extensions to the perforator unit anvil bars. Thus, all the combinations received by the teleprinter are reproduced on these bars. The other mechanism-the trip control mechanism-consists of a sixth Bowden cable, a plunger of which is pushed in once for every combination registered by the

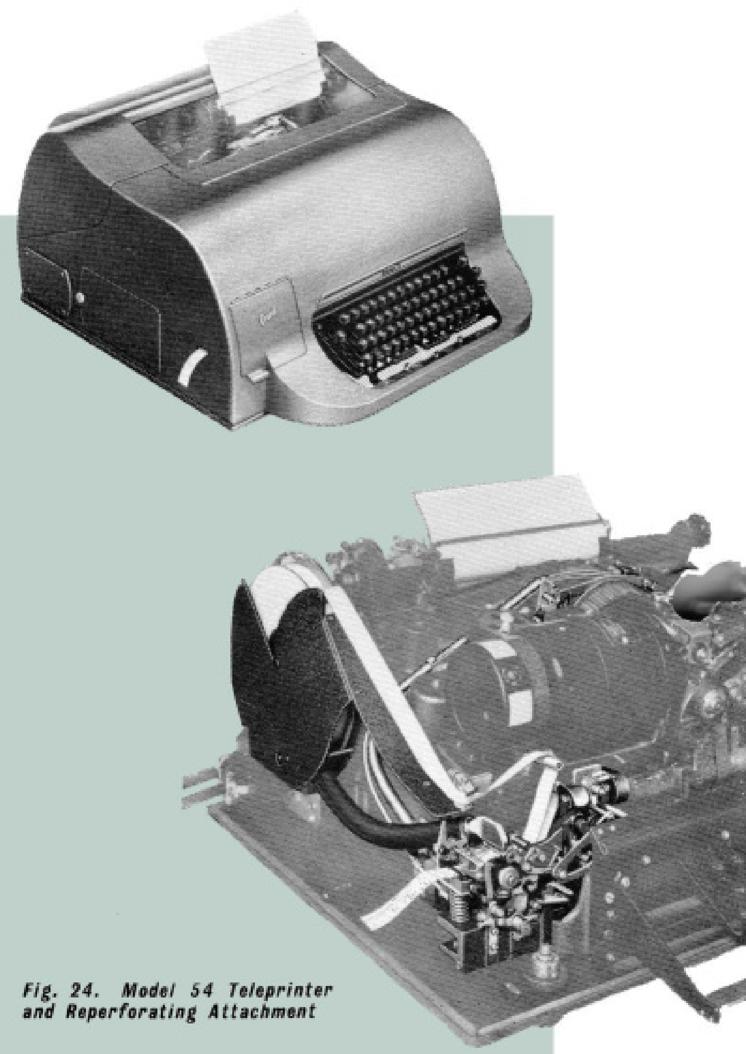


Fig. 24. Model 54 Teleprinter and Reperforating Attachment

Provision is made to interrupt the perforator unit trip whenever the `Bell' or `WRU' combinations are received and whenever the local answer-back unit is transmitting, since it is normally desirable that these should not appear in the tape.

Single-wire, Printing Reperforators

Printing reperforators produce a printed and a punched record of incoming signals simultaneously on the same tape, i.e. they record signals on tapes either of the 'chadless' or 'fully-punched and printed' kinds (see Figs. 10 and 11). Creed & Company manufacture reperforators to produce each of these tapes, viz. the Model 85 Reperforator (See Fig. 25) to produce the `chadless' tape and the Model 86 Reperforator the wide tape.

The two models are closely similar and are both modified versions of the Creed Model 7 teleprinter. The normal control unit and page attachment unit are replaced by a new control unit and perforator unit. A tape roll holder with a tape exhaust alarm is added on the right-hand side of the machine and various minor alterations are made to the combination head and ribbon feed brackets.

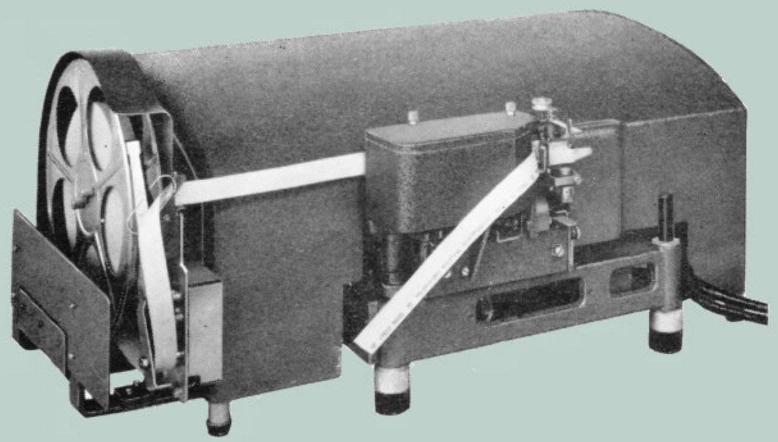


Fig. 25. Model 85 Printing Reperforator

Five new types are used in the typehead, viz. the 'Who-are-You?', 'Carriage Return', 'Bell', 'Line Feed' and 'All Spacing' types (see Fig. 12) so that every combination may have a printed equivalent. This simplifies the reading of the tape, and leaves the operator in no doubt of the exact nature of the message.

As with the reperforating attachment, the code combinations registered by the receiver are transferred from the combination head comb extensions to the perforator unit. Unlike the reperforating attachment, however, the punching and tape feeding are actuated directly from the receiver cam unit.

On the Model 86, the perforator unit is raised a little so that the printing can be done under the perforations. Also, to take the wider tape, the tape roll holder differs in certain respects from that on the Model 85.

Multiple-wire, Non-Printing Reperforators

Reperforators of this type are of considerable use in non-telegraphic applications, one of their chief functions being to serve as a part of the output equipment for digital computers. When employed for this latter purpose, their most important characteristic must be speed. Another important application of this type of reperforator is to automatic data recording, which is described on page 22. In this case the most important consideration is the amount of information which may be coded.

The standard Creedfp multi-wire, non-printing reperforator (See Fig. 26) is the Model 25. This machine is designed to perforate one or two tapes in 5, 6 or 7-unit code, 11/16 in. wide tape being used for 5-unit code and 7j8 in. wide tape for 6 and 7-unit codes. The maximum speed of operation in all three cases is 30 characters per second for pulsed operation and 333 characters per second for synchronous operation.

The reperforator operates from an input of the following kind

Code Signals : 50 or 100V d.c. pulses with a duration of at least 27 m.secs.

Trip Signal : 50 or 100V d.c. pulses commencing 2 m.secs. after the code signals and with a duration of 15-30 msecs.

Each code unit requires a separate input wire, one wire is required for the trip signal and one more for the common return path. Thus, for a 7-unit code nine input wires are needed. The power for the punching and tape feeding operations is derived from a 1,500 r.p.m. Fracmo, synchronous-type motor, the power consumption of which is approximately 15 watts. This motor can be supplied for 115V, 220V or 230V, 50c/s power supplies.

Each code input wire is connected to an electromagnet, whose armature controls, via a system of links, the position of a selector lever, which is pushed beneath a paper punch when the magnet is marking (i.e. energised) and is withdrawn from its paper punch when the magnet is spacing (i.e. de-energised). The trip signal wire is connected to one or other of two clutch trip magnets through a cam-operated change-over switch. These magnets are positioned on opposite sides of the main camshaft, their armatures having extensions attached to them which act as detents for a ratchet clutch. Incoming trip signals thus trip the magnets alternately through the action of the change-over switch, thereby causing the cam shaft to rotate a half revolution for each trip signal. During this half-revolution a cam on the camshaft causes a tape feed mechanism to feed the two tapes forward one feed hole pitch and, immediately afterwards, a punching lever, operated by a crank mechanism on the end of the camshaft, pushes the selector levers upwards. The marking selector levers, i.e. those levers that were positioned under the paper punches by the energised code signal magnets, are thereby made to push the corresponding paper punches through the two tapes. The tape feed mechanism is then reset, the punching lever lowered and the camshaft is arrested by one of the trip detents.

Fig. 26. Model 25 High-Speed Reperforator

Two standard 340 yd. length tape reels are housed in separate drawers in the base of the machine. Each drawer contains a tape-out alarm device which may be pre-set to give a warning indication when the tape is running low. The warning indications are given by two neon lights on the front of the reperforator, the power for which is derived from the motor supply.

A pair of contacts which operates off the main camshaft is provided to give a synchronising pulse, e.g. to the computer. The pulse may be adjusted to occur at any instant in the trip cycle. Each of the code magnets is also fitted with two pairs of contacts.

A modified version of the Model 25 Reperforator, the *Model 25X, Slow-speed, Solenoid-operated Reperforator*, is also in production. This machine is designed for use in process control and data recording applications in which a slow speed of operation is permissible and in which the reperforator is required to remain idle for relatively long periods although it must operate instantly when called upon to do so.

Under these conditions it is unsatisfactory to power the punching and tape feeding operations by means of a motor, which would have to run for long periods while the machine was otherwise idle as its starting time is too long to permit it to be switched off. In its place, therefore, a solenoid is used, operated by a pilot relay which, in turn, is operated by an externally applied pulse. The reperforator is designed to perforate a single 5-unit, 11/16 in. wide tape at a maximum speed of 3 characters per second. The trip and code pulses are each 100-150 ms. long and in the same phase, the applied voltages and currents for the pilot relay and code magnets being 50V and 50 mA D.C. respectively. The solenoid itself is designed to operate on 110V, 50c/s A.C.

AUXILIARY EQUIPMENT

In addition to the main items of punched tape equipment described above there are a number of auxiliary items, viz. the tape winder, the signalling rectifier and unipunch.

Tape Winder

The High Speed Tape Winder (see Fig. 27) is designed to wind a complete reel (340 yards) of $^{11}/_{16}$ in. or $^{7}/_{8}$ in. wide tape at a maximum speed of 360 in./min. i.e. 60 characters per second. The complete reel is wound on at a uniform winding tension of 500 gm. i.e. the winding tension is independent of the radius of wind and is comparable to that of an unused reel of tape. This, and the provision of a loose centre for each reel permits fully or partially-wound reels to be removed from the metal guide cheeks of the spool, handled and stored, without the need for side supports.

The winder is powered by a motor having a free speed of 6000 r.p.m., which may be supplied to operate from any voltage in the range 115-250V with variations within ±10% of nominal. Its maximum power consumption is 45 watts.

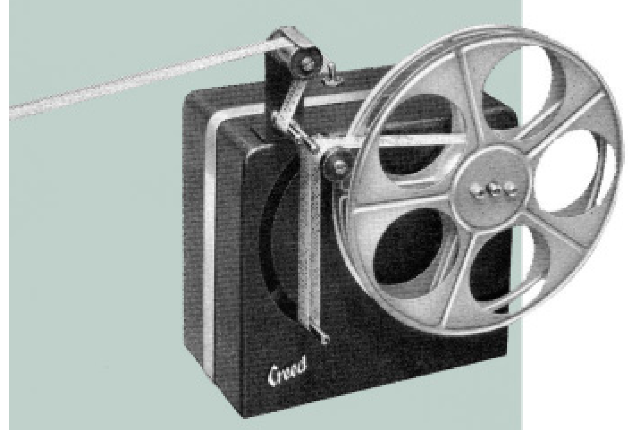


Fig. 27. High Speed Tape Winder

A Slow-speed, Solenoid-operated Tape Winder is also available primarily for use in association with the Model 25X Reperforator. This winder is designed to wind 5-unit, 11 /16 in. wide tape at a maximum speed of 3 characters per second.

Signalling Rectifiers

To provide the d.c. signalling supplies for Creed telegraphic equipment, three models of d.c. rectifier are in production :

Unipunch

Type 5.5060: Input 100-250V, 50c/s	
(See Fig. 28) Outputs	+80V 0V -80V Unprotected
	+80V O V -80V Protected
	(Total current 60mA)
	6V. IA, A.C.
Type 5.5120: Input	100-250V, 50c/s
Outputs	2x +80V 0V -80V Protected
	(Each output 60mA)
	6V. 1A, A.C.
Type 5.5180:	Input 100-250V, 50c/s
Outputs	3 x +80V OV -80V Protected
	(Each output 60mA)
	6V. 1A, A.C.

The 6 volt, 1 amp a.c. outputs are provided to supply external bell circuits, if these are used. The output voltages of +80V OV -80V are in each case obtained from full-wave metal rectifiers, a separate rectifier stack being used for each output of 80 volts, positive or negative. Adequate regulation and smoothing are ensured by the use of 3H chokes and capacitors in each output.

Circuit protection is provided by the inclusion of fuses in each leg of both input and output circuits. In addition, protection lamps are included in each 80 volts d.c. leg to limit the current to a safe value if a short circuit occurs.

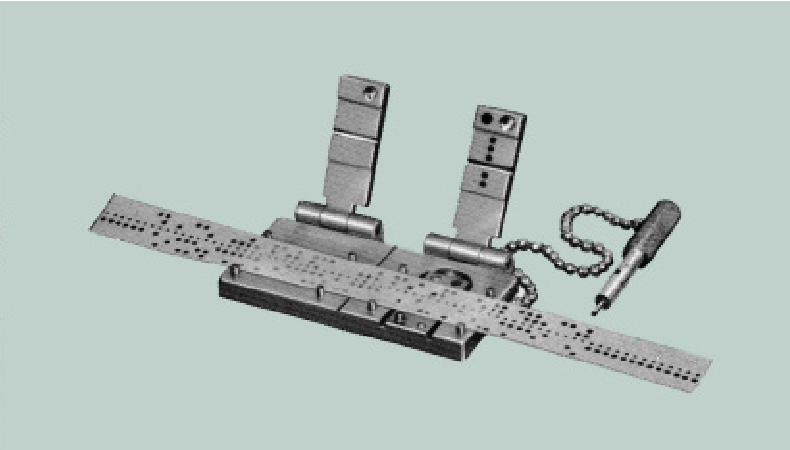


Fig. 29. The Unipunch

Unipunch

The Unipunch (See Fig. 29) is a tape editing accessory which enables incorrect combinations in a tape to be corrected by handpunching individual code holes into the tape. It is mainly of use where there are only a few errors in the tape and where these take the form of missing holes. In these cases, using a unipunch makes it unnecessary to prepare a new tape.

During recent years there has been a growing realisation that punched tape affords a valuable method of transmitting, recording and storing digital information of all kinds, and that its usefulness is not confined merely to the telegraph field.

Undoubtedly an important factor in bringing about this realisation has been the rapid development of digital computers since the war. A computer requires auxiliary apparatus for

(1) converting written programmes into coded information, e.g. on a punched or magnetic tape, and checking the accuracy of this conversion ;

(2) feeding the coded information automatically, at high speed, into the computer ;

(3) recording the computer output in coded form ; and,

(4) converting this coded output into printed characters.

Computer engineers discovered in the commercially available and well-tried punched tape and teleprinter techniques, not only a method of satisfying their most important input and output requirements, but also a very flexible means of providing a variety of auxiliary, computer information handling facilities.

INPUT PREPARATION

In the punched tape method of preparing coded information for transmission to a computer, the information is punched into a tape either manually, by using a keyboard perforator or other equivalent instrument, or automatically by arranging for the processes requiring analysis (if the information is of this kind) to control a reperforator, thereby recording the data for analysis directly on the tape without manual transcription.

In the former case, where the tape is manually prepared, the risk of error is introduced, and means must be provided for rapidly checking the accuracy of the tape. This function is fulfilled by the various types of tape editing equipment.

Manual Tape Preparation

There are three methods available for preparing perforated tape, two of which have already been described (see p. 28). Their main features will be repeated here, however, for easy reference :

(1) The *Keyboard Perforator* method uses a Model 7P/N Keyboard Perforator, producing $^{11}/_{16}$ in. wide, fully-perforated tape under the control of a 3-row or 4-row teleprinter pattern keyboard. No print-out is provided. The maximum speed obtainable is 14 characters per second, i.e. 140 words per minute.

(2) The *Teleprinter* method uses a Model 7 or 54 Page Teleprinter equipped with a reperforating attachment, producing 5-unit, $^{11}/_{16}$ in. wide, fully-perforated tape under the control of the teleprinter keyboard. The maximum speed obtainable is 63 characters per second i.e. 66 words per minute. As this method does provide a print-out, it may be used by a relatively unskilled operator.

(3) The *Printing Reperforator* method uses a Model 86/N Printing Reperforator, producing 5-unit, 7/8 in. wide, fully-perforated tape under the control of a 3-row or 4-row teleprinter pattern keyboard. There is a printed local record of the perforated information on the tape itself but this is not visible from the keyboard and there is no other printed local record. A maximum speed of 66 words per minute is obtainable.

Of the three methods given above the teleprinter method is the most widely used. Although it is less economical than the first method for preparing tape, it is easier to use and the teleprinter and perforating attachment may be employed for other purposes.

Tape Editing

It is very important to prevent errors made during the preparation of tape from reaching the computer. A well-known firm of computer manufacturers using tape input equipment has estimated that in manually-prepared unchecked tape one error may be expected to occur in every 300 to 2000 characters.

Some errors are noticed immediately after they are made : for these the tape is back-spaced until the first incorrect character is over the punches. It is then over-punched with the `erase', i.e. all-marking, character. Most computers using a punched tape input are so designed that they ignore the `erase' character.

To detect and eliminate other errors, four methods are in common use, all of them employing special tape editing equipment manufactured by Creed & Company :

(1) The proof-reading method requires a tape reader, and a teleprinter fitted with a keyboard, a reperforating attachment and a two-colour printing facility. A control unit with an `inching' key, i.e. a key for releasing the tape reader a character at a time, is also required. The print-out of the tape to be checked is first proof-read by the programmer, who marks the errors on it. The tape is then placed by the operator in the tape reader and punched and printed copies of the tape are obtained on the teleprinter. The operator watches the process and when an error on the initial print-out is neared, he stops the tape reader, inches it forward a character at a time to the error, and then uses the keyboard to introduce the correct character in place of the error. This process is repeated for all the other errors. On the final print-out, uncorrected characters are printed in black, corrected characters in red.

(2) The simple comparator method is based on the principle that if two tapes of the original programme are manually prepared by two operators and then compared automatically by a suitable machine character by character, the probability of an error remaining undetected by such a comparison is very low. Indeed, the only case which escapes detection is that in which the same error occurs in the two tapes in the same position. The method requires the use of a comparator, which consists of two tape reading heads, almost identical to the multiple-wire tape reader head referred to on p. 32, mounted on a common base and driven by a common motor. A relay control unit and alarm circuit is mounted on the rear of the main base.

The two tapes of the programme are placed in the reading heads and a start key is operated. This causes a common start signal to be fed to the two clutch magnets so that the heads begin reading at the same time. Subsequent synchronisation is automatically obtained by the design of the heads, and by the fact that they are driven by the same motor. The tapes are, therefore, fed through the heads in step until a difference between them is detected. The control and alarm unit then stops the heads with the differing combinations visible two feed holes past the sensing point and actuates a visual and audible alarm. The audible alarm can be disconnected but the visual alarm remains operated until the comparator is manually restarted after the tapes have been inspected and the errors marked on them.

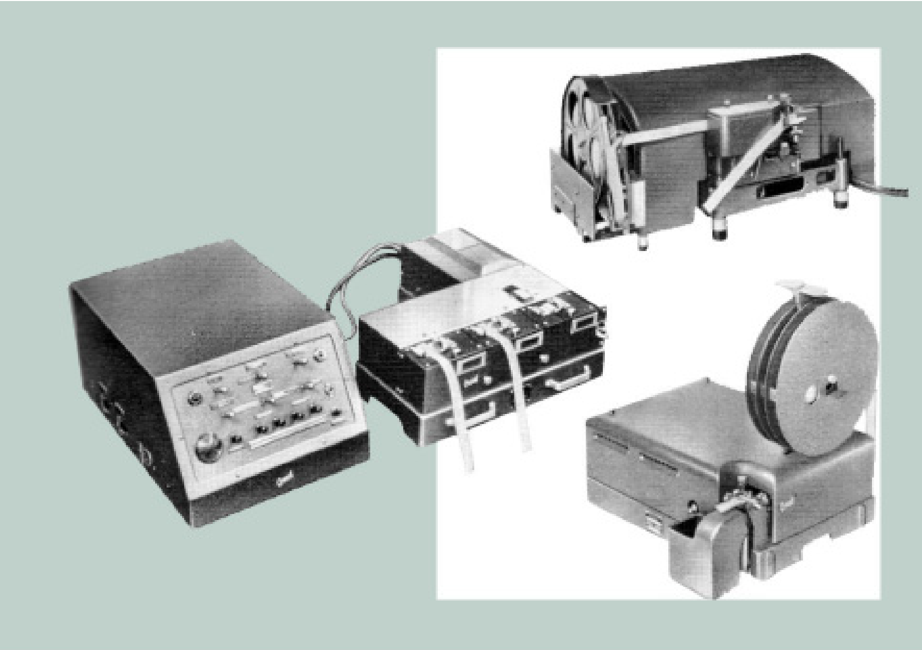


Fig. 30. The Perfect Tape Comparator (alternative models of output reperforator shown at right)

If, after comparison, it is found that there are no errors, or if the errors are on one tape only, then a correct tape is available for use with the tape reader. If, however, errors are found in both tapes, a number of courses of action are open. If any of the errors are correctable with a Unipunch this may be used. If not, the old tapes may be patched. Some times computer users permit certain errors to go through to the computer and either correct the output or rely upon the computer to detect and/or correct them. Alternatively, a corrected tape may be prepared, as in the proof-reading method, by using a tape reader and a teleprinter fitted with a keyboard, a reperforating attachment and a two-colour printing facility. A control unit with an inching key is required as before. The incorrect tape is placed in the tape reader, and punched and printed copies of the tape are obtained on the teleprinter. As the error marks on the tape are reached, the operator stops the tape reader, inches it forward a character at a time to the error, discovers the correct character by comparing the print-out with the programme, and then punches this into the tape from the keyboard. The process is repeated for each error.

The perfect tape comparator method is a refined version of the simple comparator method, a third, perfect tape being produced from the two compared tapes, thereby eliminating the necessity for correcting either of the tapes or preparing a new tape in any of the ways described in the foregoing section.

The apparatus used consists of a triple tape reader with two comparing heads and one transmitter head, and an output reperforator fitted with a keyboard, these units being interconnected by a control unit having a number of control keys. (See Fig. 30). A Model 54 Teleprinter fitted with a keyboard and reperforating attachment may be used as an alternative to the output reperforator.

Two tapes are first prepared, as in the simple comparator method, and then placed in the comparing heads of the triple tape reader. One of the tapes is then selected, by operating a switch on the control unit, as the `master' tape to control the transmitter unit on the comparator. Another switch on the control unit is then thrown to start the comparison.

As the comparison proceeds, the holes in the tapes in the two comparing heads are sensed and each pair of sensed combinations is stored on a bank of relays, this sensing and storing taking up one whole cycle of operation of the tape reader mechanism. If the tapes agree, the stored combination corresponding to the master comparing head is transmitted by the third comparator head, in sequential form, to the output reperforator (or teleprinter) which produces a new tape. If the tapes disagree, the comparator stops automatically, with the disagreeing characters one combination beyond the sensing point and with the last correct compared character printed.

The disagreeing characters and also the next few characters are then inspected to determine the type of error present. This may take the form of a single incorrect character, two or more incorrect characters, a single character omitted, two or more characters omitted, extra characters inserted or any number of wrong characters in each tape. If the correct characters are in one or other of the tapes, they may be passed on to the final tape by suitably manipulating the master keys and inching keys on the control unit. If, however, the correct characters are on neither tape, they may be inserted in the final tape by using the reperforator or teleprinter keyboard (Models 85 and 86 Reperforators only) as described earlier. When the errors are cleared, automatic comparison is resumed. This procedure is repeated each time there is any disagreement between the two tapes. The identity of the master tape may change several times during the comparison, but the third tape produced by the reperforator will not reflect these changes, but will contain in it only the correct information derived from the compared tapes except, of course, in the rare case where the two tapes contain the same incorrect characters in the same positions.

(4) The *Verifier method* is similar to the perfect tape comparator method, in so far as it is based upon the principle of double typing with automatic comparison. It differs, however, in running together the second typing and the automatic comparison into one operation. It also differs in employing simpler and quite distinct apparatus. This consists of a Model 91, 5-wire, keyboard, a Model 92 Tape Reader (see Fig. 19) and a Model 25 Reperforator (see Fig. 26). The complete unit is shown in Fig. 31.

The first tape is prepared from the programme by one of the methods described on p. 41. It is placed in the tape reader and a second operator types out the programme information once more, this time on the verifier keyboard. This keyboard, the tape reader and the high speed reperforator are connected together in such a way that if the combination for the depressed key corresponds to the combination sensed by the tape reader,

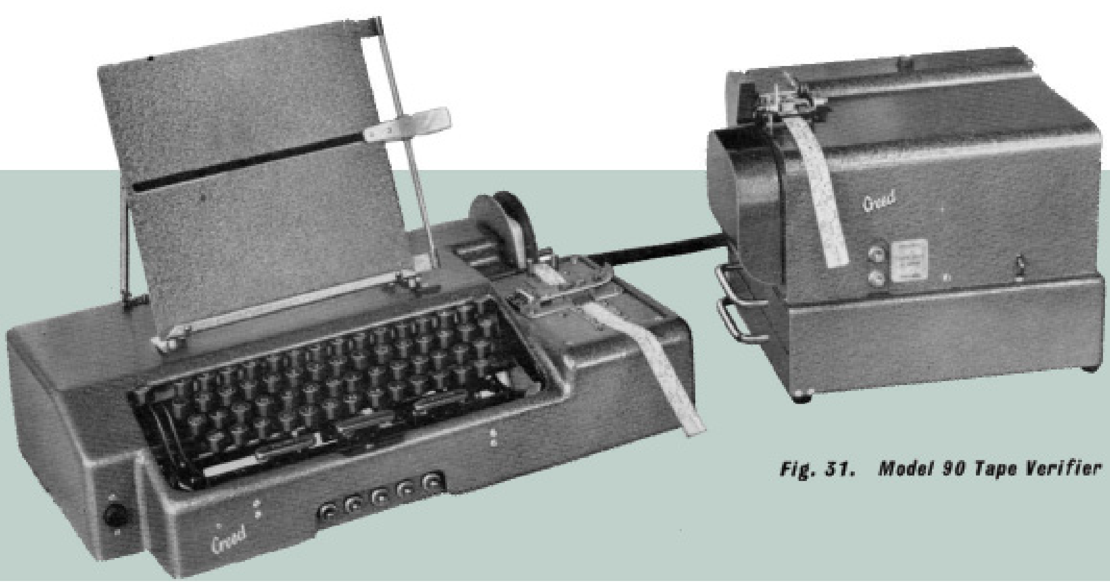


Fig. 31. Model 90 Tape Verifier

this same combination is punched in the new tape in the reperforator. If, on the other hand, the depressed key combination and the sensed combination disagree, the key is locked down and the reperforator is inhibited.

The operator has now to determine whether the fault is his or is in the control tape. To do this he first marks on the manuscript the character he is supposed to have typed, and then reads off the sensed character on the control tape by looking at the row of five lights at the base of the machine. He next compares this with the combination of the character marked on the manuscript. If they are the same, the fault is his, so he depresses a special `Cancel' key-which mechanically releases the locked key-and then depresses the correct key, which results in the correct combination being punched in the verified tape. If the combination on the lights and the combination of the manuscript are not the same, the fault is in the control tape. In this case, he depresses a special `Reader Out' key, which moves the control tape over the error and punches the correct character on the output tape in the reperforator. When the reperforator has completed its punching, the depressed key is unlocked automatically.

Provision is made for inserting characters omitted from the control tape. A special Non-Feed button on the front of the keyboard is depressed, followed by the `Reader Out' key. This causes the combination of the depressed key to be perforated in the output tape without feeding on the control tape.

The correction of tapes is perhaps the most important function of tape editing equipment, but it is not the only one. It is also required for copying tapes, for automatically checking the accuracy of such copied tapes, for making composite tapes, i.e. tapes containing information derived from two or more other tapes such as a Library tape and provisional programme tape, and for obtaining a print-out of a tape.

Creed & Company manufacture a range of tape editing sets providing different combinations of facilities to suit particular requirements. These may be classified, roughly, into two types :

(1) Comprehensive tape editing sets providing a full range of facilities for locations in which the volume of work is such as to justify their use. At least one comprehensive set of equipment would normally be required at each computer installation.

(2) Simpler tape editing sets to meet the requirements of programming groups with more limited tape editing work, e.g. groups which are preparing work to run on someone else's computer. These sets may also be used at a computer installation to augment the facilities provided by the comprehensive set if the work has grown too heavy for this to deal with.

Brief details of only two examples of each type of set can be given here. The first compre hensive set is the Model S.4042, Group 2, Reproducer and Perfect Tape Comparator Set. This is illustrated in Fig, 32 and comprises the following machines and units :

(1) Model 54 Page Teleprinter with N-type keyboard and reperforating attachment (see p.36).

(2) Model 6S/5M Tape Reader (see p. 31).

(3) S.3909 ZA Comparator Mechanical Unit. This consists of a three-gang multiple tape reader with two tape comparing heads and one separate transmitter head.

(4) S.3910, Group I, Mark II, Control Unit. This unit interconnects the other items of equipment and has all the necessary control switches, inching keys etc.

(5) Two rectifier sets.

The facilities provided by this set are as follows :

(a) Tape may be manually prepared, with a print-out, using the teleprinter.

(b) A print-out of a tape may be obtained using the 6S/5M tape reader or the third head of the comparator mechanical unit.

(c) A copy-tape may be obtained from an original tape in either the 6S/5M tape reader or the third head of the comparator mechanical unit.

(d) A composite tape may be prepared from two tapes, one in the 6S/5M tape reader and one in the third head of the comparator mechanical unit. Inching facilities are provided for both tape readers. Keyboard insertions may be made.

(e) Error correcting may be carried out by any of the first three methods described above, i.e. by the proof-reading method, the simple comparator method or the perfect tape comparator method.

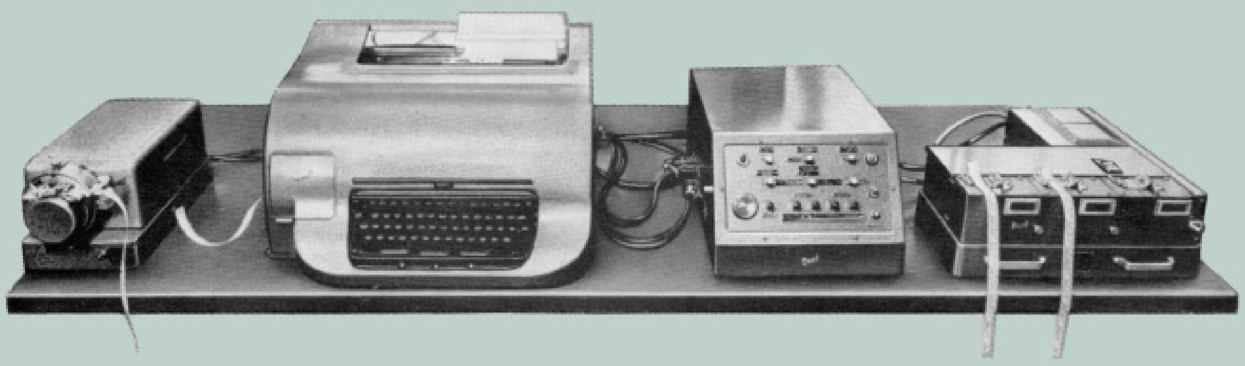


Fig. 32. Reproducer and Perfect Tape Comparator Set

The teleprinter used in this set is a standard machine which has been modified by fitting an automatic carriage return and line feed mechanism on the receiver and a keyboard inhibiting mechanism on the keyboard.

The automatic carriage return and line feed facilities are provided to enable the receiver to print out information which either does not contain the carriage return and line feed combinations, or does contain them but not in the positions to prevent overprinting and possible damage to the righthand end of the teleprinter carriage. For example, the facilities may be used to control the layout of normally printed results if this has not been fully determined by the programme. An adjustment is provided whereby the point at which the CR/LF functions take place may be predetermined. A key is also provided on the control unit for switching out the automatic CR/LF facilities, if these are not required.

The keyboard inhibition facility is provided to ensure, when preparing tape which must not contain CR and LF combinations, that no more than a pre-determined number of characters can be printed on each line of the print-out. The point at which the keyboard is inhibited is determined by the setting of the End-of-Line mechanism. The keyboard is restored to normal by depressing a special CR/LF key on the keyboard, which also causes the carriage to be returned and line fed, without punching these combinations in the tape, i.e. the reperforating attachment is suppressed while the functions take place.

Another comprehensive tape editing set is the Model S.4042, Group 1, Reproducer and Perfect Tape Comparator Set. This consists of the following machines and units :

(1) Model 86 Printing Reperforator (see p. 37), fitted with an N-type keyboard.

(2) S.3909 ZC Comparator Mechanical Unit. This is similar to the corresponding unit on the tape editing set described above.

(3) 5.3910, Group 2, Mark 11, Control Unit. The function of this is similar to the Group I unit mentioned above.

(4) Two rectifier sets.

The facilities obtainable with this set are as follows :

(a) Tape may be manually prepared, using the printing reperforator keyboard. The reperforator produces 7/8 in. wide tape with a print-out of the information on the tape itself under the punched holes.

(b) A copy tape with print-out on the tape may be obtained from an original tape in the third head of the comparator mechanical unit.

(c) If a Model 6S/5M Tape Reader is added to this tape editing set, a composite tape may be made from two original tapes as with the former comparator set. Inching and keyboard insertion facilities are available as before.

(d) Error correcting may be carried out by any of the first three methods described earlier.

The perfect tape in this case will, of course, have the print-out on it.

A typical example of a simplified tape editing set as the S.4041, Group 2, Reproducer Set (See Fig. 33), which consists of the following machines and units :

(1) Model 54 Teleprinter fitted with N-type keyboard, reperforating attachment, automatic CR/LF facilities and keyboard inhibition.

(2) No. 6S/5M Tape Reader.

(3) S.4060, Group 7, Teleprinter Desk equipped with Rectifier Set 5.5060 and Control Equipment.

Fig. 33. Reproducer Set

This set provides the following facilities :

(a) Tape may be prepared manually, with a print-out, using the teleprinter.

(b) Tape may be copied or printed using the Model 6S/5M Tape Reader and teleprinter. For printing alone, the reperforating attachment may be inhibited.

(c) Errors are checked by the proof-reading method. A correct tape is made by copying the first tape, using the tape reader and teleprinter. The operator watches the new print-out and stops the tape reader just before the error occurs. The tape is then inched up to the last character, and the correct character inserted from the keyboard. On the final print-out, the copied characters are in black, and corrections and additions are in red.

A still simpler tape editing set is the S.4041, Group 1, Reproducer. This is similar to the Group 2 set but is not fitted with automatic CR/LF and keyboard inhibition facilities. The other facilities provided by the set are unchanged.

Automatic Tape Preparation

By automatic tape preparation is meant the automatic recording of data in punched tape directly under the control of the processes being investigated. Tapes prepared in this way can be fed into a computer for analysis without the necessity for any manual preparation.

In certain types of investigation, the recording of the data and the subsequent translation of this into punched tape form can take up the majority of the time devoted to the investigation. Many operational studies and investigations based on instrument recordings fall into this category. The direct punching of the computer input tape under the control of the processes or instrument readings providing the data considerably simplifies experimental procedure and reduces analysis time.

In *operational studies*, the simplest system of automatic tape preparation makes use of a multiple-wire, non-printing reperforator of the kinds described on pages 38 and 39. The processes under investigation are arranged to operate the signal magnets of the reperforator through suitable external circuitry and to perforate the tape according to one of the coding arrangements described on pages 22 to 25.

In *instrument recording* studies, the position of the instrument pointer with respect to the scale must first be converted into one or two 5-unit combinations in accordance with one of the coding arrangements described on page 23. Various methods of analogue to digital conversion which could be applied to this problem have been described in the computer literature. The output from the converter is made to control a multiple-wire, non-printing reperforator as before.

INPUT TRANSMISSION

When the tape has been prepared and checked in the manner described in the previous section, it is placed in an automatic tape reader either of the single-wire or multiple-wire type which feeds the information into the computer.

The multiple-wire type is preferable for this purpose as, other things being equal, it affords a greater speed of transmission for a given code signal length and the separate inputs are more easily accepted by the computer.

The two Creed multiple-wire tape readers are described on pages 31-32. The faster of the two is the Model 92 Tape Reader which has a maximum speed of 20 characters per second.

OUTPUT RECORDING AND PRINTING

In the punched tape system of recording the output from a computer, the output is fed to a multi-wire, non-printing reperforator of the kind described on pages 38-39. The fully-perforated tape is then fed into a single-head, single-wire automatic tape reader, the output of which is fed into a standard receiving-only teleprinter. This produces a printed copy, or multiple printed copies, of the information.

It has been mentioned above that this print-out facility is provided in most types of tape editing equipment. There is, however, a demand for apparatus which has no other function than to provide a print-out or, at the most, to provide tape-preparing facilities in addition. To

cater for this demand, Creed & Company have developed a range of Interpreters. Some of these are desk-mounted and are arranged in self-contained, packaged, units, suitable in appearance etc. for installing in a business office. Others are panel-mounted and are suitable for use with computer installations.

The chief sets are :

S.4043, Group l, Interpreter Set. Desk-mounted. Print-out facilities. No tape-preparing facilities. No automatic CR/LF facilities.

S.4043, Group 2, Interpreter Set. Panel-mounted. Print-out facilities. No tape-preparing facilities. Automatic CR/LF facilities.

S.4043, Group 3, Interpreter Set. Panelmounted. Print-out facilities. Tape-preparing facilities. Automatic CR/LF facilities.

S.4043, Group 4, InterpreterSet. Deskmounted. Print-out facilities. Tape-preparing facilities. No automatic CR/LF facilities.

This section has been confined to a description of some of the ways in which punched tape equipment provides input and output facilities for computers. The non-telegraphic applications of punched tape equipment are not, however, limited to the computer field. In the next section, three examples will be described briefly of other uses of punched tape.

Fig. 34. Interpreter Set

Punched Tape-Punched Card Systems

The interoperation of punched tape equipment with punched card machines considerably increases their speed and efficiency and results in important economies.

An example of this interoperation is provided by the use of punched card machines for preparing invoices. With the present method of preparing invoices two keyboard operations are required : first, the preparation of the invoices on a typewriter and, then, the operation of a card punch to transfer this information to the accounting cards.

If the typewriter used in the first operation is replaced by a teleprinter with reperforating attachment, the second operation may be dispensed with, since the perforated tape that is simultaneously prepared when the invoice is typed can be fed straight into a tape-to-card translator (a part of the punched card system) which automatically produces punched cards at high speed from the tape perforations.

Punched tape also increases the flexibility of the punched card system by adding remote control facilities to it. The method of operation in this case is to prepare the tape, as above, on a teleprinter reperforator, and then to transmit the information on it to the central office by means of an automatic transmitter. It is recorded there by a reperforator and, if a printed record is required, a teleprinter is also used, in parallel with the reperforator.

If two-way operation is required between distant offices, a card-to-tape translator is used for translating information from punched cards to 5-unit tapes, for onward transmission.

Mechanised Addressing Equipment

Punched tape may be used to speed up the preparation of the embossed plates that are used in addressing machines.

The ordinary method of preparing these plates is to select the required character manually on an embossing or die typewheel and to point it to the address plate in the required position. A lever is then manually operated which forces the selected die type upon the plate and thus produces the embossed character. Two manual operations are, therefore, required for each character and, as a consequence, the method is tedious and time-consuming, especially in comparison with the subsequent printing operation which is carried out automatically at high speed.

The punched tape method of preparing embossed plates uses a teleprinter-reperforator, a tape winder and an automatic tape-controlled embossing machine. The addresses are typed out on the teleprinter and the simultaneously perforated tape is wound on to the tape winder. It is then fed into the plate embossing machine which automatically produces the plates embossed in accordance with the perforations in the tape.

Apart from speed and ease of operation, the main advantage of this method of preparing embossed plates is that the printed page record of the addresses provides a simple check on the correctness of the plates.

The punched tape technique has the further advantage that it permits the remote control of plate embossing equipment, i.e. tapes prepared in one office or town may be used to control plate embossing equipment in another office or town. The method adopted is analogous to that employed in punched card applications.

Process Control

Punched tape may be used not only to record information but also to control processes, by using the code perforations to represent instructions. This type of application is relatively new, but with the growing interest in automation, it is likely to be more widely used in the next few years.

The principle involved here is the converse of the principle used in the automatic preparation of tape for digital computer systems. In the latter case, the processes under investigation were arranged to control a multiple-wire reperforator which produced a record of the changes in these processes automatically in coded form on a 5-unit tape. In the present case, a 5-unit tape is prepared containing the required instructions, and this is fed into a multiple-wire tape reader, the outputs of which are arranged to control, through the external circuitry, a number of processes.

A striking example of this is the *automatic control of machine tools* by means of punched tape. Until recently, the mechanisation of machines had reached the stage where several conventional machine tools could be made to operate consecutively on a succession of workpieces which were automatically conveyed from one to the other. In addition to these `transfer' machines, `copying' machines came into use. These could cut a profile of almost any shape by following the outline of a template. They had the advantage that they were quick to set up and could be rapidly changed from one job to another. However, the templates for them could be costly, so that copying machines proved economic only for long runs.

With the introduction of electronic analogue and digital computers, it has become possible to take mechanisation a step further. Instructions for controlling the actions of a machine tool can be prepared on punched tape and fed into a computer associated with the tool. The computer then moves the servo-controls of the feeds in accordance with the instructions to produce the required part. This system has all the advantages of a copying machine without the cost and labour of making templates, with the consequence that short runs or prototype parts can be produced as cheaply as longer runs. Another advantage is that by building interpolating and other calculating circuits into the computer, the work of the production-planning engineer who prepares the instructions for the computer can be considerably reduced.

The following brief description of an actual installation will provide a concrete example to illustrate this type of punched tape application. The installation in question consists of a Model 54 Teleprinter with reperforating attachment, a small computer-control unit fitted with an input tape reader and an ordinary vertical milling machine which has been modified by replacing the hand-controls on the longitudinal and transverse feedscrews of the table by electric servo-motors under the control of the computer, and by adding a mechanism to give a continuous and accurate indication of the position of the table to the computer.

The programme for the computer is prepared by a production-planning engineer who converts the dimensional information for the part to be manufactured into a sequence of figures representing the Cartesian x and y co-ordinates through which the cutter must pass. These instructions are typed out on the Model 54 Teleprinter, a control tape being obtained together with a printed check-copy. The workpiece is clamped in position on the work table and the punched tape is fed into the tape reader in the control computer. The machine cutter-head is located on the starting datum position of the table so that it can be synchronised with the starting datum position on the tape. The computer is then switched on, and the workpiece is thereafter automatically cut to the correct contour.

The sequence of operations, very briefly, is as follows : three contour datum-points on the control tape are taken into the computer store at a time. An electrical analogue computing circuit then interpolates eleven points between each pair of these datum-points. These are arranged on a smooth parabolic curve through the three points. Sixty-four further linear interpolations are then made between each pair of these intermediate points in order to ensure accuracy of control and consistency of the cutter path.

The required degree of accuracy (± .001 in.) is obtained by comparing voltage analogues of the input instructions and table positions. Any difference between the compared voltages causes the servo-motor controlling the movement of the work table to move the table in a direc tion to reduce this difference to zero. The position of the table then agrees with the input instructions.

The application of punched tape to the control of machine tools is only a special case of process control by punched tape, although a very important one. A somewhat different example is the use of *punched tape to control the shape of a wind tunnel* in order to vary the speed and character of the air currents through it. The tunnel is constructed of sheet steel and its shape is controlled by the pressure of ten rams spaced along its sides, five being placed on each side. These are arranged to advance or withdraw according to a pre-arranged sequence under the control of two five-wire tape readers in accordance with the instructions perforated in the tapes.

It is necessary in this application for the tapes to be able to feed forwards or backwards through the tape reader, the direction being controlled electrically from a distant point. To satisfy this condition, the standard multiple tape reader that is used is fitted with a special feed reversing Machanism actuated by a rotary-type switch.

Punched tape in co-operation with auxiliary control apparatus may be used to control the sequence of operations of almost any type of machine. There is little doubt that it will play an important role in converting the ideal of automation into an everyday fact. Its potential scope in this field is at least as great as in any other of the fields described in this bulletin.