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IBM Systems Reference Library

IBM 1440 System Component Description
1442 Card Read-Punch
1443 Printer
Console Printer

This manual contains a detailed description of the Card Read Punch, Printer, and Console Printer including the operation codes for these devices. Also contained in this manual is a complete description of input/output timing, samples of program timing, and a description of a method for determining throughput timing for the 1440 System. A list of input/output instruction times and a character coding chart are also included.

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IBM 1440 Data Processing System

INTRODUCTION

The IBM 1440 Data Processing System represents a major advance in low-cost data processing systems. Processing methods of the 1440 are similar to those of the IBM 1401 Data Processing System, but the 1440 has input and output devices that enable it to be effective in system areas where there has long been need for a data processing system but not the volume of work to justify such a system.

The IBM 1440 is primarily a file system, providing a group of balanced input/output devices to work in conjunction with the high-speed 1441 Processing Unit and the 1311 Disk Storage Drive. The 1440 is a solid-state system with compact components and input/output devices that enable it to be located in an area approximately 15 x 15 feet. Available with the 1440 are the IBM 1442 Card Read Punch (in two models), and the IBM 1443 Printer.

The 1442 Card Read-Punch, Model 1, reads cards at a rate of 300 cards per minute (cpm). Punching speed depends upon the last column punched and ranges from 50 cpm, when all 80 columns are punched, to 180 cpm when the first 10 columns are punched.

Model 2 reads at a rate of 400 cpm. Punching speed ranges from 91 cpm when all 80 columns are punched, to 270 cpm when the first 10 columns are punched.

The IBM 1443 Printer, Model 1 is capable of printing from 120 to 430 lines per minute. A print span of 120 positions of alphabetic and numerical data is standard. The print scan can be expanded to 144 positions as a special feature.

IBM 1442 CARD READ-PUNCH

The Card Read-Punch provides the system with card input and output. The 1442 reads cards serially, that is, column by column beginning with column 1 and ending with column 80.

The 1442 reads cards, using the principle of solar sensing to convert light energy to electrical energy. Figure 2 illustrates the path of a card through the solar-sense reading mechanism.

Twelve solar cells, one for each row of punching positions in the card, are exposed to light as holes in the card pass between the light source and the solar cells. This new reading feature makes possible the high-speed serial-reading ability of the 1442 Card Read-Punch.

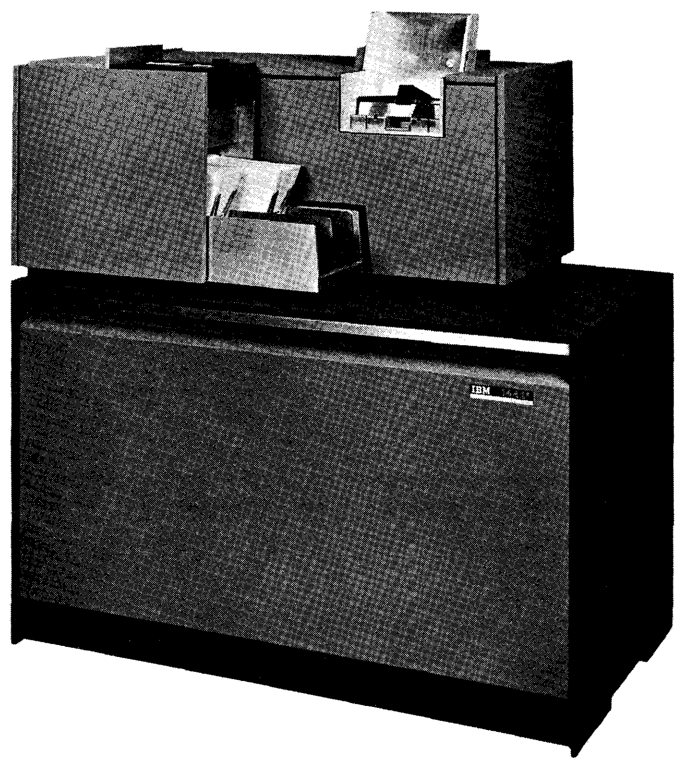


Figure 1. 1442 Card Read-Punch

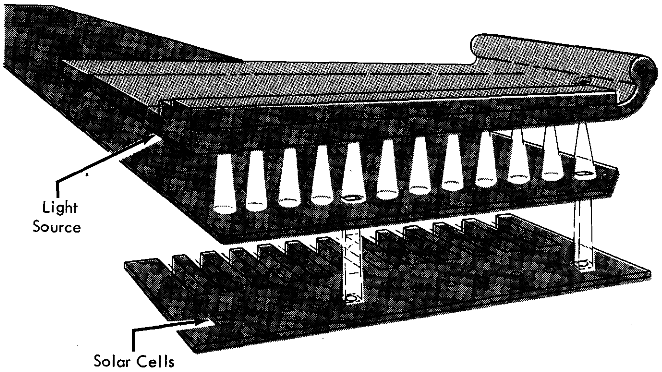


Figure 2. Solar Cell Reading

Figure 3 illustrates the path followed by cards during reading or punching operations.

This arrangement allows the results of calculations to be punched into the cards that contained the data to be calculated.

After the 1442 punches data into a card, the program can eject the card into the stacker so that the next card is positioned for punching. Program requirements may demand that the card not be ejected in which case it remains in position (at the next column following the last column punched) so that the 1442 can punch other calculated results into it in subsequent punching operations.

Punching speed depends upon the position of the last column punched.

Last Column Punched	Cards per Minute	
	Model 1	Model 2
80	50	91
60	63	112
40	85	146
20	130	210
10	180	270

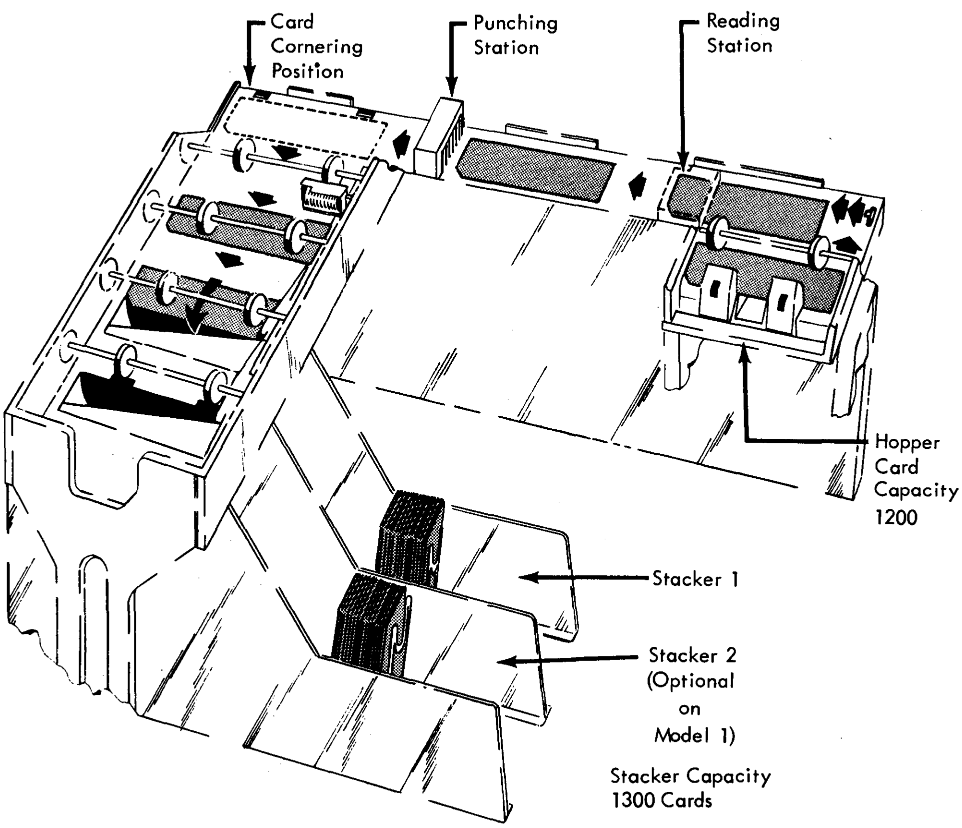


Figure 3. 1442 Card Feed and Punch Diagram

If it is necessary to separate reading and punching operations, it is possible to attach an additional 1442 to the system. When this is done, either of the 1442's can be used to read only, to punch only, or to read and punch.

The read hopper has a capacity of 1200 cards. The stacker is a radial-type stacker, which permits cards to be removed from the stacker without stopping the machine. The capacity of the stacker is 1300 cards. An optional stacker is available for the Model 1 if it is necessary to separate the cards after they have been processed. The Model 2 has two stackers as standard equipment.

IBM 1443 PRINTER, MODEL 1

The Printer (Figure 4) is another output medium for the 1440 system. This unit has a rated printing speed of 150 lines per minute. With the special Selective Character Set feature, the rated printing speed ranges from 120 to 430 lines per minute. The actual printing speed that can be obtained for a particular job or application depends in part upon the total number of lines to be printed for the job, the amount of processing required for each line that is printed, and the "character set" that is used. The term "character set" is explained in a following paragraph. The standard number of positions that can be printed on one line is 120, with an additional 24 positions available as a special feature.

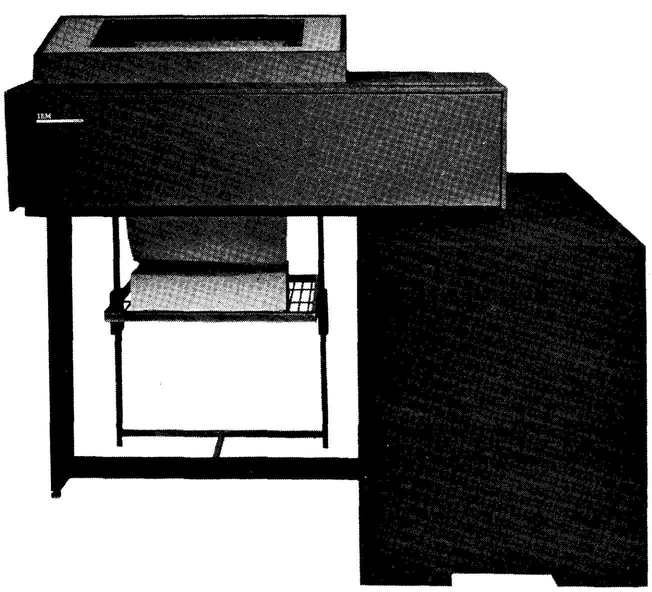


Figure 4. 1443 Printer

Horizontal spacing is 10 characters to the inch. Vertical spacing of six or eight lines to the inch can be manually selected by the operator. The vertical spacing between lines is performed by a tape-controlled carriage directed from the 1441 stored program. The sequence and arrangement of data on a line of printing is also controlled by the 1441 stored program.

The 1443 is equipped with a standard 52-character set: this means that each of the 120 or 144 print positions can print 52 different characters: 26 alphabetic; 10 numerical; and 16 special characters, namely: & . ⌑ - $ * , % / @ ? ! ‡ : ƀ # .

With the 52-character set, the 1443 is capable of printing 150 lines per minute. Other character sets are available. The specifications for these character sets are provided in the "Special Features" section.

Method of Printing

Alphabetic, numerical, and special characters, are located on a thin metal bar (Figure 5) that travels back and forth in a horizontal plane. As each character is positioned opposite a magnet-driven hammer, the hammer presses the print bar against the paper form and the character prints.

A line to be printed should be assembled in core storage in exactly the same manner in which it must appear as output. Before a character is printed, it is checked against the corresponding position in the print area of core storage to ensure the accuracy of printer output.

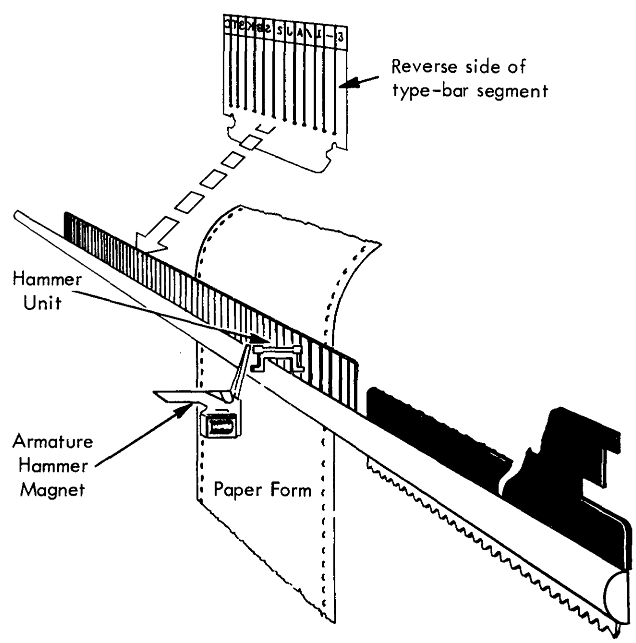


Figure 5. Printing Schematic

IBM 1447 CONSOLE, MODEL 2 CONSOLE PRINTER

The Console Printer is available on the 1447 Model 2 to provide communication between the operator and the processing unit, or between the operator and the disk storage units. The Console Printer can be used for direct input and output to the 1440 system or as a secondary printer. When the high-speed output of the 1443 Printer is not required, the 1447 can be used as the only printer.

Since the Console Printer, under program control, can read from and write into storage, the 1440 system operator can either examine or alter the status of a particular account, record, or instruction stored in the system.

This feature is especially useful in obtaining information that is in disk storage, such as customers' accounts, stock status data, and payroll details. Through the console printer the operator can request specific data from any disk record, and have the information typed out immediately. This typed copy also serves as a log of information entered into or received from the 1440 system.

The Console Printer also operates in conjunction with the Alter and Character Display modes of the Console Mode switch.

Alter Mode

Data in core storage can be altered by using the following sequence of instructions:

1. Set the Mode switch to ALTER.
2. Set the Manual Address switches to the storage location where the data is to begin. (Data is entered from left to right.)
3. Press the Type key to unlock the keyboard.
4. Type the data to be entered.
5. After all data has been typed, press the Carrier Return key. This returns the carrier and locks the keyboard.

A word mark can be entered into core storage with a data character, by pressing the WM key before the data character is typed. Pressing the WM key causes the Console Printer to print a circumflex and take one space. The word mark is entered into core storage with the next character that is typed.

Figure 6. Console Printer

Character Display Mode

Data in core storage can be displayed by using the following sequence of instructions:

1. Set the Mode switch to CHARACTER DISPLAY.
2. Set the Manual Address switches to the storage location of the first character of the data to be displayed. (Data is read out from left to right.)
3. Press the Type key to start the printing of data.
4. Pressing the Stop key on the console stops the printing of data.

Word marks are indicated by the printing of a circumflex just prior to printing the character the word mark is associated with in core storage. After the Stop key has been pressed to end the operation, pressing the Type key again resumes the Character Display operation at the next successive higher core storage location.

The Console Printer has character spacing of 10 characters per inch. This spacing provides 85 characters per line.

This section describes the operation codes that the 1440 uses to control card reading, card punching, and printing.

Read Card

Mnemonic	OP code	A address	B address	d modifier
R	M	%Gn	XXX	R

This instruction is used to enter data from the Card Read-Punch into core storage.

The B address specifies the leftmost core storage position where the input data will be located. A group mark-word mark must be placed one position to the right of the core storage location where the last character of the input data will be placed. The instruction is stopped by the GM-WM; therefore the number of characters read from the card depends upon the length of the B field that is established. The length of the B field may be from 1 to 80 positions, plus one position for the GM-WM.

Word marks already in the storage positions of the B field are neither considered nor affected.

If the length of the data record is longer than the number of positions from the B address to the largest position in core storage, a wrap-around error is created. For example, in a system with 4000 positions of storage, if the input data consists of 75 characters, and the B address is 3979, the first 20 characters of the input data will be read in 3979 through 3999, and the remaining 55 positions will be placed in core storage positions 0 through 54, and the Storage Address light will be turned on.

If there is more than one Card Read-Punch in the system, the last character in the A address designates which Card Read-Punch is to be used.

As the card at the read station is being read, a card at the punch station is being moved past the punch station at the same speed and ejected into the stacker.

Punch Card

Mnemonic	OP code	A address	B address	d modifier
PS	M	%Gn	XXX	P

This instruction is used to transfer data from core storage into the Card Read-Punch. The B address specifies the leftmost core storage location of the data to be punched. The length of the B field is determined by a group mark-word mark placed adjacent to its rightmost core storage position. Data is punched in successive columns of the card at the punch station. When a punch card operation follows a read operation, the card at the punch station station is at column one, and punching begins at column one. When a punch card operation follows another punch card operation, the card at the punch station is the card that has been punched in the previous operation, and punching begins in succeeding columns of the card, following the last column punched in the previous operation. This instruction is stopped by the GM-WM, therefore the number of characters punched into the card depends upon the length of the B field.

Word marks within the data being punched are neither considered nor affected.

Punch and Feed

Mnemonic	OP code	A address	B address	d modifier
P	M	%Gn	XXX	G

This instruction serves the same function as the punch card operation, except that upon completion of the punching operation, the card is advanced completely past the punch station, regardless of the last column punched. The card that was waiting at the read station is advanced so that column one is under the punch station, and a card from the hopper is advanced to the read station. When cards are advanced past the reading station by this operation, data in the cards is ignored. The card that is punched by this operation is advanced past the punch station, and is ejected into the stacker.

Word marks within the data field being punched are neither considered nor affected.

Print

(Write a Line)

Mnemonic	OP code	A address	B address	d modifier
W	M	%Y1	X01	W

This instruction is used to transfer data from core storage to the 1443 Printer. The B address specifies the core storage location of the data to be printed. The B field is addressed by its leftmost core storage address. The length of the B field is determined by a GM-WM in its rightmost core storage position. The instruction is stopped by the GM-WM; therefore the number of characters printed depends upon the length of the B field that is established.

Word marks within the data being printed are neither considered nor affected.

The tens and units position of the B address must always be zero one.

NOTE: The last 100 positions of storage cannot be used for printing operations. (For example, address 3901 cannot be used, when the system contains only 4000 positions of core storage.)

Print and Suppress Space

Mnemonic	OP code	A address	B address	d modifier
WS	M	%Y1	B01	S

This instruction prints a line following which the automatic carriage space is suppressed.

Write Console Printer

Mnemonic	OP code	A address	B address	d modifier
WCP	M	%T0	XXX	W

This instruction is used to transfer data from core storage to the Console Input/Output Printer. The B address specifies the core storage location of the data to be printed, and the B field is addressed by its leftmost core storage address. The length of the B field is determined by a group mark-word mark in its rightmost storage position. The instruction is stopped by the GM-WM; therefore the number of characters printed depends upon the length of the B field that is established. Sensing of the GM-WM terminates the operation, returns the print element to the left margin, and causes the Printer carriage to line space. If the field length exceeds the typewriter line length, a print element return and line space are initiated automatically and the printing is continued on the next line until a GM-WM is sensed. Data is printed as it appears in core storage. Should editing of data be required, the editing must be accomplished by the program before the Write Console Printer operation is initiated.

Word marks within the data field are neither affected nor considered in the execution of this instruction.

Read Console Printer

Mnemonic	OP code	A address	B address	d modifier
RCP	M	%T0	XXX	R

This instruction is used to enter data into core storage from the Printer keyboard. The B address specifies the core storage location where the input data will be placed, and the B field is addressed by its leftmost core storage address. The operation is normally terminated when the machine operator presses the Carrier Return key. Pressing this key returns the print element to the left margin, effects a line space, and causes a GM-WM to be stored in the next sequential core storage location.

Word marks in the entry area of core storage are neither considered nor affected by this operation.

NOTE: If, during the keying operation, a GM-WM is sensed in the core location next in sequence, the Read Console Printer operation will be terminated, the print element returned, the carriage line spaced and the keyboard locked. When the number of data positions to be entered exceeds the number of printing positions in one typewriter line, the print element will automatically be returned from the right hand margin and the entry operation continued on the next line. The number of printing positions in one line is determined by the setting of the margin stops and cannot exceed 85 positions.

Stacker Select (Optional 1442 Model 1 Card Read-Punch)

Mnemonic	OP code	d character
SS	K	2

This instruction causes the card at the punch station to fall into stacker 2. Unless stacker 2 has been selected before the operation that ejects the card (Read or Punch and Feed), the ejected card is directed to stacker 1.

Word marks are not affected.

Control Carriage

Mnemonic	OP code	d character
CC	F	X

This instruction causes the Printer Control carriage to move as specified by the d character in one of the following ways:

1. A digit causes an immediate skip to a specified channel in the carriage tape.
2. An alphabetic character containing a 12 zone causes a skip to a specified channel after the next line is printed.
3. An alphabetic character containing an 11 zone causes an immediate space.
4. An alphabetic character containing a zero zone causes a space after the next line is printed.

Figure 7 shows the function of the d character. If the carriage is in motion when a CONTROL CARRIAGE instruction is given, the program stops until the carriage comes to rest. At this point, carriage action is initiated again, and then the program advances to the next instruction in storage.

Word marks are not affected.

d	Immediate skip to	d	Skip after print to
1	Channel 1	A	Channel 1
2	Channel 2	B	Channel 2
3	Channel 3	C	Channel 3
4	Channel 4	D	Channel 4
5	Channel 5	E	Channel 5
6	Channel 6	F	Channel 6
7	Channel 7	G	Channel 7
8	Channel 8	H	Channel 8
9	Channel 9	I	Channel 9
0	Channel 10	?	Channel 10
#	Channel 11	.	Channel 11
@	Channel 12	⌑	Channel 12
d	**Immediate space**	**d**	**After print space**
J	1 space	/	1 space
K	2 spaces	S	2 spaces
L	3 spaces	T	3 spaces

Figure 7. d-character for Forms Control

1442 CARD READ-PUNCH (Figure 8)

Power Light

This light indicates that power is applied to the Card Read-Punch control circuits.

Validity Check Light

This light is turned on when an invalid combination of punches occurs in the card column being read. If the I/O Check Stop switch is off, a program test will turn the Validity Check Light off. If the I/O Check Stop switch is on, pressing the Check Reset key on the console will turn the Validity Check light off.

Punch Check Light

This light is turned on when an error is detected in output punching. If the I/O Check Stop switch is off, this light is turned off by a program test. If the I/O Check Stop switch is on, this light is turned off by pressing the Check Reset key.

Card Register Light

The light is turned on when a card is fed which is sufficiently off register, either in punching and/or in feeding, to prevent accurate data transfer. If the I/O Check Stop switch is off, this light is turned off by a program test. If the I/O Check Stop switch is on, this light is turned off by pressing the Check Reset key on the console.

Ready Light

This light indicates that the Card Read-Punch is prepared to accept instructions from the Processing Unit. The following conditions are required:

1. Power on
2. Cards registered at the punch and at the read stations.
3. Cards in hopper
4. Stacker not full
5. No error conditions

NOTE: After run-in, a card need not appear at the punch station. If the first operation calls for punching, a read and eject cycle will automatically be initiated before punching occurs.

Feed Check Light

This light is turned on when a card is mispositioned in the card path, or a Read Station Lamp Check occurs. The Read Station Lamp Check determines that all the lights in the solar-cell reading mechanism are functioning properly. The light will be turned off by the following action.

Card mispositioned	Run out cards (clear jam if necessary). Run in cards with Read Punch start.

The IBM Customer Engineer must be called if there is a solar-cell lamp check failure.

Start key

To run in	1. Power on 2. Card path empty 3. Cards in hopper 4. Press Read Punch Start key to feed one card. Ready light comes on.
To restore to ready status after manual stop	Press Read Punch Start key

Stop key

Removes the Read Punch from ready. The system is unaffected unless the Read Punch is selected by the program.

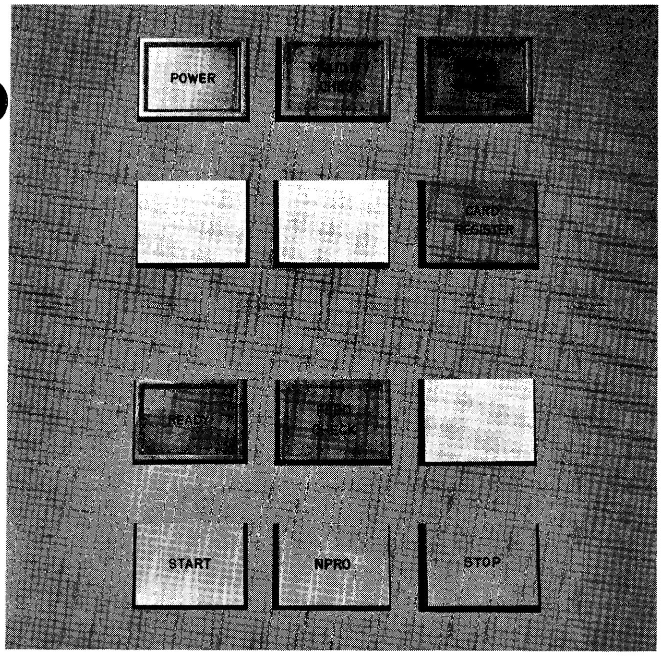


Figure 8. 1442 Operating Keys and Lights

Nonprocess Runout Key

This key is used to eject cards from the card path, without processing them. The key is ineffective unless the Read Punch is removed from ready status and the hopper is empty.

Last Card Sequence (Sense Switch A on Console)

The last card operation provides the logical means of terminating an application after the final card has been processed. The sequence is initiated when the last card has been fed from the hopper into the read station and the system is stopped. The operator then

1. turns Last Card switch on (Sense switch A, Console Panel), and
2. presses the Read Punch Start key.

This releases the interlock and allows the remaining card to be read and processed as the program requires. As the card passes the read station the last card indicator is turned on for subsequent testing (B IIIA)

1443 PRINTER (Figure 9)

Power On Light

This light indicates when DC power is applied to the Printer control circuits.

Ready Light

This light indicates that the printer has been conditioned by the operator to accept instructions from the processor. It is turned off when the Stop key is pressed, when an error is detected, or when the Printer runs out of forms.

SYNC (Synchronization) Check Light

This light is turned on when the type bar is not properly synchronized. When this occurs, the Printer is removed from Ready. Pressing the Printer Reset key turns the light off.

Parity Check Light

This light is turned on when a parity error is detected by the error check circuits. It is turned off when the Check Reset key on the Console is pressed, or when the Parity indicator is program-tested.

Form Light

This light is turned on when approximately four inches of the last form remain to be printed. When this occurs, the Printer is automatically removed from ready status. Pressing the Start key will cause the remaining lines of the form to be printed, one at a time, each time the Start key is pressed.

Start Key

Pressing this key with power on and with printed forms in position places the 1443 Printer in a ready status to accept instructions from the 1441 Processing Unit.

Pressing this key with the Forms light on causes the Printer to take only one print cycle, if the processing unit directs the Printer to do so.

Stop Key

When pressed, this key removes the Printer from ready status. The remainder of the system is not affected unless the program selects the Printer in a not-ready status.

Carriage Restore Key

Pressing this key positions the carriage at channel 1. If the carriage feed clutch is disengaged, the form will not move. If it is engaged, the form will move in synchronization with the control tape.

Carriage Space Key

Pressing this key causes the form to advance one space.

Ribbon Switch

When this switch is turned off, the ribbon and the mechanism of the print bar stop and the latter is disengaged. This switch must always be turned off before the ribbon is changed or the type bar is removed. For normal printing operation, this switch must be turned on.

Reset Key

Pressing this key resets all Printer check circuit indicators.

Carriage Stop Key

Pressing this key stops carriage operation and removes the Printer from ready status.

Carriage Clutch Knob (not shown in Figure 9)

The Carriage Clutch controls the carriage tape drive and the form feeding mechanism. If it is set to neutral, automatic form feeding cannot take place.

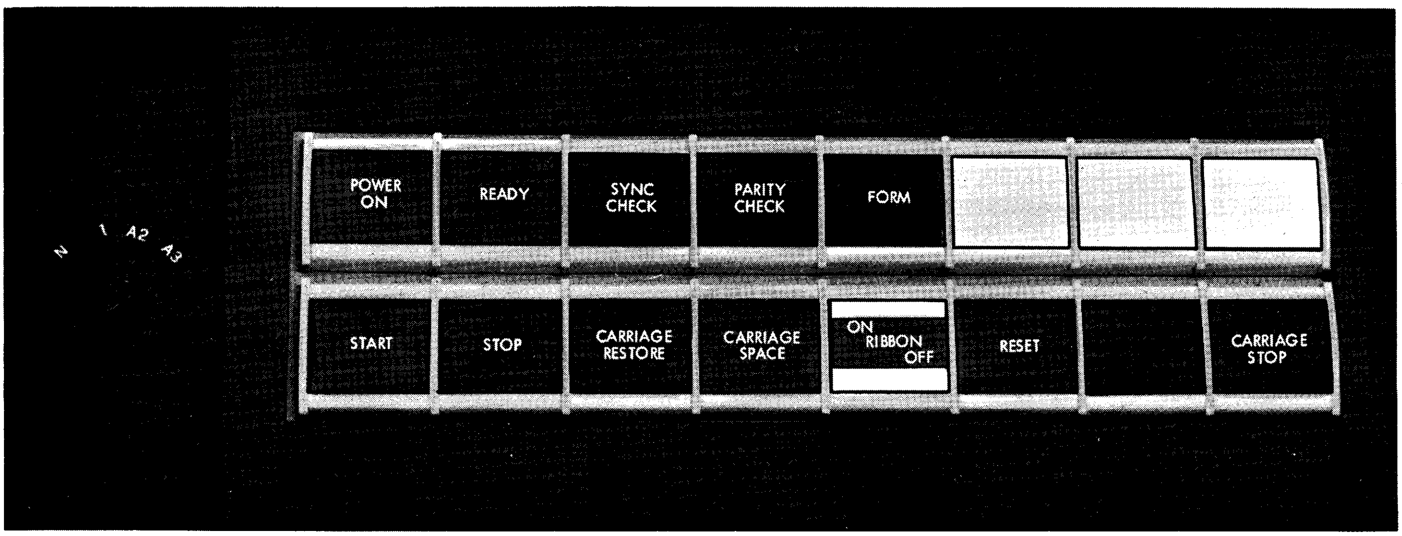
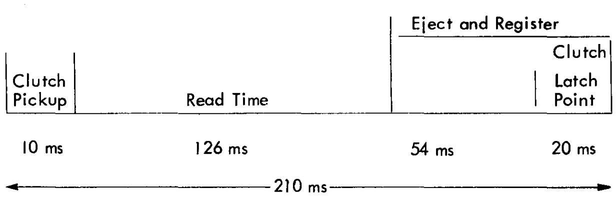


Figure 9. 1443 Operating Keys and Lights

1442 CARD READ-PUNCH, MODEL 1

Card Reading

Cards are read at two speeds: 285 cpm and 300 cpm. Either of these speeds is possible if the card read instruction is given within certain bounds. The 285 cards per minute cycle is:



If 80 columns of a card are read and the Card Read instruction is given during the 20 ms at the end of the total card read cycle of 210 ms, then a rate of 285 cards per minute will be achieved. If less then 80 columns are read, there is commensurately more time available for computation.

$$T = .0111\,(L_I + 1) + 10 + \left[21 + 1.3\,(L_B + 1)\right] \quad (1)$$

The figures in the bracket represent that portion of the total card cycle during which the card is actually being read and the 10 represents the clutch pickup time. $(L_B + 1)$ is the number of card columns being read plus an additional cycle that is required to sense the terminating group mark-word mark in core storage. Formula (1) can be consolidated as follows:

.1 ms	Instruction Time $.0111\,(L_I + 1)$
10.0	Clutch Pick up
21.0	
1.3	Time to read the GM-WM
32.4	

$$T = 32.4 + 1.3L_B$$

The time available for the computation to take place within the card read time (overlap) is given by the following formula:

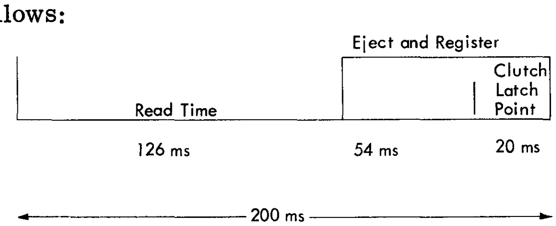
$$C = 210 - T \quad (2)$$

The following table shows representative times based upon formula (1) and formula (2).

No. of Card Columns Read	Interlocked for Reading (ms)	Process Time Available (ms)	Approximate No. of Instructions Executed*
1	33	177	708
40	84	126	504
80	136	74	296

*Assuming four instructions per millisecond.

If the Card Read instruction is given before the last 20 ms of the card read cycle, the clutch will still be engaged and 10 ms will be deleted from the total cycle, assuming all 80 columns are read, as follows:



The above cycle is equivalent to a rate of 300 cpm. The formula to compute read time is now

$$T = 42.4 + 1.3L_B$$

The clutch pickup time (10 ms) is eliminated, but the program will be interlocked for the 20 ms beyond the clutch latch point. The formula to compute the computation time available for overlap must be adjusted as follows:

$$C = 200 - T \quad (3)$$

The following table shows representative times based upon formula (3).

No. of Card Columns Read	Interlocked for Reading (ms)	Process Time Available (ms)	Approximate No. of Instructions Executed
1	43	157	628
40	94	106	424
80	146	54	216

If the total cycle exceeds 210 ms, that is, if the card read time and the computation or other time is greater than 210 ms, then there is a corresponding drop in the number of cards read per minute. The formula to compute the effective number of cards read per minute is as follows, where X is the elapsed time between card read impulses and it is greater than or equal to 210 ms:

$$\text{cpm} = \frac{60{,}000}{X} \quad (4)$$

The following table shows representative times based upon formula (4).

Cycle Time X (ms)	cpm	Approx. No. of Instructions Executed per Cycle
210	285	840
300	200	1200
400	150	1600
500	120	2000

Card Punching

The 1442 Card Read-Punch punches a column in 12.5 ms. 210 ms is necessary to move the card from the read station to the punch station and can be overlapped with computation time according to the rules for reading. A Punch and Feed instruction makes all 210 ms available for overlap. If reading and/or computation can be confined to this 210 ms period, then the following formula provides the number of cards punched per minute:

$$\text{cpm} = \frac{60,000}{12.5\ L_B + 210} \qquad (5)$$

The following table shows representative speeds based upon formula (5).

Columns Punched	cpm
1	270
20	130
40	85
80	50

If the total cycle time is greater than 1210 ms — the time required to punch 80 columns plus 210 ms — the formula for the number of cards punched per minute is given by the following, where X is the time between punch instructions and is greater than or equal to 1210 ms.

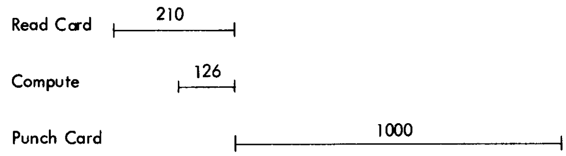
$$\text{cpm} = \frac{60,000}{X} \qquad (6)$$

The following table shows representative speeds.

Cycle Time X (ms)	cpm
1210	50
1300	46
1400	42
2000	30

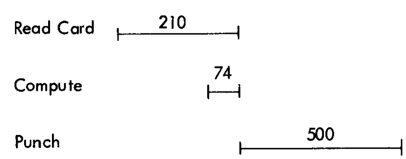
At certain times, a program may call for the reading of a card, processing of the information, and then subsequently punching into the same card. It is important to consider the card design in such cases.

For example, suppose a card containing 40 columns of information is read into the system. Subsequently, 40 columns are to be punched into the same card. If columns 1-40 were to be read, and columns 41-80 to be punched, then a graphical representation of the operation would be as follows:



Using formulas (1) and (2), the overlap available when reading 40 columns is 126 ms. Since the last 40 columns are to be punched, the L_B field in core storage must be 80 characters in length, of which the first 40 are blanks. Although no punching takes place for the blank columns, 12.5 ms is involved for every card column skipped until column 41 is positioned under the punches, at which time significant data is punched into the remaining 40 columns. Hence, the total punch time is 80 x 12.5 = 1000 ms for a total cycle time of 1210 ms.

Now consider the reverse card design situation. Suppose the last 40 card columns of the card were read and the first 40 columns were punched. The cycle would then be as follows:



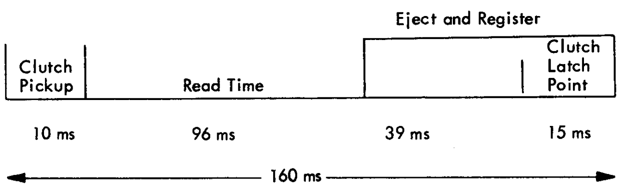
Although only the last 40 columns contained data, the entire card was read in order to get this data into core storage. Hence, for the determination of overlap time, an 80-column card is considered as being read and formulas (1) and (2) give an overlap time of 74 ms. Since only the first 40 columns are to be punched, the punch time is thus, 12.5 x 40 = 500 ms for a total cycle time of 710 ms. It is assumed that computation time can be performed within card read time. If not, there is still considerable advantage to organizing the card form as shown in the second example above, since an additional 500 ms are gained by this method. In the first case, the cycle time is 1210 ms and the throughput is 50 cpm. In the second case, the cycle time is 710 ms and the throughput is 85 cpm, a significant increase in card throughput.

In the operation of reading a card and then punching into the same card, the total cycle time can be determined from formulas (5) and (6), since overlap depends upon the card read portion of the cycle and punching time is the same in both cases. As mentioned, however, card design is quite important in this case.

1442 CARD READ-PUNCH, MODEL 2

Card Reading

The Model 2 reads at either 375 or 400 cpm, depending upon when the card read instruction is given.



The basic cycle is 160 ms (equivalent to 375 cpm), which is reduced to 150 ms (400 cpm) if a card read instruction is given prior to the last 15 ms of the end of the card read cycle. Reading time for a card is given by the following formula:

$$T = .0111\,(L_I + 1) + 10 + \left[15 + 1.0\,(L_B + 1)\right] \qquad (7)$$

Here, the 10 is the clutch pickup time and the quantity in the bracket represents the time actually spent in reading the card. This formula can be consolidated to:

$$T = 26.1 + 1.0 L_B$$

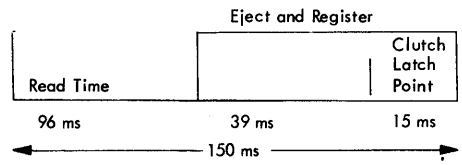
The time available for overlapping computation is given by:

$$C = 160 - T \qquad (8)$$

The following table shows representative times based upon formulas (7) and (8).

No. of Card Columns Read	Interlocked for Reading (ms)	Overlap (ms)
1	27	133
40	66	94
80	106	54

If a card read instruction is given before 15 ms of the end of the cycle, a rate of 400 cpm can be achieved.



The formula to compute read time is now:

$$T = 31.1 + 1.0\,L_B$$

The formula for determining the overlap time available for computation is now:

$$C = 150 - T \qquad (9)$$

The following table shows representative times based upon formula (9).

No. of Card Columns Read	Interlocked for Reading (ms)	Overlap (ms)
1	32	118
40	71	79
80	111	39

If the total cycle is greater than 160 ms, the following formula, with $X \geq 160$, provides the number of cards per minute:

$$\text{cpm} = \frac{60,000}{X} \qquad (10)$$

The following table shows representative speeds based upon formula (10).

Length of Cycle	cpm
160	375
200	300
300	200
500	120

Card Punching

The Card Read-Punch punches a column in 6.25 ms. 160 ms is necessary to move the card from the read station to the punch station and can be overlapped according to the rules of reading. A Punch and Feed instruction allows 160 ms to be overlapped. The following gives the number of cards punched per minute:

$$\text{cpm} = \frac{60,000}{6.25\,L_B + 160} \qquad (11)$$

The following are some representative times:

Columns Punched	cpm
1	361
40	146
80	91

If the total cycle is greater than 660 ms, which is the time required to punch an 80-column card, the following formula, with X equal to or greater than 660, applies:

$$cpm = \frac{60,000}{X} \qquad (12)$$

The following table shows representative speeds based upon formula (12).

Cycle Times (ms)	cpm
660	90
750	80
900	66
1000	60

Figure 10 shows card read time and the overlap time available for processing of all 80 columns of a card in increments of 5 columns. Figure 11 shows card punching time, the overlap time available for punching, and the equivalent card-per-minute speed.

Reading in Conjunction with Punching

Many applications involve a combination of reading and punching. The punching speeds in Figure 12 are based on a program of reading a card, performing calculations on its data, and punching results in the same card.

The emphasis in this type of application is not placed on the number of columns punched but where the punched columns are in the card. With the Model 1, punching the 5 columns in the beginning of the card gives 118 cpm greater throughput than punching columns 26 to 30; with the Model 2, throughput is increased by 149 cpm.

1443 PRINTER, MODEL 1

The Printer can accommodate four different character sets. The speed of each model depends upon the set used. The amount of time available for overlapping operations is 24 ms in all cases. The following table gives the lines per minute for corresponding character sets:

Char. Set	Lpm	Cycle Time	Overlap (ms)
13	430	140	24
39	190	316	24
52	150	400	24
63	120	497	24

The 24 ms at the end of the cycle permit the spacing or skipping of two lines within this time. Each additional line skipped or spaced requires an additional 10 ms. This period of time must be allowed for in the over-all cycle time.

If the time between print operations exceeds the total print cycle for any given character set,

	MODEL 1 at 285 cpm			MODEL 2 at 375 cpm	
Cols. Read	Process or Overlap Time (ms) Available	Card Read Time (ms)	Cols. Read	Process or Overlap Time (ms) Available	Card Read Time (ms)
80	74	136	80	54	106
75	81	129	75	59	101
70	87	123	70	64	96
65	94	116	65	68	91
60	100	110	60	74	86
55	107	103	55	79	81
50	113	97	50	84	76
45	120	90	45	89	71
40	126	84	40	94	66
35	133	77	35	99	61
30	139	71	30	104	56
25	146	64	25	109	51
20	152	58	20	114	46
15	159	51	15	119	41
10	165	45	10	124	36
5	172	38	5	129	31
1	177	33	1	133	27

Figure 10. Card Read Times

Last Column Punched	MODEL 1 *			MODEL 2 **		
	Punch Time (ms)	Total Time (ms)	cpm	Punch Time (ms)	Total Time (ms)	cpm
80	1000	1210	50	500	660	91
75	937.5	1147.5	52	468.75	628.75	96
70	875	1085	55	437.5	597.5	100
65	812.5	1022.5	59	406.25	566.25	106
60	750	960	63	375	535	112
55	687.5	897.5	67	343.75	503.75	119
50	625	835	72	312.5	472.5	127
45	562.5	772.5	78	281.5	441.25	136
40	500	710	85	250	410	146
35	437.5	647.5	93	218.75	378.75	159
30	375	585	103	187.5	347.5	173
25	312.5	522.5	115	156.25	316.25	189
20	250	460	130	125	285	210
15	187.5	397.5	151	93 75	253.75	237
10	125	335	180	62.5	222.5	270
5	62.5	272.5	221	31.25	191.25	314
1	12.5	222.5	270	6.25	166.25	361

* 210 ms of process time available during card movement time
** 160 ms of process time available during card movement time

Figure 11. Card Punch Times

formula (13) should be used to obtain the corresponding lines per minute, with X, the time between print operations as follows:

$X \geqq$	140	13 - Character set
$X \geqq$	316	39 - Character set
$X \geqq$	400	52 - Character set
$X \geqq$	497	63 - Character set

$$\text{lpm} = \frac{60{,}000}{X} \qquad (13)$$

Available with the Printer is a Print Storage Feature, which permits an overlap during most of the print cycle. The execution time for a print instruction when the Print Storage feature is installed is:

$$T = 2.4 \text{ ms} \qquad (14)$$

This time includes the instruction time and the time required by the processing unit to place the data to be printed in the special print storage positions. The remainder of the print storage cycle involves sending data to the printer from the special print storage positions in core storage. This time can be completely overlapped with other processing or input/output operations. It is important to note that 2.4 ms is the total time required, regardless of whether 120 or 144 positions are printed.

Columns to be Punched	MODEL 1	MODEL 2
	Cards per Minute	Cards per Minute
1 - 5	221	314
6 -.10	179	270
11 - 15	151	236
16 - 20	130	210
21 - 25	115	189
26 - 30	103	172

Figure 12. Card Punch Times - Punching into a Card Just Read

Process overlap time available is the difference between 2.4 ms and the corresponding cycle times for the different character sets. For example, for the 52-character set,

$$\text{Overlap} = 400 - 2.4 \tag{15}$$

Figure 13 shows the effect of the Print Storage Feature.

Character Set	Lpm	Cycle Time	Overlap Possible Without Print Storage	Overlap Possible With Print Storage
13	430	140	24	137.6
39	190	316	24	313.6
52	150	400	24	397.6
63	120	497	24	494.6

Figure 13. Printing Time - with and without Print Storage

CONSOLE PRINTER TIMING

The console printer serves as both input and output for the 1440 system. In either of these modes, it is an unbuffered operation. No overlap time is available. The timing of the console printer is:

Input
$T = .0111\ (L_I + 1) + \text{Operator Keying Time}$
Output
$T = .0111\ (L_I + 1) + 68\ (L_B) + 800\ (CR-1)$

The only possibility of overlap time in either of these operations comes on the last carrier return which signals the end of the respective operations. Thus, the time needed to print out two lines of 50 characters each is:

.0111 x 8	=	.088 ms
68 x 100	=	6800.000 ms
1 x 800	=	800.000 ms *
		7600.088 ms

*The second carrier return is overlapped by processing.

The Timing Reference card in Figure 14 and the Timing Layout Chart in Figure 15 are available as aids to developing throughput times. The information in the Timing Reference card consists partially of material summarized from the timing considerations provided in this Manual and the timing considerations provided in 1440 System Component Description, 1311 Disk Storage Drive (Form A26-5668). The same principles used in the Timing Layout Chart has been used in previous examples.

The remaining portion of this manual describes how a 1440 program can be indicated on the Timing Layout Chart and how the throughput time for each transaction can be calculated.

USING THE TIMING LAYOUT CHART

The Timing Layout Chart is designed to show the basic operations the 1440 System is performing. If it is used with care and discretion, it can give a very good idea not only of how to time out an application, but of how to judiciously program it as well. Suppose there is an operation involving the reading of a card, the processing of data from the card, the printing of a line and the punching of that line into the same card. In this example, forms design is important because how the last 40 columns are programmed to be read and how the first 40 columns of the same card are programmed to be punched will affect the speed of the operation. In this operation it is assumed that the Print Storage feature is not installed.

The first operation, reading the card, takes 210 ms. This line is drawn to scale as all others. The formulas in the Timing Reference Card show that 74 ms of the card read cycle are available for processing. During this time a seek is initiated which on the average takes 250 ms. Since this seek is purely on a random basis and there is no fore knowledge of when the record will be found, the maximum time for finding it (250 ms) must be allowed before processing is started.

When the proper cylinder has been found, it is necessary to wait until the appropriate sector has come under the read-write heads before Read Disk Time is started. This may take anywhere from 0 to 40 ms. An average rotational delay of 20 ms is shown. From this point on, however, assuming that it has taken 20 ms to find the record, it must be assumed that the same sector will be available every 40 ms, and this relationship should be taken advantage of in determining the write disk and write disk check times. As shown, it takes 4 ms to read the disk and processing of the record follows it. If the record is subsequently to be written back onto the same sector in the same cylinder, the crucial point in the timing is the number of revolutions the disk has made by the time the record is ready to be written back on its respective cylinder. It is important to note that whenever the cylinder addressed is the one just used in a prior operation, no Seek instruction is required, because the cylinder is still under the read-write heads. The only delay is the delay caused by the rotation of the individual disk itself. This analysis is shown by the increments of 40 ms laid off on the line depicting Rotational Delay. In this way, one can determine when it is possible to perform the next disk operation.

Processing time can be estimated at about .250 ms per instruction. In this case, process time can be assumed to be approximately 96 ms. As can be seen from Figure 16, a process time of approximately 96 ms involves waiting for the cylinder to be properly positioned. If a write disk operation of 4 ms is depected, there will be another delay of 20 ms until the sector again comes under the read-write heads, and the time for the write check operation begins. At the conclusion of this cycle (approximately 570 ms) the print operation begins. The print operation is started before the punch operation in order to overlap the two during the last 24 ms. Total cycle time, for this example is 1446 ms, the equivalent of 41 transactions per minute.

The total cycle time in milliseconds can be converted to throughput time in minutes by dividing the total cycle time into a constant of 60,000 (see Timing Reference Card, Figure 14). This table shows total cycle times, ranging from 100 ms to 3080 ms, in increments of 20 ms, and the corresponding throughput times in minutes. In using this table, one should take the total cycle time, find a corresponding, or closely corresponding, time from the "millisecond" column of the table, and note the number opposite the millisecond figure which is the total number of transactions that can be processed in one minute. This number, divided into the total number of transactions in a job, will give the total job time.

The order in which certain operations take place is important and should be considered from the standpoint of overlapping those operations which can be overlapped. This is more clearly shown in Figure 17 where the same problem, programmed for a system containing the Print Storage feature, is depicted.

Disk Timing:

Maximum Seek Time	400 ms
Mean Seek Time (cylinder 49 to cylinder 49)	250 ms
Total Rotational Delay Time	40 ms
Average " " "	20 ms
Head Select Delay	2 ms
Read 1 sector	2 ms
Write 1 sector	2 ms
Write Check (1 Sector)	2 ms

Overlap Available:

All other functions can be overlapped with Seek time except other disk operations.

Direct Access Feature:

250 ms maximum
150 ms average

Seek Time (Without Direct Access)

To ↓ From →

To \ From	00	09	19	29	39	49	59	69	79	89	99
00	75	88	101	114	127	140	153	167	179	192	204
09	175	188	201	214	227	240	253	267	279	292	304
19	143	156	169	182	195	208	221	235	247	260	272
29	153	166	179	192	205	218	231	245	257	270	282
39	168	181	194	207	220	233	246	260	272	285	297
49	184	197	210	223	236	249	262	276	288	301	313
59	200	213	226	239	252	265	278	292	304	317	329
69	215	228	241	254	267	280	293	307	319	332	344
79	232	245	258	271	284	297	310	324	336	349	361
89	248	261	274	287	300	313	326	340	352	365	377
99	263	276	289	302	315	328	345	355	367	380	392

Seek Time
(Direct Seek)

No. of Cylinders	Traveled (ms)
1	54 Minimum
2	67
3	80
4	90
5	105
6	115
7	130
8	140
9	155
10	165
20	130
30	137
40	154
50	170
60	185
70	202
80	217
90	235
99	248 Maximum

Seek Time
Dummy Seek Technique

Cylinder	Return To 00 From:	Advance From 00 To:
00	75 ms	75 ms
09	88	175
19	101	143
29	114	153
39	127	168
49	140	184
59	153	200
69	167	215
79	179	232
89	192	248
99	204	263

IBM

International Business Machines Corporation
Data Processing Division
112 East Post Road, White Plains New York

Form No. X24-3098 Printed in U.S.A.

BACK

IBM 1440 Data Processing System Timing Reference Card

IBM Reference Manual, 1440 System Component Description (A26-5667) illustrates timing methods for the 1440 System and the use of this card.

Processing:

Average Instruction time = .250 ms

Card Reading:

at 285 cpm	210 Cycle	- Model 1
300 cpm	200 "	- Model 1
375 cpm	160 "	- Model 2
400 cpm	150 "	- Model 2

Computing time available (in ms):

		no. of columns		Card Speed
Model 1	(210 - 136) + (	not read	X 1.3 ms)	285 cpm
" 1	(200 - 146) + (	"	X 1.3 ms)	300 cpm
" 2	(160 - 106) + (	"	X 1.0 ms)	375 cpm
" 2	(150 - 111) + (	"	X 1.0 ms)	400 cpm

Card Punching:

Last Column punched X 12.5 ms + 210 ms Model 1
" X 6.25 ms + 160 ms Model 2
Computing time available:
210 ms for Model 1
160 ms for Model 2

Note: If read follows punch, computing time is calculated as indicated in Card Reading above (210 ms or 160 ms will then also include read time).

Printing

Char. Set	Model 1 Lpm	Model 1 Print Cycle	Computing Without Print Storage	Overlapping With Print Storage
13	430	140	24	137.6
39	190	316	24	313.6
52	150	400	24	397.6
63	120	497	24	494.6

Two-line skipping can be accomplished with the 24 ms. available. Each additional line skipped requires 10 ms.

Print Storage Load Time:

2.4 ms regardless of number characters printed.

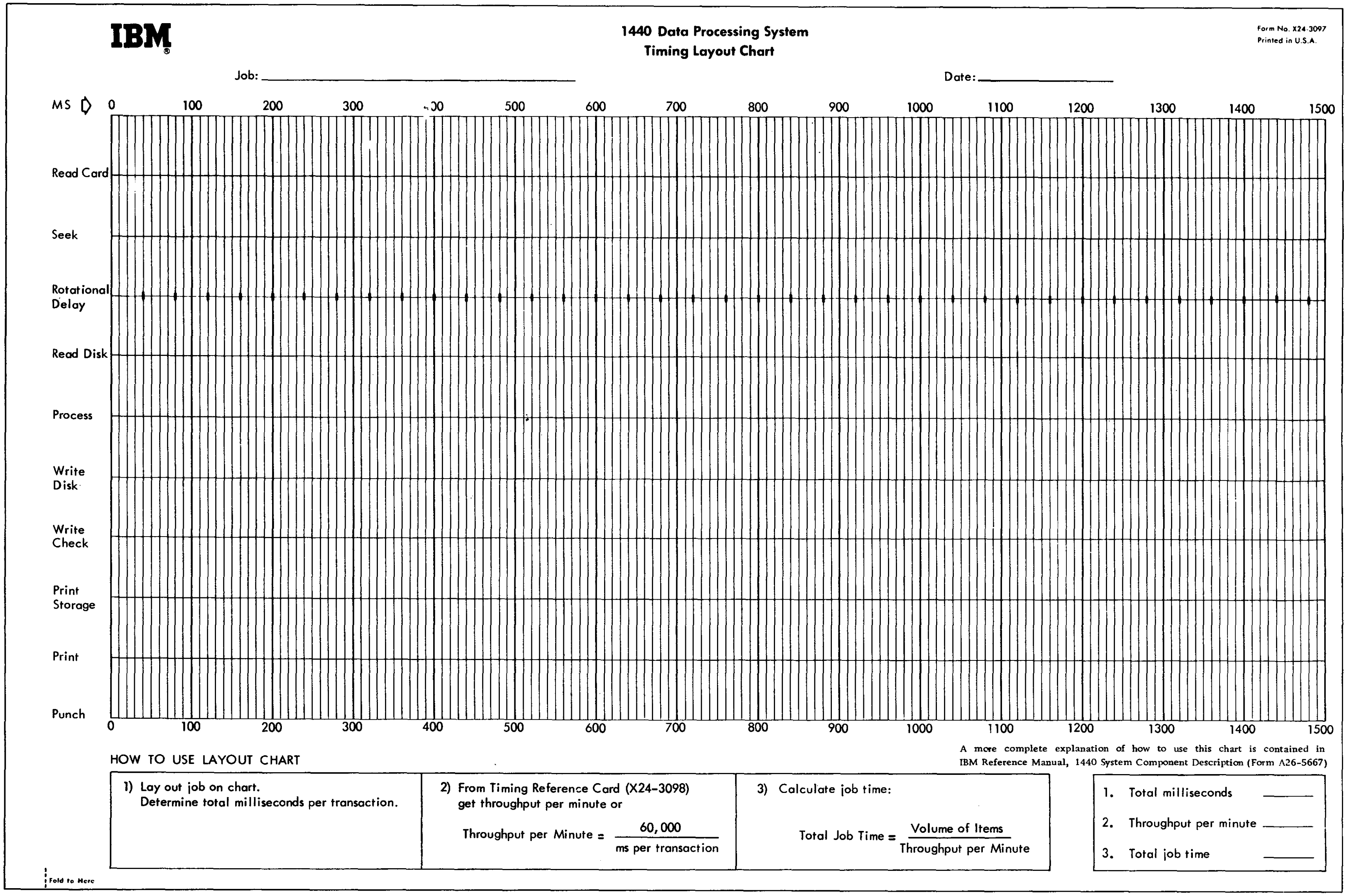
FRONT

Converting Total Cycle Time to Throughput Time

ms per Transaction	Throughput per Minute	ms per Transaction	Throughput per Minute	ms per Transaction	Throughput per Minute	ms per Transaction	Throughput per Minute	ms per Transaction	Throughput per Minute
100	600	700	85	1300	46	1900	31	2500	24
120	500	720	83	1320	45	1920	31	2520	23
140	428	740	81	1340	44	1940	30	2540	23
160	375	760	78	1360	44	1960	30	2560	23
180	333	780	76	1380	43	1980	30	2580	23
200	300	800	75	1400	42	2000	30	2600	23
220	272	820	73	1420	42	2020	29	2620	22
240	250	840	71	1440	41	2040	29	2640	22
260	230	860	69	1460	41	2060	29	2660	22
280	214	880	68	1480	40	2080	28	2680	22
300	200	900	66	1500	40	2100	28	2700	22
320	187	920	65	1520	39	2120	28	2720	22
340	176	940	63	1540	38	2140	28	2740	21
360	166	960	62	1560	38	2160	27	2760	21
380	157	980	61	1580	37	2180	27	2780	21
400	150	1000	60	1600	37	2200	27	2800	21
420	142	1020	58	1620	37	2220	27	2820	21
440	136	1040	57	1640	36	2240	26	2840	21
460	130	1060	56	1660	36	2260	26	2860	20
480	125	1080	55	1680	35	2280	26	2880	20
500	120	1100	54	1700	35	2300	26	2900	20
520	115	1120	53	1720	34	2320	25	2920	20
540	111	1140	52	1740	34	2340	25	2940	20
560	107	1160	51	1760	34	2360	25	2960	20
580	103	1180	50	1780	33	2380	25	2980	20
600	100	1200	50	1800	33	2400	25	3000	20
620	96	1220	49	1820	32	2420	24	3020	19
640	93	1240	48	1840	32	2440	24	3040	19
660	90	1260	47	1860	32	2460	24	3060	19
680	88	1280	46	1880	31	2480	24	3080	19

INSIDE

Figure 14. Timing Reference Card



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1440 Data Processing System
Timing Layout Chart

Form No. X24-3097
Printed in U.S.A.

Job: ______________________ Date: ______________

MS 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500

Read Card

Seek

Rotational Delay

Read Disk

Process

Write Disk

Write Check

Print Storage

Print

Punch

0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500

HOW TO USE LAYOUT CHART

A more complete explanation of how to use this chart is contained in IBM Reference Manual, 1440 System Component Description (Form A26-5667)

1) Lay out job on chart.
Determine total milliseconds per transaction.

2) From Timing Reference Card (X24-3098) get throughput per minute or

$$\text{Throughput per Minute} = \frac{60,000}{\text{ms per transaction}}$$

3) Calculate job time:

$$\text{Total Job Time} = \frac{\text{Volume of Items}}{\text{Throughput per Minute}}$$

1. Total milliseconds ______
2. Throughput per minute ______
3. Total job time ______

Fold to Here

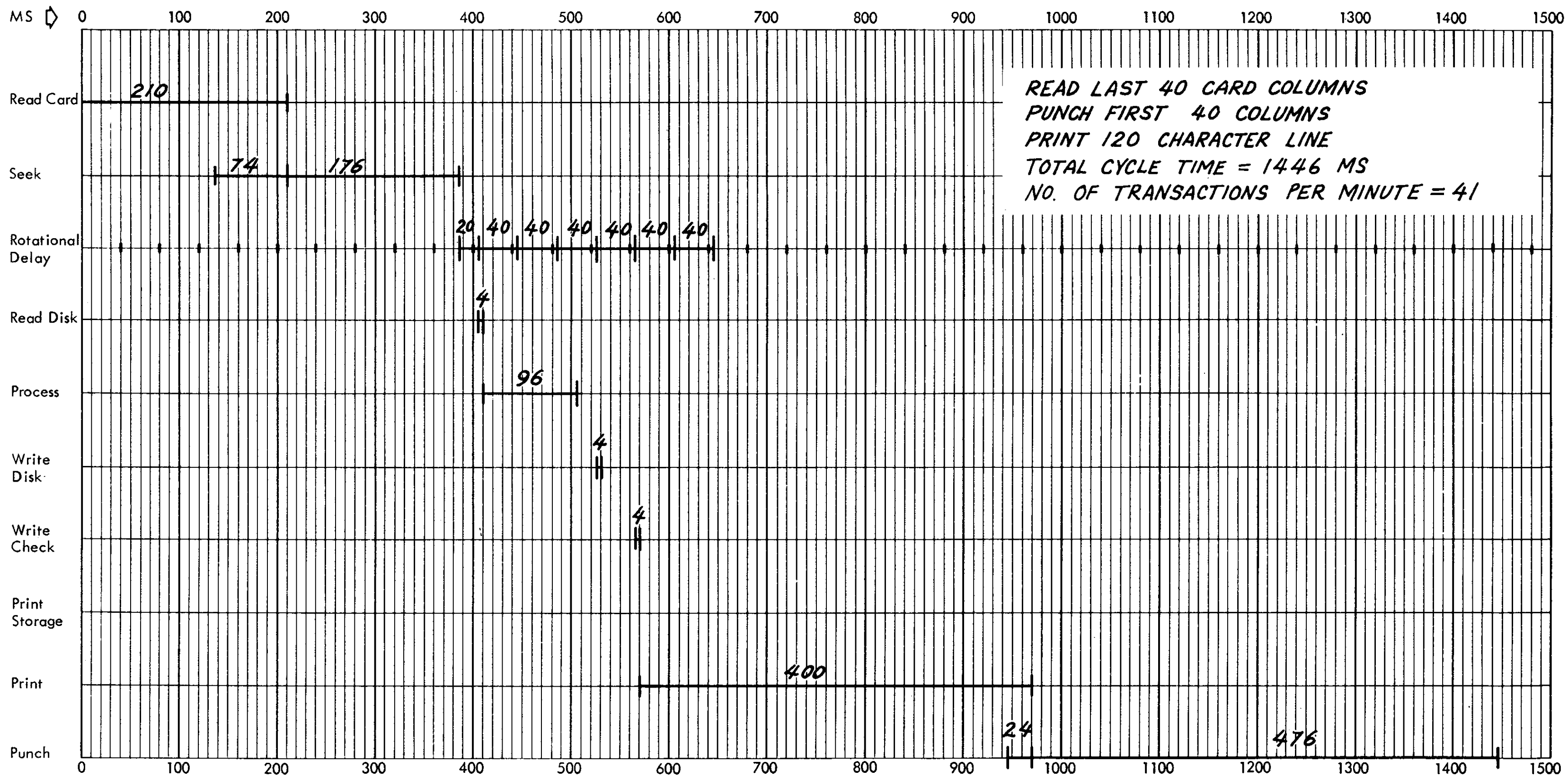
Figure 15. Timing Layout Chart

IBM

1440 Data Processing System
Timing Layout Chart

Form No. X24-3097
Printed in U.S.A.

Job: ____________________ Date: ____________



A more complete explanation of how to use this chart is contained in IBM Reference Manual, 1440 System Component Description (Form A26-5667)

HOW TO USE LAYOUT CHART

1) Lay out job on chart. Determine total milliseconds per transaction.	2) From Timing Reference Card (X24-3098) get throughput per minute or Throughput per Minute = 60,000 / ms per transaction	3) Calculate job time: Total Job Time = Volume of Items / Throughput per Minute

1. Total milliseconds ______
2. Throughput per minute ______
3. Total job time ______

Fold to Here

Figure 16. Timing without Print Storage

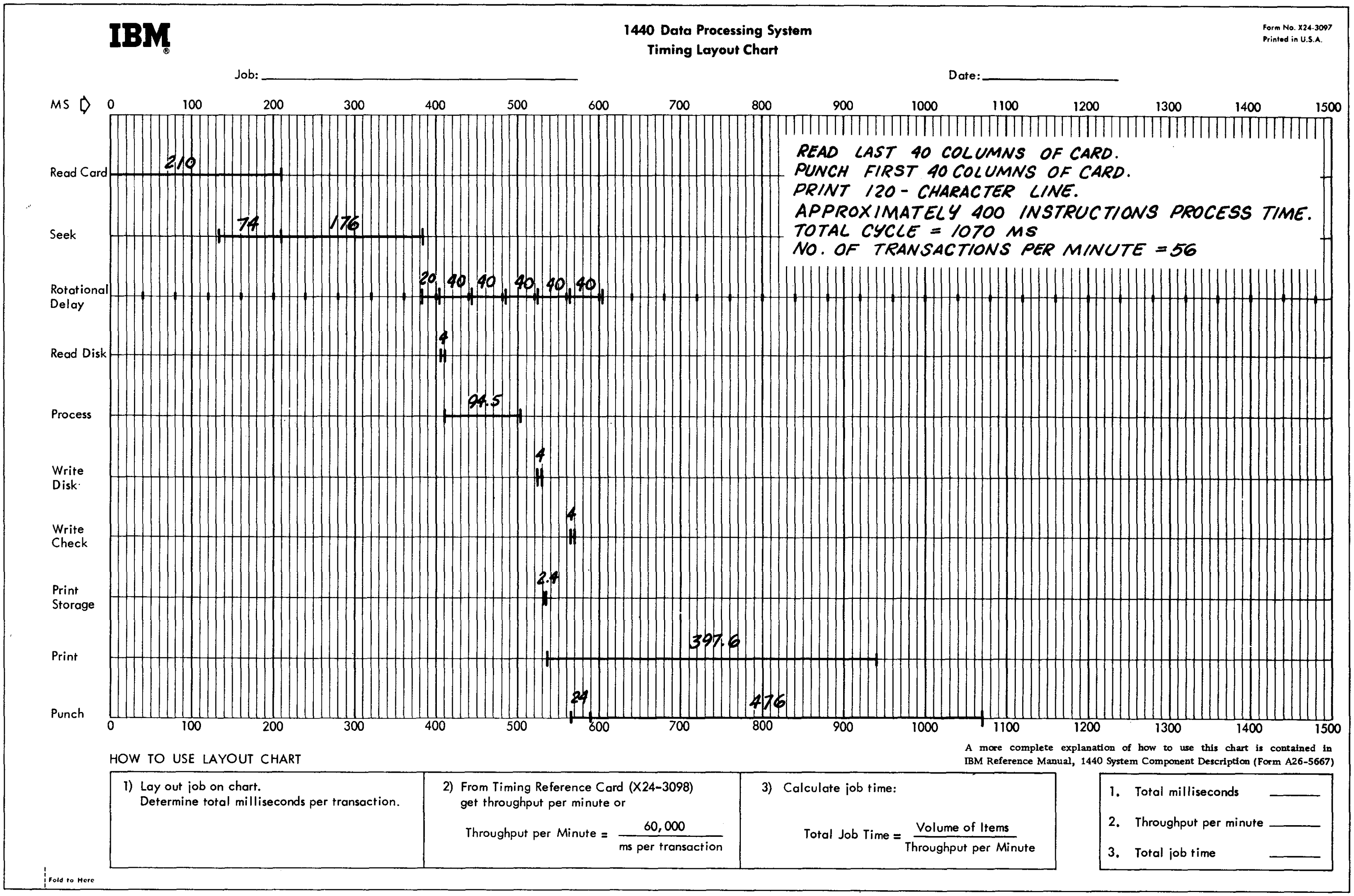


Figure 17. Timing with Print Storage

With the Print Storage feature installed the last portion of the print cycle which involves sending the print line to print storage, takes only 2.4 ms. Within the balance of the print cycle, a period of 397.6 ms for the 52-character set, one can write back and check the record on its respective cylinder, and most of the punch cycle can take place. The over-all cycle time is thus reduced from 1446 ms in the first example to 1070 ms in this example, the equivalent of going from a rate of 41 transactions per minute to 56 transactions per minute or an increase of 36%. This points up the importance of the Print Storage feature. From this example, it can be seen that those operations which can be overlapped, such as the Read, Seek, Punch, and Print with Print Storage, should be given special attention when one is laying out the timing chart, so that as much work as possible can be done within their framework.

Instruction	Timing (ms) .0111 x (L_I + :	Address Registers after Operation		Notes
		A address	B address	
Control Carriage	1)	---	---	Plus remaining form-movement time, if carriage is moving when instruction is given.
Load Characters	1 + 2 L_A)	A-L_A	B-L_A	
Move Characters	1 + 2 L_W)	A-L_W	B-L_W	
Print (write a line)	1)+ 376 ms	B + 197	B + 197	
Punch Card	1)+ 12.5 (L_B)ms	%Gn	B + L_B+1	
Punch Card	1)+ 6.25 (L_B)ms	%Gn	B + L_B+1	High-Speed Model
Punch and Feed	1)+ 12.5 (L_B)ms	%Gn	B + L_B+1	
Punch and Feed	1)+ 6.25 (L_B)ms	%Gn	B + L_B+1	High-Speed Model
Read Card	1)+10+[21+1.3(L_B+1)]	%Gn	B + L_B+1	
Read Card	1)+10+[15+1.0(L_B+1)]	%Gn	B + L_B+1	High-Speed Model
Read Console Printer	1)	%TO	B + L_B+1	
*Stacker Select	1)	---	---	
*Write Console Printer	1)+68(L_B)+800 (CR-1)	%TO	B + L_B+1	CR = Number of Print Element Returns

*Special Feature

Key to abbreviations used in formulas:

L_A	=	Length of the A field	Fm	=	Forms movement times
L_B	=	Length of the B field	A	=	A address of instruction
L_I	=	Length of Instruction	B	=	B address of instruction
L_W	=	Length of A or B field, whichever is shorter	X	=	Thousands and tens of starting address
I/O	=	Timing for Input or Output cycles	NSI	=	Next Sequential Instruction

APPENDIX B CHARACTER CODING CHART

DEFINED CHARACTER	CARD CODE	BCD CODE	13	39	52 A	52 H	63
Blank		C	X	X	X	X	X
. Period	12-3-8	B A 8 2 1	X	X	X	X	X
⌑ Lozenge	12-4-8	C B A 8 4			⌑	)	X
[Left Bracket	12-5-8	B A 8 4 1					X
< Less Than	12-6-8	B A 8 4 2					X
‡ Group Mark	12-7-8	C B A 8 4 2 1					X
& Ampersand	12	C B A			&	+	X
$ Dollar Sign	11-3-8	C B 8 2 1		X	X	X	X
* Asterisk	11-4-8	B 8 4	X		X	X	X
] Right Bracket	11-5-8	C B 8 4 1					X
; Semicolon	11-6-8	C B 8 4 2					X
△ Delta	11-7-8	B 8 4 2 1					X
- Hyphen	11	B	X		X	X	X
/ Diagonal	0-1	C A 1			X	X	X
, Comma	0-3-8	C A 8 2 1		X	X	X	X
% Percent Mark	0-4-8	A 8 4			%	(	X
⋎ Word Separator	0-5-8	C A 8 4 1					X
\ Left Oblique	0-6-8	C A 8 4 2					X
⧻ Segment Mark	0-7-8	A 8 4 2 1					X
b̸ Substitute Blank	2-8	A			X	X	X
# Number Sign	3-8	8 2 1			#	=	X
@ At Sign	4-8	C 8 4			@	'	X
: Colon	5-8	8 4 1			X	X	X
> Greater Than	6-8	8 4 2					X
√ Radical	7-8	C 8 4 2 1					X
? (Plus Zero)	12-0	C B A 8 2			X	X	X
A	12-1	B A 1		X	X	X	X
B	12-2	B A 2		X	X	X	X
C	12-3	C B A 2 1		X	X	X	X
D	12-4	B A 4		X	X	X	X
E	12-5	C B A 4 1		X	X	X	X
F	12-6	C B A 4 2		X	X	X	X

DEFINED CHARACTER	CARD CODE	BCD CODE	13	39	52 A	52 H	63
G	12-7	B A 4 2 1		X	X	X	X
H	12-8	B A 8		X	X	X	X
I	12-9	C B A 8 1		X	X	X	X
! (- zero)	11-0	B 8 2			X	X	X
J	11-1	C B 1		X	X	X	X
K	11-2	C B 2		X	X	X	X
L	11-3	B 2 1		X	X	X	X
M	11-4	C B 4		X	X	X	X
N	11-5	B 4 1		X	X	X	X
O	11-6	B 4 2		X	X	X	X
P	11-7	C B 4 2 1		X	X	X	X
Q	11-8	C B 8		X	X	X	X
R	11-9	B 8 1		X	X	X	X
⧧ Record Mark	0-2-8	A 8 2			X	X	X
S	0-2	C A 2		X	X	X	X
T	0-3	A 2 1		X	X	X	X
U	0-4	C A 4		X	X	X	X
V	0-5	A 4 1		X	X	X	X
W	0-6	A 4 2		X	X	X	X
X	0-7	C A 4 2 1		X	X	X	X
Y	0-8	C A 8		X	X	X	X
Z	0-9	A 8 1		X	X	X	X
0 (Zero)	0	C 8 2	X	X	X	X	X
1	1	1	X	X	X	X	X
2	2	2	X	X	X	X	X
3	3	C 2 1	X	X	X	X	X
4	4	4	X	X	X	X	X
5	5	C 4 1	X	X	X	X	X
6	6	C 4 2	X	X	X	X	X
7	7	4 2 1	X	X	X	X	X
8	8	8	X	X	X	X	X
9	9	C 8 1	X	X	X	X	X

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