D. A. Bishop
R. S. Heard
R. E. Hunt
J. E. Jones
R. A. Rahenkamp

Development of the IBM Magnetic Tape SELECTRIC® Composer

Abstract: The IBM Magnetic Tape SELECTRIC Composer (MT/SC) is a direct-impression (or "cold-type") typesetting system that combines the recording capabilities and automatic operation of the Magnetic Tape SELECTRIC Typewriter with the proportional spacing, justification and multiple-type-size features of the SELECTRIC Composer. Intended to permit high-volume, high-quality composition at moderate cost for users of offset printing methods, its design and development are described in this paper.

Introduction

The IBM Magnetic Tape SELECTRIC Composer (MT/SC) has been designed to provide for the printing industry a direct impression typesetting system whose output is comparable with hot type in print quality. The requirements to be met included, of course, those expected for any composing system—variable type size and style, multiple format capability, proportional spacing, and line justification, but it was also desirable to accommodate high-volume applications (newspaper work, for example) and minimize the time spent in keyboarding. To accomplish this, requirements for revision and error correction, for recording and playback, and for automatic justification, were added to the design objectives.

Several of the needed capabilities were already available. The ability to vary type style and a mechanism suitable for high speed operation were provided by the IBM SELECTRIC Typewriter. The Magnetic Tape SELECTRIC Typewriter (MT/ST) added recording, playback, and the capability of rapid error-correction and revision. The SELECTRIC Composer,[1] also in development at the time, added variable type size and line justification but lacked a recording capability. It remained, therefore, to combine these functions in one moderate-cost system.

The following new features were needed:

A new output unit. The existing MT/ST, with the control code modifications discussed below, was found quite suitable as an input station for the system. However, because input rates are bounded by operator speed while output rates (on an independent output unit) need be bound only by signal rates and mechanical limitations of the printer, it was decided to design a separate unit for use as an output station. This would consist of a tape reader, a control unit whose control code set had to be compatible with that of the input station, and a SELECTRIC Composer linked to the control unit through an electromechanical transducer.

The separation of input and output stations also had other advantages. The input operator would not need to control format, justification, or changes in type size except by entering appropriate instruction codes, while the output station would not receive copy until all pre-proof error correction and revision had been completed. The output operator would need to intervene only for paper loading, type font changes, and hyphenation decisions.

An expanded control code set. The basic elements for recording, playback and error correction were the magnetic tape unit and the associated control logic and internal control code set of the MT/ST. For the MT/SC, however, new interpretations of certain control codes were required to accommodate formatting operations and justification. The MT/ST reference code had to be retained, and all appropriate control codes had to be accommodated in the output station control unit.

Automatic justification. In the SELECTRIC Composer the justification function is semiautomatic[2]; the machine computes the amount of line-end space to be filled but the operator must set a dial and retype the line to justify. A more automatic procedure was needed for the MT/SC, and a scheme was devised wherein ordinary justification and line expansion would be automatic. The output station operator would be required only to make the hyphenation decision causing, at most, a portion of one word to be printed (the word being hyphenated) for each decision.

A means (discussed below) was found to adapt this scheme to the SELECTRIC Composer without mechanically modifying that machine.

As work proceeded, certain other constraints had to be borne in mind. It was necessary, for example, to retain the ease of original keyboarding and related error correction capabilities and the capacity for successive author alterations that were offered by the MT/ST. Also, there was some possibility of "overdesign." Internal data flow rates and signal delays would not be efficient nor economical if they greatly exceeded the mechanical capacity of the keyboards and printer, and although speed and output capacity were important, these were not to be obtained by sacrificing print quality.

This paper describes the MT/SC system and explains its design. A general description is given in the next section, followed by a section on internal organization in which the important design decisions are reviewed, and a section on adaptation of the SELECTRIC Composer. Finally there is a discussion of system efficiency and generalized cost-performance, in which the MT/SC is compared with larger and smaller cold-type systems.

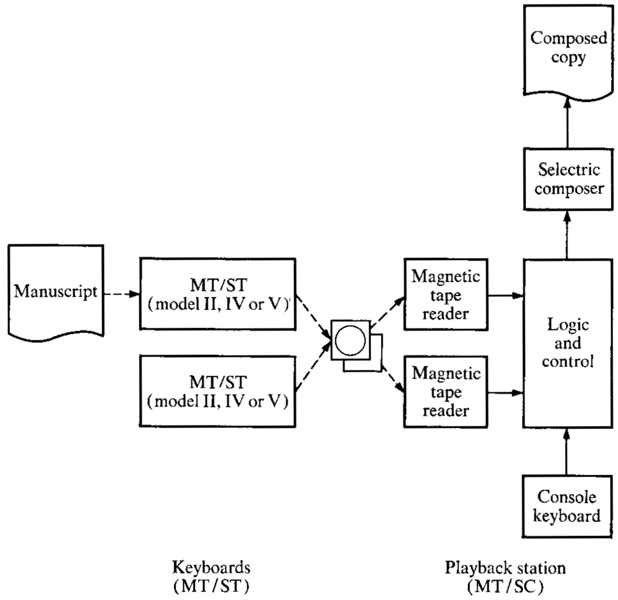


Figure 1 Block diagram of MT/SC system.

MT/SC system

A typical configuration for the MT/SC is diagrammed in Fig. 1; Fig. 2 is a photograph of the same version. The input station may be an MT/ST Model V or a modified Model II or IV. The output station consists of a two-station tape reader, a console containing all the circuitry necessary for justification and other composition functions, and a modified SELECTRIC Composer as the printer.

Each unit can be used alone when appropriate. MT/ST Model II and IV input stations can be used for playback error correction and revision, while the Composer station has a keyboard and can receive manual input. (Manual input is expected occasionally when a minor change might be made after composition.) Since the elements are separate, however, each can operate at its own maximum efficiency. On straight justified material with few typefont changes, the Composer unit is capable of more than 120 words per minute. Keyboard rates at the input unit depend, of course, on the operator. A person with average typing skills is probably capable of 50 words per minute. With such an assumption a typical balanced system, matching sustained recorder rates to output rate, contains two entry keyboards and one Composer unit.

Copy is prepared for composition by means of control and reference codes which can (and normally will) be recorded on tape at the entry keyboard along with the copy itself. (Copy can remain uncoded, however, and composition instructions may be entered manually at the Composer keyboard and output unit console just prior to final printing.) There are five printing modes (full justify, flush left only, flush right only, line-by-line centering, and flush right with dot leaders); each of these is selected by entering the appropriate single-character control code. Other codes, which are combinations of single letters or symbols and decimal numbers, are used to specify column width, indentation, etc. and to indicate stopping points for typefont changes or revisions. Codes are recorded at the entry keyboard by first depressing a special key called the prefix key, which indicates to the system that the subsequent signal will be a code and not a text character. The operator then enters the code character itself. In addition to being recorded, the codes appear in red on the input station printout; this permits the operator to confirm that the recording is correct. Codes do not appear, however, on the final Composer output.

Errors can be corrected in several ways. Simple keying errors can be corrected through backspace and strikeover or by means of line return. Some corrections, such as author alterations, may be required after the original tape has been completed. These are made by merging an appropri-

Figure 2 Photograph of the configuration shown in Fig. 1.

ately coded correction tape with the original tape after delivery to the output unit. Corrections can also be made by preparing a new original tape at the entry keyboard.

Final printing is accomplished by mounting the original tape and a correction tape, if any, on the two-station reader output unit, setting the pitch, leading, impression control and dead key space selector of the Composer unit to the desired values, and entering set-up instructions on the console control panel (e.g., one-station or two-station tape read, depending on whether a correction tape is present; line count instructions for format control and space to be left for pictures, etc.; special format instructions; and any required control codes known to have been omitted from the input tape). During printing the operator changes type elements when necessary, loads paper as required, and makes and enters hyphenation decisions if justified copy is being printed.

The result of this playback is composed copy which is proofread. If no errors exist, the copy is sent to a page layout operation along with illustrations, headlines, etc. A completed page layout is photographed for offset printing.

There are, of course, a number of procedures for using the system that are not covered fully above. These and a full description of the instruction and control codes will be found in the Appendix.

System modularity

Because the printing industry frequently needs to observe urgent deadlines, the system can provide a measure of "back-up" for the user. Should one of the elements of the system become inoperative, a reserve unit can be substituted. Since the keyboards and output unit are separate, an additional keyboard can be installed to serve either as back-up or as an additional production unit during peak loads. Design of the output console permits easy attachment and removal of the SELECTRIC Composer. A reserve SELECTRIC Composer can also be used as a manual composing machine during peak loads. Full back-up can be achieved by installing an entire additional playback unit.

• *Paper tape attachment*

Many newspapers are able to reduce their keyboarding costs by using pre-justified paper tape to feed tape-driven linecasters. The tape used is TeleTypeSetter* (TTS)-coded, six-channel paper tape. It is produced by perforators attached to wire service terminals, by computers, or by manually operated perforators.

A paper tape attachment is available for the MT/SC which enables it to produce composed copy directly from pre-justified TTS-coded paper tape without intermediate keyboarding. This reproduces the lines exactly as punched on the tape, with all line endings and hyphenation points predetermined. Special type elements are available which contain the TTS character set. The paper tape attachment is available either with or without magnetic tape input to the playback unit. If both inputs are available, the system can be converted from operation with one medium to operation with the other in approximately three minutes. With the ability to utilize press wire paper tape, the system can also accept the output of many standard TTS-coded paper tape justifying keyboards and of computer systems such as those now used to produce hyphenated justified copy for linecaster operation.

MT/SC control unit: internal design and organization

The control unit within the playback station console provides the logical capability required to perform all of the composition functions of the system. Because the input/output devices and keyboard stations were adaptations of existing equipment, the control unit provided the best opportunity to favorably influence total system cost. The overriding consideration in designing the control unit was to achieve the required functions at minimum cost.

A secondary objective was to provide flexibility so that the machine could be easily adapted to different applications in word processing. The basic configuration had to satisfy the widely varying requirements of general composi-

* Trademark, Fairchild Camera and Instrument Co., Inc.

tion. It would not be permissible to allow application complexity to be reflected in equally complex hardware. Another objective was to simplify maintenance procedures. The machine organization also had to allow quick implementation of any changes in required function which might occur during the development period.

One of the required functions was to provide output copy at the maximum printing speed of the SELECTRIC Composer (14.1 characters per second) with minimum interruptions. The input unit, a 20 characters-per-second magnetic tape reader, is also an incremental device. In general, it is necessary to read enough text from the tape to make up an entire output line before sufficient information is available to compose the line. Thus the control unit must have storage capacity for at least two lines of text, the line being read in and the line being printed. To process the text, the control unit must have available escapement information (between zero and 9 units per character[3]) for each of 106 possible input codes from the magnetic tape (88 printing characters plus control codes). This information could be obtained if generated by decode logic, but this would be quite expensive for so many codes. A simpler solution was to locate an escapement table permanently in storage, which could be the same as that used for the buffer. The requirement for permanency effectively required the use of magnetic cores, although delay line storage might have been otherwise competitive. Finally, a number of working registers (for example, to accumulate line length in units) were needed and could be implemented in core storage more cheaply than by any other means. These storage requirements could be satisfied by a core memory of about 500 8-bit bytes.

A means for controlling the sequence of operations was needed. Since the incremental cost of expanding the core memory was low, a microprogrammed approach to control was selected as the most economical solution. At its final size of 2048 bytes, the memory fulfills all the above storage requirements. The microprogram approach has the following advantages:

1. Hardware cost for implementing the control logic is low.
2. Engineering changes, changes in the functions to be performed, and new features require little or no hardware change and can be implemented rapidly.
3. The training of service and manufacturing personnel is simplified, since they need only to understand how the machine executes a simple instruction set, rather than to understand a complex application.

A single basic application program sufficiently versatile to meet the needs of the majority of users was to be provided. To relieve these users of any involvement in software, it was decided that the program should be factory loaded, that there would be no operator controls to modify it, and that adequate safeguards should be provided against accidental loss (such as by power failure). Variations of the basic program have been developed to meet specific needs, such as the press wire paper tape application.

The circuit family chosen for the control unit was low speed SLD, a more densely packaged version of SLT (Solid Logic Technology).[4] This family has an average circuit delay of approximately 450 nanoseconds. The choice was made on the basis of minimum machine cost and ready availability. Factors influencing the selection were:

1. Only a single, wide tolerance power supply (+12 volts, plus or minus 7%) is required for logic circuits.
2. No forced air cooling is required in a small machine such as the MT/SC control unit.
3. The high circuit density per module reduces packaging costs. To take advantage of this density all logic cards were functionally packaged, with an average of 17 modules per card, a number limited only by the 44 signal pins available per card. Density averages about three circuits per logic module, with about 1000 circuits in the machine.

For the core memory a 4-bit-wide, 3-D configuration was selected as being the most economical for the desired size. It uses the same 12-volt power supply required for the logic circuits. Many of the memory circuits and array components were selected from those used in existing products such as the IBM 2740 Buffer Terminal. Many of the memory circuits operate from logic-level inputs, so that no well-defined interface is needed between memory and logic.

Because of the high reliability and small number of components, no parity check is built into the memory or any other data path of the control unit. An overall check on system output is provided by proofreading the final copy. In the printing industry, this proofreading is invariably done on the final copy in any case, so that type style, copy fitting, and hyphenation can be checked.

Internal speed was not a major requirement for the control unit, since output is limited by the printer speed. Although the memory is capable of a read-write cycle time of approximately 8 microseconds, the actual cycle time is 25 microseconds, which allowed the logic to be designed for minimum cost rather than minimum delay. As is shown below, this results in adequate overall machine speed.

• *Instruction Set*

The internal organization of the control unit was determined largely by the specialized instruction set, which was selected for efficiency in word processing. The prime objective was to achieve maximum function using minimum storage for the program, since the economically feasible storage capacity was fixed at 2048 bytes while the desirable machine functions were in effect unlimited. Since there was no likelihood of interfacing at the program level with any other equipment, compatibility at this level with other

Branch (32.4%)

16	15	14–13	12	11–2	1
0	0		L	Program step address	

Link if L = 1

Conditions	Bits 14	13	1
Unconditional	0	0	0
Unconditional	0	0	1
Non-negative	0	1	1
Negative	1	0	0
Zero	1	0	1
Non-zero	1	1	0

Incremental branch (8.6%)

16	15	14	13	12	11–8	7–6	5–2	1
1	0	F	0	B	Bit	Q register	Increment	0

Increment positive if F = 1, negative if F = 0.
Branch taken when bit = 1 if B = 1, taken when bit = 0 if B = 0.

Bit control (9.9%)

16	15	14	13	12	11–8	7	6–2	1
0	0	1	1		Bit		Q register	1

Operations	Bits 12	7
Test and reset	0	0
Test	0	1
Test and set	1	0
Test	1	1

Immediate (24.2%)

16	15	14–13	12–9	8–1
1	1		P register	Immediate data (I)

Operations	Bits 14	13
Subtract P—I → P	0	0
Compare P—I	0	1
Add P + I → P	1	0
Transfer I → P	1	1

Register (18.0%)

16	15	14–13	12–8	7	6–2	1
0	1		P register	0	Q register	0

Operations	Bits 14	13
Subtract P—Q → P	0	0
Compare P—Q	0	1
Add P + Q → P	1	0
Transfer Q → P	1	1

Byte (indirect) (3.7%)

16	15	14	13	12–8	7	6–2	1
0	1		I	P register	Q	Q register	P

P address indirect if P = 1.
Q address indirect if Q = 1.
Indirect addresses indexed if I = 1.

Operations	Bit 14
Compare P—Q	0
Transfer Q → P	1

Output (2.0%)

16	15	14	13	12	11	10–8	7	6–2	1
0	0	0	1	0	M	Device	Q	Q register	0

Q address indirect if Q = 1. (Index automatic)
Interrupt mode if M = 1.
(Must have Q = 1, Q register must be number zero)

Input (1.2%)

16	15	14	13	12	11–8	7	6–2	1
0	0	0	1	1	Device	0	Q register	0

Figure 3 Instruction set for control unit. Numbers in parentheses indicate relative usage in percent for each type of instruction.

machines was not a consideration. Since the basic application called for only one program and all programming was to be performed in machine language by engineers in the logic design group, no programmer aids were built into the machine.

Each 8-bit byte of the memory is sufficient for a single character, which enters the control unit in 7-bit form from magnetic tape. Since the largest number encountered in the composition application is approximately 1000, a two byte length for working registers is more than adequate. All numeric quantities are in binary form, with negative numbers in two's complement form. Instructions are also 16 bits long, primarily in order to provide a conditional branch in a single instruction. This instruction length allows data manipulation operations to be in the two-address form if the directly addressable registers are limited to 32 in number. The two-address instruction was chosen over single-address on the basis of storage efficiency. However, as shown below, implementation is essentially single-address in that only one Memory Address Register (MAR) is required. Figure 3 shows the complete instruction set, together with percentage use of each class of step in the basic microprogram.

The composition application requires a great many logical decisions to be made, but only a few calculations. Therefore the primary aim in designing an instruction set was to make decisions using minimum storage. Thus the set includes two types of branch instruction. One is capable of branching to any other instruction, with the decision to branch determined by the state of two condition latches set in a previous step. The other (incremental branch) is capable of branching to an instruction located only a few steps away from the branch, with the decision to branch determined by the state of a specified bit within a working register. A link option is available with the first type of branch to facilitate the use of subroutines.

A second major function is character testing, modification, and generation. Instructions are available to test, set, or reset any bit in any register. By means of immediate operations it is also possible to generate any character or to compare it with another.

Character movements are also important. For this purpose directly addressed register-to-register operations are available. To compensate for the limited direct addressing capabilities, indirect addressing is also available, together with indexing in the same instruction. The indexing and the fact that all indirectly addressed operands are automatically limited to one byte in length facilitate handling of character sequences.

Arithmetic addition and subtraction are used mainly for maintaining counts and modifying indirect addresses. Both register-to-register and immediate instructions are available for this purpose. More complex operations are performed by subroutine if needed.

The I/O instructions allow for the servicing of one output device on an interrupt basis, while all other operations must be handled on a single-character-per-instruction basis. This is sufficient for the desired applications.

In practice this instruction set has met its objectives very well. The limitation to only 32 directly addressed registers is perhaps the least desirable feature. In some applications the limitation of interrupt-mode output to a single device at a time has been inconvenient. However, this is a limitation of the implementing hardware rather than of the instruction set.

• *Implementation of instruction set*

The internal data paths and latch registers are shown in Fig. 4. There is a single Memory Address Register. However, there are three words in memory which can be addressed independently of the MAR. These are the Instruction Address Word (IAW), A Word (AW), and B Word (BW). The use of these special-purpose words reduces the hardware required for the instruction set, but essentially doubles the time required.

For each type of instruction, execution is governed by sequencing a word counter. Normally this counter advances in a binary fashion at the end of each word time, but it can be permuted to skip unused states or to return to the initial state. Figure 5 shows the word time sequence for each type of instruction, together with the operations performed in each word time. Note that odd word times are devoted to loading the MAR from memory. I1 and I2 may be regarded as instruction access times. All arithmetic operations take place during I10, with intervening times used for data and address preparation. Indexing, for both the IAW and the indirect addresses, is accomplished by writing from the accumulator rather than from the data register.

The operations indicated under the word times of Fig. 5 are controlled by a very few signals which are usually generated from the operation codes, word times, and clock states. The most important signals are two which control writing into memory from the data register or from the accumulator and three which control selection of IAW, AW, and BW. If none of the three special-purpose words is selected, the word (MW) addressed by the MAR is automatically selected.

A word time consists of four half-byte times. In each half-byte time four bits of the selected word, or words, may be read and/or written. Certain word times, such as I4 and I10, require operations between two words. In this case the half-byte time has a read-read-write-write (RRWW) sequence as shown in Fig. 6. However, most word times do not require two-address operation. In this case, the half-byte time has a RWW sequence as shown in Fig. 7. If the accumulator is used during a word time, the result must be written during the second write time, with the first write

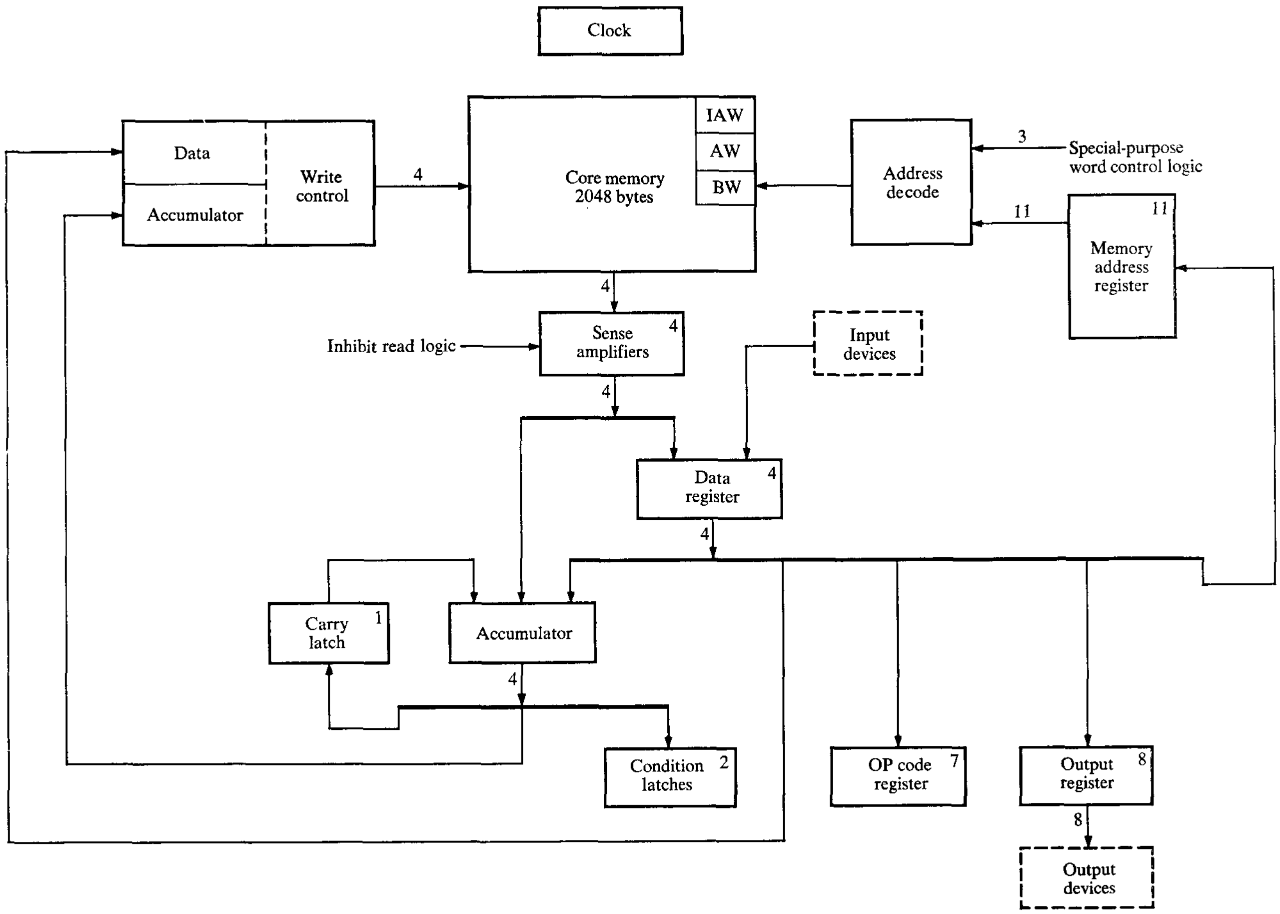


Figure 4 Internal data flow of control unit.

time providing delay time for carry propagation. In I4, I6, and I8, the first write time is used to transfer the data read to a second word, which was left cleared by a read operation in a previous word time. In single-address situations where the time from the read to the final write is fixed by accumulator delays, the use of the intervening time for a write operation (RWW) costs no time over a RW cycle. However, when two-address operation is required, only a read time need be added, resulting in faster operation than would be the case had RW been used for single address and two single-address cycles used for two address;

• *I/O operations*

The I/O operations required in the composing application are not complicated. A standard interface was defined so that several I/O devices might be attached, but the interface operates on the basis that no more than one input device and one output device will be active at a given time. Normally, the active devices are the magnetic tape reader input and the Composer output. None of the devices associated with the control unit is capable of both input and output. Since all devices are of an incremental nature, all I/O operations involve the transfer of a single character. If an input instruction is encountered while an input device is busy, the system waits until that device completes its operation. A similar wait occurs if an output instruction is encountered while an output device is busy.

One exception to these rules is made to allow output of one line concurrently with the processing of input text for the next line. It is possible for an output device to operate in an interrupt mode by forcing simulated output instructions to occur between instructions of the routine being executed by the program. The output characters for this mode are indirectly addressed by a working register which is indexed at each interrupt. To simplify the hardware there is only one such register, so that this mode is limited to one device at a time. The interrupt mode is terminated by the detection of a halt code as a character in the stored output data.

The maximum I/O rates are far in excess of the requirements of any of the I/O devices or of the ability to process the data—833 characters per second for output and 1667

Instruction type	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	Comments
Branch	IAW → MAR +2	MW → AW	AW → MAR +2	IAW → MW						AW → IAW	If branch not taken, return to I1 from I2. If branch taken, but no link, skip to I10 from I2. If branch taken with link follow sequence I3, I4, I10 after I2.
			Branch taken with link							Branch taken	
Incremental branch	IAW → MAR +2	MW → AW	AW → MAR	MW Test bit						IAW±AW → IAW	If branch not taken, return to I1 from I4. If branch taken, skip to I10 after I4.
										Branch taken	
Bit control	IAW → MAR +2	MW → AW	AW → MAR	MW Test, *set, or* reset bit							
Immediate	IAW → MAR +2	MW → AW					AW → MAR			MW * AW → MW	* represents subtract, compare, add, or transfer operation.
Register	IAW → MAR +2	MW → AW	AW → MAR			MW → BW	AW → MAR			MW * BW → MW	Note: BW is always left cleared after an instruction.
Byte	IAW → MAR +2	MW → AW	AW → MAR	MW → BW +1 if I=1	BW → MAR	MW → BW	AW → MAR	MW → AW +1 if I=1	AW → MAR	MW * BW → MW	Skip from I3 to I6 unless Q is indirect. Skip from I7 to I10 unless P is indirect.
				Indirect Q				Indirect P			
Input or output	IAW → MAR +2	MW → AW	AW → MAR	MW → BW +1	BW → MAR	MW → 0 Reg or Input device → MW					Skip from I3 to I6 unless Q is indirect.
				Indirect Q							
	Access instruction		Install link, operate on Q data, or place Q data in BW				Place Q address in MAR			Execute	

Figure 5 Word time sequences for instructions. Blank word times are skipped during execution (see comments on diagram). Arrows indicate transfers of data among IAW, AW, BW, MW (memory word), MAR, O Register and input devices. Indexing before writeback is indicated by +1 or +2.

characters per second for input. There is no provision for testing the state of I/O devices. Error conditions cause a stop until the error has been manually cleared. In an operator-oriented system with relatively small volumes of I/O data this is an acceptable procedure.

• *Control panel*

Operator control is performed by means of a 12-key panel (Fig. 8). Information may be displayed to the operator by means of 11 display lights (and by the printer). When set in a unique mode not available to the operator, the same keys and lights can be used to gain access to, display, or change the contents of any byte in memory. The same lights may also be used as a service aid to selectively display 50 different internal signals. Also present but not available to the operator are means to step the control unit through operations by half-byte time, word time, and program step. These aids are normally sufficient to locate from the control panel a probable faulty logic card. This multiple usage of keys and lights on the control panel results in a considerable cost saving.

No hardware is provided specifically for loading the program. A short (3-step) routine capable of loading a program can be manually entered at the control panel by service personnel. Although there are several variations of the application program, they all contain an identical

Figure 6 Read-read-write-write (RRWW) half-byte timing diagram, showing selected clock signals and memory drive signals. The sequence requires 50 μsec.

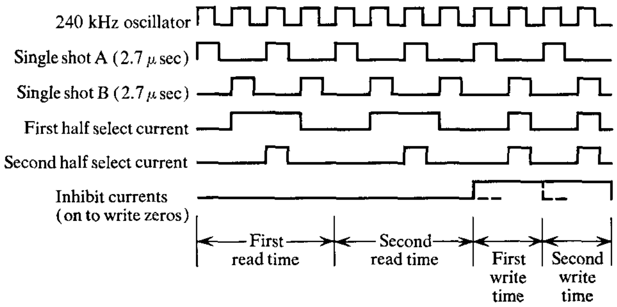
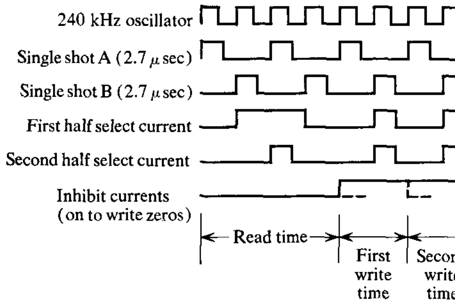


Figure 7 Read-write-write (RWW) half-byte timing diagram. This sequence requires 33.3 μsec.

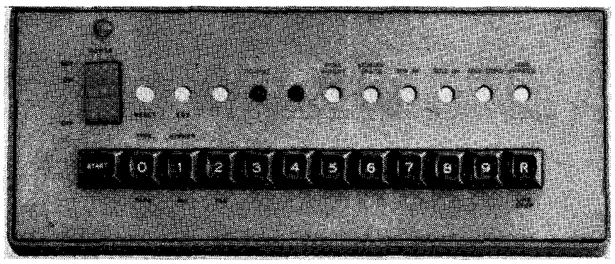


portion capable of loading factory-recorded program tapes. This routine can be accessed by normal operator actions at the keyboard. This avoids the need for operator knowledge of the internal operations or instructions of the machine and any need for special program-loading hardware. Special circuits monitor the logic power supply voltage and shut the machine down in case of power failure to prevent loss of the program. The power-on sequence always starts the machine at the same instruction to avoid any operator intervention in addressing.

Table 1. Allocation of core memory.

Assignment	*Bytes*
Working registers	64
Microprogram	1584
Input block	150
Output block	120
Escapement table	64
Other tables and stored quantities	60
Special-purpose words (IAW, AW, and BW)	6
Total	2048

Figure 8 Composer output unit control panel.



• *Program*

For the basic composing application program, the memory is allocated as shown in Table 1. In typical operation, characters are read in at 20 characters per second from the magnetic tape reader to the input block of storage. The characters are analyzed to determine whether they are control codes or require some other special handling. The escapement values are looked up and added to the line length counter.

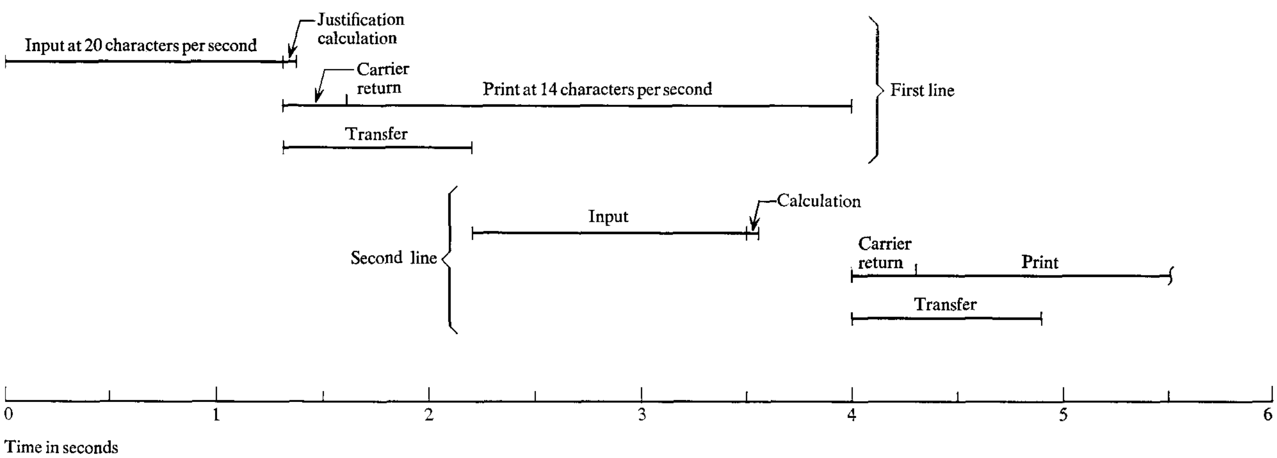
When a word is detected which causes the line length to exceed the desired line length, a justification calculation is made neglecting this last word. If the calculation does not result in interword spaces of acceptable size, the last word is presented to the operator for manual hyphenation. After the operator's decision, the calculation is repeated.

After a successful calculation, the line is transferred from the input block to an output block, with appropriate modifications which convert internal codes to the coding required by the output printer. As the transfer begins, a printer output operation in the interrupt mode is initiated, beginning at the start of the output block. Since the transfer is faster than printing, loading of the output block always stays ahead of the output from the block.

Once the transfer is complete, the remaining portion (if any) of the last word is moved to the beginning of the input block and input of the next line begins. The input operation normally is completely overlapped by the print operation.

Figure 9 shows timing for a typical 25-character newspaper line. Because of case changes and the carrier return, the input line will have about 26 codes and the output line will have about 30 codes. Note that, despite the large amount of time taken in the transfer operation, speeds are sufficiently well matched that the overall throughput is strictly a function of Composer speed.

Figure 9 Timing diagram for two typical 25-character lines. Since printing is overlapped with other operations, throughput is limited only by output speed. For 25-character lines, the rate is about 25 lines per minute.



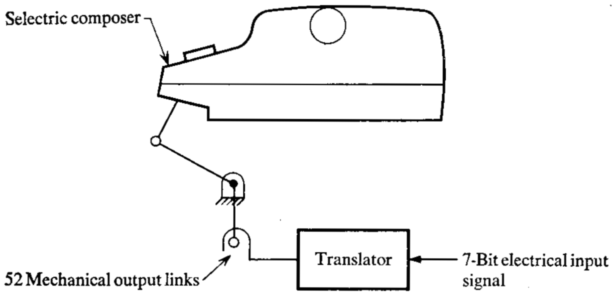


Figure 10 Schematic illustration of electromechanical translator arrangement.

Figure 11 Mechanical coding system for translator.

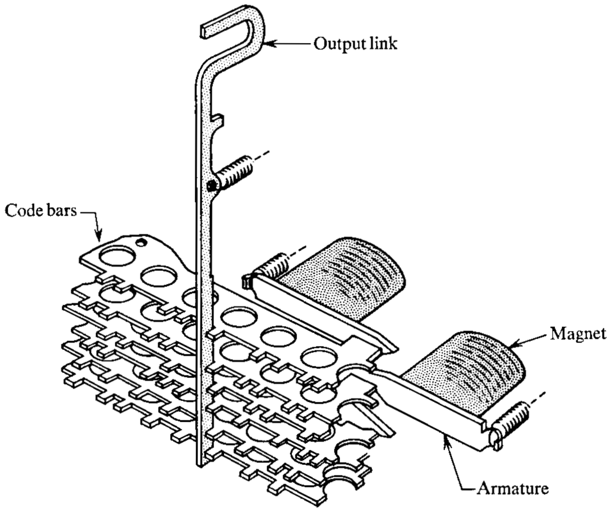
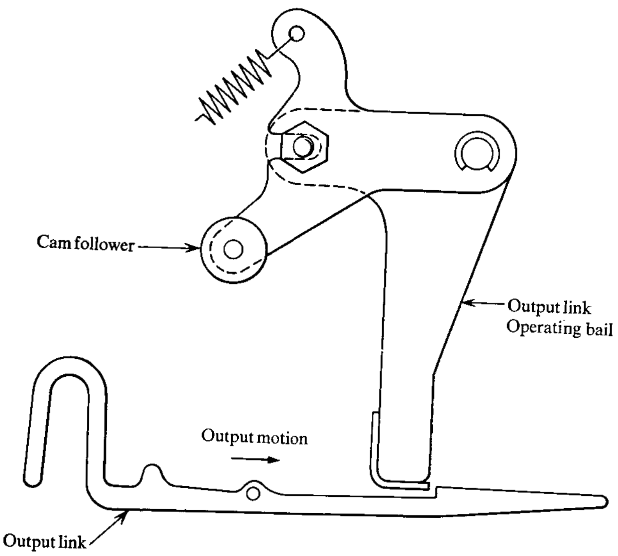


Figure 12 Translator actuating mechanism.



Printer output

In adapting the IBM SELECTRIC Composer to automatic operation it was deemed unwise to develop this machine into an I/O unit through the addition of magnets, contacts, etc. Instead, the Composer is driven by pulling its keylevers, including function keylevers, from an external translating device. This arrangement is represented schematically in Fig. 10.

The function of the translator is to accept an eight-bit electrical input in the code configuration of the processor and to convert this input to one or more of 52 outputs to pull the appropriate composer keylever(s). The translator accomplishes this through a series of edge notched code bars, each actuated by a bit magnet. Along each code bar edge, there are 52 positions arranged in such a way that once the appropriate code bars are selected, only one of 50 links can pass through the bars shown in Fig. 11. Two other links correspond to special escapement and the no-print function and each of these two links will pass through whenever its corresponding magnet is energized. Six bit magnets control the 50 output links. When the output link(s) pass through, they are selected and pull the appropriate Composer keylever(s).[5]

The translator is basically a clutch-operated rotary device, Fig. 12. Its cycle starts when the clutch and code magnets are selected. All other motions are then cam-controlled during the cycle, including the motion of the selected code bars, the selection of the output links and the motion of the output links to pull the keylevers of the Composer.

The translator can operate at an output speed of up to 16 characters per second, more than enough to drive the Composer at its nominal rate of 14.1 characters per second. For the most part, the translator was developed from pre-existing hardware.

• *IBM* SELECTRIC *Composer modifications:*

A prime object in developing the system was to utilize the Composer with the minimum possible modifications. (A full discussion of the Composer is given elsewhere.[1–3,5,6] The following additions were necessary:

Variable spacing. The basic Composer has an adjustable spacebar controlled by setting a dial[2] which permits interword spacing varying between three and nine units. To adapt this method for automatic operation would have required an indexing mechanism for stepping the value dial plus a linkage for actuating the spacebar. This would be a major addition of parts to the manual machine.

An alternate solution to the variable interword space problem was found by utilizing the no-print capability[5] of the Composer. The no-print key allows character escapement without printing. When used in conjunction with a character, the carrier will escape the given value of escape-

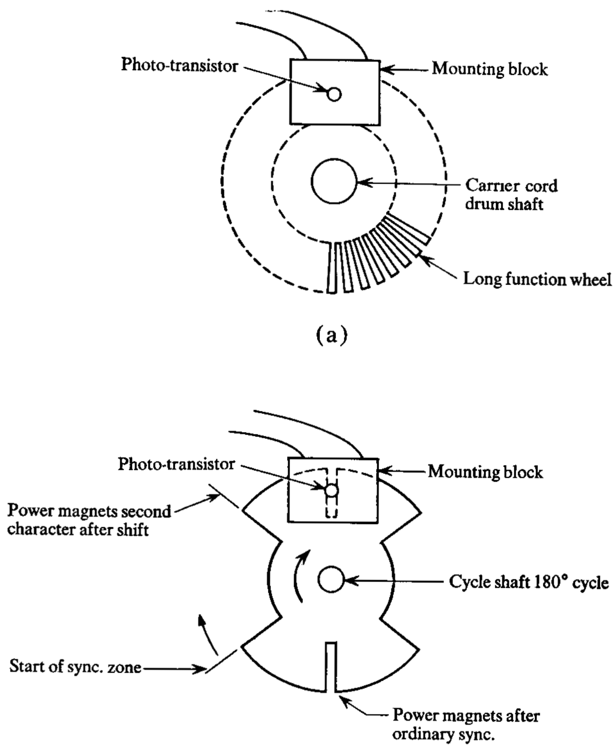


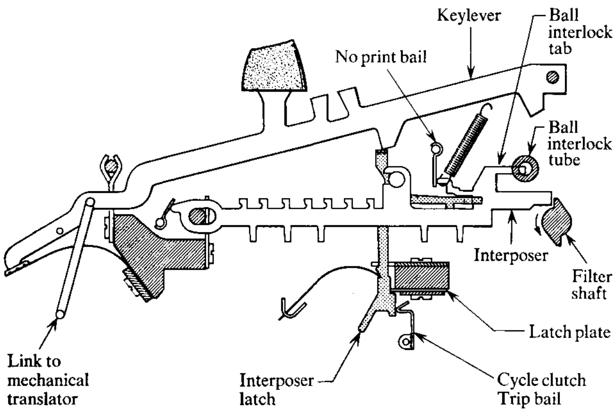
Figure 13 Photoelectric synchronization feedback: (a) inhibit feedback device for long functions (carrier return and tabulation); (b) synchronization feedback from print cycle shaft.

ment for the character but will not print the character. Therefore, if a character with the desired escapement value and the no-print key are selected simultaneously, any desired space can be achieved. A special no-print keylever and interposer are required in the Composer. This interposer is designed so that it is not locked out by the ball interlock[5] and is coded to actuate the no-print bail when selected. A simultaneous pull of two keylevers is accomplished by adding a no-print code bar to the mechanical translator. This code bar, when selected by the electronic logic, pulls the no-print lever, in addition to the keylever for any other desired character. The character is selected from the logic for its escapement value which, when employed in no-print mode, results in the proper interword space. The Composer is so designed that if the no-print keylever alone is pulled, a nine unit space will result.

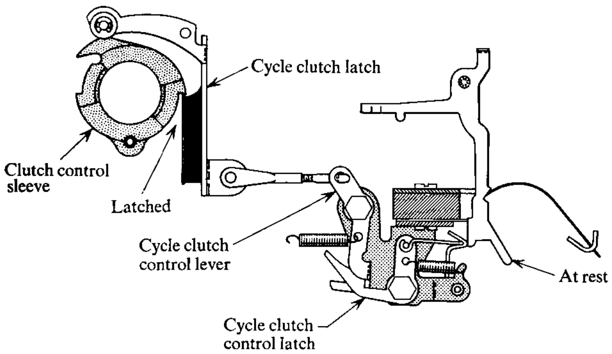
Photoelectric feedback. To provide synchronization between the printer and translator, photoelectric devices are added to the printer to indicate its cyclic state. One device, on the spring motor shaft, indicates motion of the carrier and is used to inhibit input to the printer during the long functions, Carrier Return and Tabulation, Fig. 13(a). The second device is a cycle shaft angular indicator and is utilized during normal character input to the printer, Fig. 13(b), as described in the next section.

Synchronization. Maximum output of printed copy can be achieved only by operating the output device at maximum speed. In the Composer, this is accomplished by entering characters through the keyboard at such a rate that the cycle clutch does not latch or stop the printer between characters. The Composer input is from a mechanical translator driven with a separate motor, and because of the inherent speed differences of motors due to line voltage fluctuations and varying loads, exact speed synchronization is impossible. Fortunately, the Composer has incorporated into its keyboard a feature known as stroke storage which eliminates the problem of crowded or missing characters when typing manually. As early as 23 degrees in the 180 degree printer cycle, the selected interposer has been driven forward out of the ball tube interlock by the filter shaft and a new keylever can be pulled, Fig. 14. This new interposer will be latched down and will hold the cycle clutch open until the filter shaft revolves around and drives this interposer. If a keylever begins its pull before 100 degrees in a previous cycle, the interposer will be latched in time to prevent the cycle clutch from latching up. Therefore there is a zone from 23 degrees to 100 degrees in the cycle in which another keylever can be pulled to enable the printer to free-run. This zone is called the "permissible pull zone." Since the translator and printer cannot run at exactly the same speed, the translator is geared to run slightly faster than the composer. The resynchronization which is required simply because of the speed difference between the Composer and the translator is referred to as Ordinary Synchronization. If one observes the action of the translator with the Composer as a reference, the translator motion appears to regress, or back through the Composer's permissible pull zone. Specifically, if one observes the translator contact signal with respect to the Composer cycle shaft photoelectric feedback, the leading edge of the translator's normally closed contact signal appears to "back into" the trailing edge of the wide part of the Composer feedback signal. When these two points actually overlap, the next keylever pull would be in the nonpermissible pull zone of the Composer (refer to Fig. 15). Therefore, it is necessary to temporarily halt the translator. The points mentioned, when overlapped, cause a "SYNC" latch to be set.

The "SYNC" signal serves as an inhibit function to the output logic, and no further action takes place in the output device as long as the "SYNC" signal is on, but the composer does not stop, nor does its clutch latch. Note the narrow part of the Composer feedback, which occurs just before the end of the composer cycle. This causes the "SYNC" latch to be reset, thus freeing the output logic.



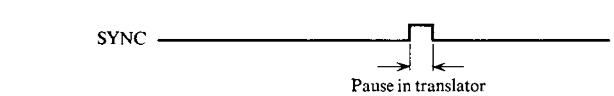
(a)



(b)

Figure 14 Composer keyboard section: (a) keylever and interposer section, showing interlock, latch, and link to translator; (b) cycle clutch mechanism.

Figure 15 Timing diagram for synchronization. Depicted are six cycles, including one at which ordinary synchronization becomes due. Note that in the first three cycles the leading edge of the translator contact signal FB-1 approaches (by regression) the trailing edge of the longer portion of the Composer cycle shaft feedback signal. When these two finally overlap, as in the fourth cycle, the SYNC latch is set and then reset at the end of the feedback signal. This delays the fall of FB-1 and keeps the translator clutch in a latched condition until the SYNC is reset. The total delay is such as to maximize the time which will elapse before the next synchronization becomes necessary.



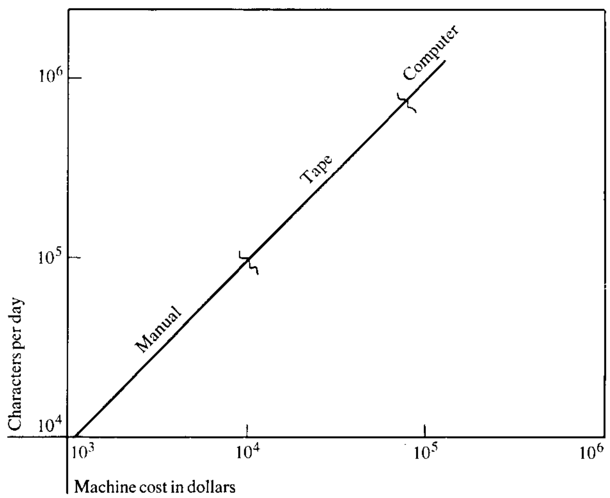


Figure 16 Output per day vs. machine cost for the three major classes of cold-type composing systems.

The translator begins running again, and the next keylever pull will occur just before the end of the Composer's permissible pull zone; thus the translator will run the maximum number of cycles before another such synchronization will become necessary. Note that at no time is it necessary for the Composer to halt, even momentarily.

This is the basic synchronization scheme used on the automatic Composer, although it is complicated by various functions such as shift, tabulation, carrier return and backspace that will not be treated here.

System evaluation

The principal factor in comparative system evaluation is cost, which is here understood to mean final cost to the user per unit of throughput with all factors considered. This presumes that all necessary quality features of the machine, such as type style and size variability, proportionality, image quality, etc., are present. Once these factors are established the most meaningful comparison between systems must be based on cost.

The machine cost comparison is shown in Fig. 16. The "manual" category consists of manually-operated direct-impression machines such as the SELECTRIC Composer. These machines generally require that the copy be typed twice for justification. The second category consists of tape-operated (both paper and magnetic) systems in which the tape is generally recorded on one keyboard and played out and composed on another output unit. The MT/SC falls in this category as do several paper tape machines. The third category consists of computer systems used in conjunction with tape-operated linecasters or photocomposers. Many general-purpose machines fall in this category. Figure 16 illustrates that equipment output versus equipment cost is

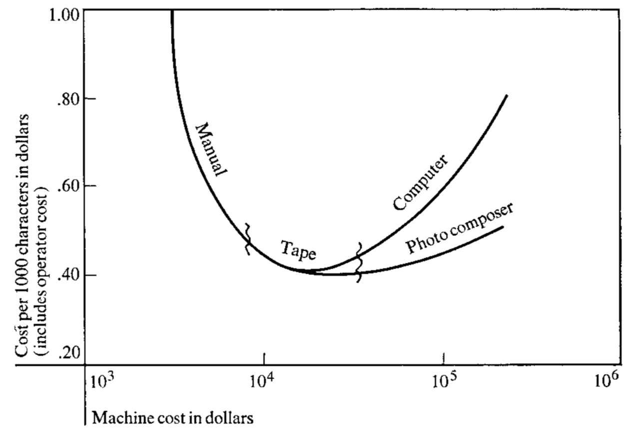


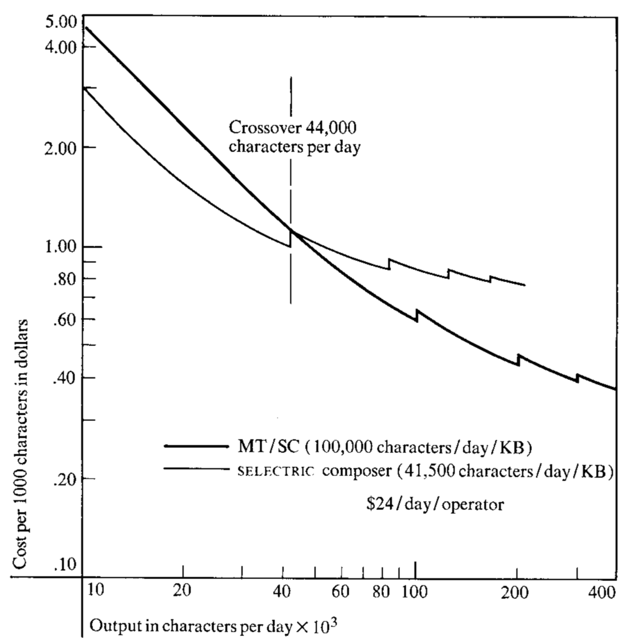
Figure 17 Cost per character, including operator cost, vs. machine cost.

Table 2. Comparison of keyboard efficiency.

Keyboard	*Useful keystrokes,* %	*Hot zone loss,* %	*Handling loss,* %	*Net useful keystrokes,* %
MT/SC	94.8	—	—	94.8
PT(HZ)*	78.8	3.0	1.0	74.8
SELECTRIC Composer	42.4	3.0	—	39.4

* Paper tape system employing a "hot zone" at line endings for hyphenation.

Figure 18 Character cost vs. output; MT/SC and SELECTRIC Composer.



a generally linear relationship. The most desirable system is, of course, one which falls to the left of the line representing the highest output for a given capital investment.

When one considers operator cost in addition to the equipment cost shown in Fig. 16, however, a different relationship, shown in Fig. 17, is obtained. For the manual keyboard system "character cost" is almost totally dependent on operator cost. The tape system introduces the efficiency of automatic composition calculation, which produces a much more efficient utilization of operator time and resulting lower total cost. Computer systems also increase operator efficiency, but these introduce considerable equipment costs. Thus, in some cases, the computer system cost per character exceeds that of the tape systems. The computer systems do, in some cases, have the advantages of higher speed and greater flexibility. However, the MT/SC can meet many needs in a much lower cost system when demand for speed and volume is moderate.

• *Operator keyboarding rates*

Since it is apparent that operator cost is important it is useful to relate actual operator keyboard rates for various systems to the MT/SC. The factors that can affect the rate at which an operator records useful text include:

1. the ease of keystroking—lightness, shape of key, etc.;
2. "hot-zoning" (for justification) versus free-zone line endings;
3. error correction (Must the entire line be deleted when an error occurs or may the operator simply backspace and correct?);
4. ease of tape loading, paper handling, etc.;
5. the frequency of codes (How many composition codes are required to produce the desired output?);
6. the hard copy that must be provided to aid in proofreading and error correction (Alternately, is it necessary that the operator read codes on the recording medium?); and
7. media handling (Must the recording medium be rewound or otherwise set and reset, or is it immediately usable?).

These factors, however, are necessarily subjective and meaningful comparisons depend on individual operator differences, skill levels, etc.; a more exact comparison of keyboards may be made by measuring the number of input keystrokes necessary to produce a given amount of output text. Fortunately a quantity of data is available in the newspaper industry for columnar justified text with subheadlines.*

* For example, a study based on such factors was conducted in 1962 by Mr. D. D. Dissly, *Louisville Courier Journal* and *Louisville Times*, Louisville, Ky.

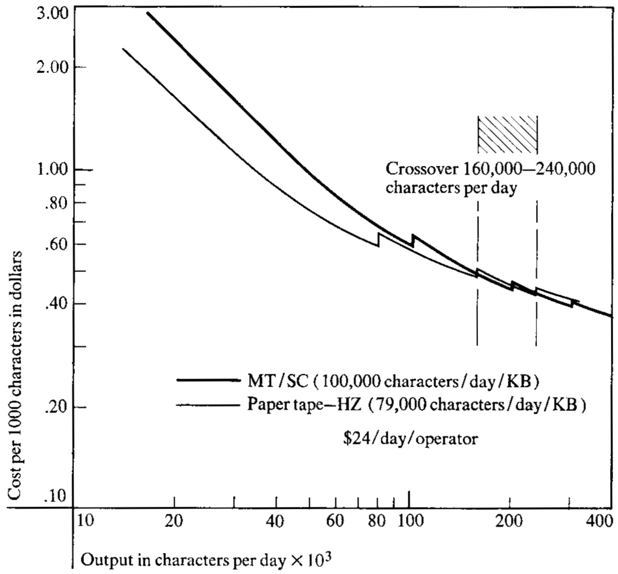


Figure 19 Character cost vs. output; MT/SC and paper tape system.

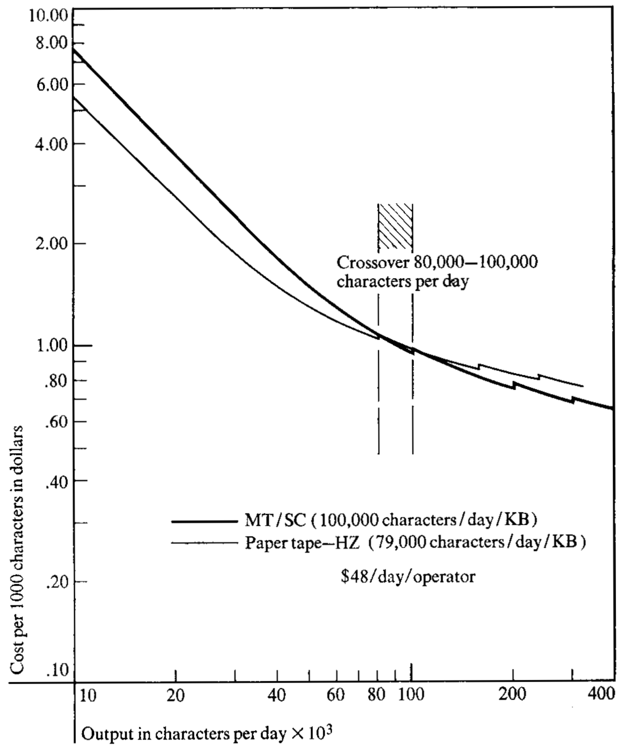


Figure 20 Replot of Fig. 19 with operator cost doubled.

The keyboard factors shown in Table 2 result from applying this data to the systems of interest. Column 1 indicates that 100 keystrokes on the MT/SC result in 94.8 output characters or operations, the balance being either coding or error keystrokes. In the case of the paper tape-hot zone machine 100 input keystrokes produce approximately 78.8 output operations. The primary difference between the two machines is in the difficulty of error correction. A keystroke error on the paper tape machine generally results in a line deletion.

The SELECTRIC Composer requires 100 input keystrokes to produce 42.4 output keystrokes; the determining factors are that justification requires the copy to be typed twice and errors on the "good" copy generally result in rekeying.

By assigning a value of 1% loss to the ease of tape loading and 3% to the distraction of watching for a hot zone, the last column in Table 2 results.

• *Detailed systems comparison*

With the keyboard factors shown in Table 2 the data are available to compare any two systems at any output rate. For example, Fig. 18 shows a comparison between the MT/SC and the SELECTRIC Composer. This figure illustrates that at lower usage rates the lower equipment costs of the manually-operated SELECTRIC Composer give a lower cost per 1,000 characters—in fact an advantage of about 50% at 10,000 characters per day. As the usage increases, the increased operator efficiency on the MT/SC produces a lower operating cost. The break point occurs at about 44,000 characters per day. At 70,000 characters per day the MT/SC enjoys a cost advantage of about 18% and at 100,000 characters per day an advantage of about 42%. The first "tick" or discontinuity occurs on the MT/SC curve at 100,000 characters per day. This indicates that the capacity of one keyboard has been reached and another must be added.

This same comparison of the MT/SC vs. a paper tape-hot zone machine in Fig. 19 illustrates a similar type of crossover. Even though the equipment cost is higher the MT/SC shows a cost superiority at rates above 160,000 characters per day due to its increased keyboarding efficiency.

Another important variable is operator cost. As the operator cost increases, the keyboard efficiency becomes more significant. If, for example, the operator cost is doubled the comparison in Fig. 20 illustrates that the crossover between the MT/SC and the paper tape-hot zone machine occurs at about 80,000 characters per day compared with about 160,000 characters per day at the lower operator cost. The systems comparison thus indicates that the efficiency of keystroke utilization is the most important cost consideration, and the system evaluation thus points the way to a composing machine which emphasizes ease of coding, efficiency of keystroking and a low burden of operator calculation.

Conclusions

Office equipment introduced during the past few years has placed increasing emphasis on the processing of words. Equipment has been designed to address the flow of words from human expression to printed page which, in the process, requires a considerable amount of correction and revision. Ultimately, many of the processed words must end on a quality-printed page. The MT/SC was developed to carry the processing of words to this final step.

The MT/SC provides a high level of quality and flexibility to direct impression typography and addresses this cost-sensitive area with an efficiently organized system and internal logic. In designing the MT/SC, current developments and existing hardware were used extensively to meet cost and schedule objectives. Comparison of the MT/SC with alternative systems demonstrates the economic advantages of the system.

```
(X)(M)288,(C)(S) PR-B 11/12, More is demanded of
      beginning office workers(S) PR-B 8/9,(M) 384,
      CR>
   (L)More productivity(S) PR-M,
      CR>
   (J)The faster pace of business today demands more of all
      beginning office workers-more highly developed skills
      and increased technical "know-how."  Company training
      programs take for granted that basic skills have
      already been mastered.  Employers expect that new
      people will be quickly productive, and will meet the
      requirements for a faster, more efficient flow of
      paperwork.(S) PR-B,
      CR>
   (L)More responsibility
      CR>
   (J)New employees must have the ability and confidence to
      handle independently a growing volume of correspondence
      and detailed assignments.  Why?  Because the people
      to whom they report often lack time to do it themselves.
      And this work must be delegated to persons who can use
      both sound judgment and productive skills to complete
      jobs correctly, on time...and on their own initiative.
```

(a)

```
xm288,cspr-b 11/12,More is demanded of
beginning office workersspr-b 8/9,m384,

1More productivityspr-m,

jThe faster pace of business today demands more of all
beginning office workers-more highly developed skills
and increased technical ''know-how.''  Company training
programs take for granted that basic skills have
already been mastered.  Employers expect that new
people will be quickly productive, and will meet the
requirements for a faster, more efficient flow of
paper work.spr-b,

1More responsibilityspr-m,

jNew employees must have the ability and confidence to
handle independently a growing volume of correspondence
and detailed assignments.  Why?  Because the people
to whom they report often lack time to do it themselves.
And this work must be delegated to persons who can use
both sound judgment and productive skills to complete
jobs correctly, on time.,.,.and on their own initiative.
```

(b)

References

1. G. A. Holt, "The IBM SELECTRIC Composer: Philosophy of Composer Design," *IBM J. Res. Develop.* **12**, 3 (1968).
2. J. S. Morgan and J. R. Norwood, "The IBM SELECTRIC Composer Justification Mechanism," *IBM J. Res. Develop.* **12**, 68 (1968).
3. B. W. Miles and C. C. Wilson, "The IBM SELECTRIC Composer Proportional Escapement Mechanism," *IBM J. Res. Develop.* **12**, 48 (1968).
4. E. M. Davis, W. E. Harding, R. S. Schwartz and J. J. Corning, "Solid Logic Technology: Versatile High-Performance Microelectronics," *IBM J. Res. Develop.* **8**, 102 (1964).
5. B. T. Crutcher and D. E. Sederholm, "The IBM SELECTRIC Composer Letter Keyboard," *IBM J. Res. Develop.* **12**, 15 (1968).
6. "The IBM SELECTRIC Composer," *IBM J. Res. Develop.* **12**, 2–91 (1968).

Appendix: MT/SC operating procedures

While this paper has been concerned primarily with design of the MT/SC system, a reasonably thorough discussion of how it is used may be of interest. Accordingly, a description of the operating procedures and a definition of the control codes are given below. This discussion, however, illustrates application only for purposes of this paper; it is not a complete specification for the user.

• *Keyboarding*

Copy to be entered into the system will normally be accompanied by general instructions as to how it should be printed. The copy must be marked to indicate the specific codes required to translate these general instructions into the details of font selection, modes required, page format, etc. A cover sheet, showing initial setup for the playback unit must also be prepared. The marked copy is then transmitted to a keyboard station. In some cases, however, copy may remain uncoded and go to the playback unit where controls may be manually entered.

The operator will type and record the control codes as marked (producing both a magnetic tape and hard copy record) on the MT/ST keyboard (Model II, IV, or V). The MT/ST incorporates features designed to facilitate preparation of tapes for composition. The keyboard character set and arrangement are identical to those of the SELECTRIC Composer and a special series of type elements matches this set. For recording control codes, a Prefix key is placed in a location on the keyboard which allows the operator to use it without a break in the typing rhythm. It is important that the copy produced at the keyboard indicate all codes which have been recorded on the tape. For this reason, depressing the Prefix code key causes the succeeding character to print in red for ready identification. Control codes recorded on tape will not appear in the output copy on playback (see Fig. A-1).

These first five prefixed codes control the printing mode of the playback unit:

j—The text which follows is to be justified. That is, the output copy will be produced with straight right and left margins and the desired column width.

l—The text which follows is to be set flush left. That is, left margins are to be straight but right margins may be ragged.

c—Each line of the text which follows is to be centered within the column.

r—The text which follows is to be set flush right. That is, the output copy will have straight right margins and ragged left margins.

Figure A-1 (a) (opposite, top) Example of material as submitted for composition. Instructions are marked by hand; (b) (opposite, bottom) print-out of input tape, including recorded instructions; (c) (below) composed copy as received from output unit.

More is demanded of
beginning office workers

More productivity

The faster pace of business today demands more of all beginning office workers-more highly developed skills and increased technical "know-how." Company training programs take for granted that basic skills have already been mastered. Employers expect that new people will be quickly productive, and will meet the requirements for a faster, more efficient flow of paper work.

More responsibility

New employees must have the ability and confidence to handle independently a growing volume of correspondence and detailed assignments. Why? Because the people to whom they report often lack time to do it themselves. And this work must be delegated to persons who can use both sound judgment and productive skills to complete jobs correctly, on time. . .and on their own initiative.

(c)

d—The text which follows is to be set with dot leaders. This is similar to the flush right mode, except that the space between the left edge of the column and the text is filled with dot leaders, which are vertically aligned.

When r (or d) occurs in the midst of a line of text, the portion of the line to the left of the code is set flush left, the portion to the right is set flush right, and the intervening space is left blank (or filled with vertically aligned dot leaders). It is not possible to perform this function at the playback unit control panel. Examples of the five modes (j, l, c, r, and d) described above are shown in Fig. A-2.

The following are control, reference, and format codes; these are also entered using the prefix key.

mxxx,—This code sets the measure, or column with, equal to xxx SELECTRIC Composer units[3] where xxx is a decimal number. A unit is 1/72, 1/84, or 1/96 of an inch, depending upon the Composer pitch selected.

ixxx—This code causes all lines of the following text to be indented by xxx units, where xxx is a decimal number.

Figure A-2 Examples of the five printing modes.

This is a sample of justified copy.
Both margins are straight and
define the column edges.

Flush left material
has straight left
margins.

Centered material
is centered
within the column.

Flush right material
has straight
right margins.

. . . . Dot leader material
. . . . is similar to flush
. . . . right copy.

Lines can be split
left and right,
with or . . . . without
vertically . . . . aligned
. . . . leader dots.

,—A fixed space of three units, equal to the width of a comma, will be inserted at the point in the output copy where this code occurs. This is useful in tabular work and elsewhere.

sxxx—The playback unit will stop at the point in the output copy where this code occurs. xxx represents a message of arbitrary length which may appear on the hard copy to instruct the playback unit operator to take some desired action such as a change to some particular font. This message does not appear on the output copy. A typical message is illustrated in Fig. A-1 where the operator is notified of required font changes by such notations as "pr-b 11/12", meaning change to Press Roman Bold, 11 point on 12 point leading.

x—This code is ignored by the playback unit. The x merely serves to mark the location of reference codes on the hard copy at the keyboard. These reference codes should appear at the beginning of line one on each page.

axx—This code appears only on correction tapes and specifies the line number, given by decimal number xx, which is to be replaced by the text following the code on the correction tape.

• *Error correction and revision*

The system provides several means for error correction and revision. A simple typing error noticed shortly after it is made can be corrected by the backspace-and-strikeover method. Where this is not feasible, line return may be used.

To allow corrections and author alterations to be made after a tape has been completed, a procedure is provided for merging a correction tape with the original tape. The correction tape is keyed on the MT/ST in the usual manner, with control codes specifying the number of the line in the original copy which is to be replaced. This control code is then followed by the replacement text. The line may be replaced by nothing (line deleted), by another line, or by several lines or paragraphs. Since the line count begins again at each reference code (normally placed at the beginning of each page) on the original copy, reference codes must be placed on the correction tape for each page, so that the playback unit can determine in which page the line specified occurs. To facilitate determining the line numbers, pre-numbered paper can be used for typing the hard copy.

For repetitive corrections or extensive changes merging is not suitable. A modified MT/ST-IV can be used in such cases to generate correct tapes by a transfer operation.

In many instances corrections may be made by pasting in correction strips on the camera-ready copy. The strips can be generated at the playback unit from tape or may be manually keyed on the SELECTRIC Composer which is part of the playback unit.

• *Playback*

After all original and correction tapes have been prepared they are delivered to the playback station along with the draft copy and instruction sheet. Original tapes are loaded on the right station of the playback unit tape reader and correction tapes on the left station. If playback of only a portion of the tape is desired, they may both be searched automatically to the desired reference codes. Before starting the playback, the composer must be set up by loading paper, attaching the proper type element, and setting pitch, leading, impression control, and dead key selector to the desired values. There are a number of setup decisions which must also be made on the console control panel. These decisions are made by entering decimal quantities via the control panel keys. For some decisions, these quantities may be interpreted by the machine as "yes" or "no" entries or in other ways which are marked on the control panel below the keys (refer to Fig. 8). A brief discussion of these decisions and how they affect the output copy follows.

CLEAR—Entry of YES clears the memory of all old text and resets line counters.

MERGE—Entry of YES instructs the machine to read from both stations of the tape reader. Entry of NO will cause only the right station to be read.

MODE—This provides a means of manually entering the composition mode. Five modes are possible: justify (j), flush left (l), center (c), flush right (r), and dot leader (d).

LINE COUNT—Entry of a number for line count instructs the machine to stop after that number of output lines has been produced. This is useful in controlling the length of indented portions of text, text adjacent to pictures etc., and in setting the length of pages or columns.

MEASURE—Entry of a number instructs the machine to make the column width equal to that number of SELECTRIC Composer units.

LINE INDENT—Entry of a number will cause the machine to indent the succeeding material by that number of units. In effect, this allows the left margin to be moved without physically moving the margin stop on the Composer or changing the measure. If the playback unit stops because the set line count has been reached, the line indent is automatically reset to zero. This is useful in performing complex copy fitting.

PARAGRAPH INDENT—In justify mode a new paragraph begins with an indentation. The number of units for this indentation may be entered on the control panel.

LEADER SPACE—The space between the dots of automatically inserted dot leaders can be specified by the entry of a number.

DEAD KEY—Character sets for some languages include many accented characters. On the Composer these are obtained by printing the accent without escapement and then printing the character, which falls beneath the accent. This entry is used to tell the machine when the Composer is using a font requiring the use of the dead key (no escapement) characters.

MINIMUM INTERWORD SPACE (MIN IW), MAXIMUM INTERWORD SPACE (MAX IW), MAXIMUM QUAD SPACE (MAX QUAD), and LINE EXPAND are related functions and give the operator a degree of control over the tightness of lines and the frequency of hyphenation for a justified line. Values for each of these can be specified by entering numbers on the control panel.

Although many composition functions may be accomplished by manual entries at the playback unit control panel, it is more efficient to place control codes on the tape. The control panel is mainly used for entering factors which are not usually decided at the time of keyboarding. (An example is the exact fitting of copy in complex formats. This is possible because justified output copy is not restricted to the line endings of the input copy. See Fig. A-3.) The control panel is also used for correcting control code errors. In cases for which a variable may be controlled either by control panel entry or by being read from tape, the most recent entry is the controlling one.

During the playback operation the operator is responsible for monitoring the copy, changing type elements, paper,

Figure A-3 Examples of format control through manual setup at the output unit.

Manual Control Example

This example illustrates the effect on the format of manual setup changes at the playback unit. Both samples were run from the same tape, but with different control panel entries and different fonts. Note that the mode of the heading, the measure, the use of runarounds, the type size and style, and the leading are all different.

Manual Control Example

This example illustrates the effect on the format of manual setup changes at the playback unit. Both samples were run from the same tape, but with different control panel entries and different fonts. Note that the mode of the heading, the measure, the use of runarounds, the type size and style, and the leading are all different.

Figure A-4 Examples of interword space variation and hyphenation.

This example demonstrates the effects of varying the minimum interword space, the maximum interword space, the maximum quad space, and line expand. For all samples the minimum interword space is three units. The first two samples are run with YES entered for line expand and the last one with NO. For the first sample, maximum interword space and maximum quad space are, respectively, twelve and twenty units. For the last two samples they are nine and twelve units.

This example demonstrates the effects of varying the minimum interword space, the maximum interword space, the maximum quad space, and line expand. For all samples the minimum interword space is three units. The first two samples are run with YES entered for line expand and the last one with NO. For the first sample, maximum interword space and maximum quad space are, respectively, twelve and twenty units. For the last two samples they are nine and twelve units.

This example demonstrates the effects of varying the minimum interword space, the maximum interword space, the maximum quad space, and line expand. For all samples the minimum interword space is three units. The first two samples are run with YES entered for line expand and the last one with NO. For the first sample, maximum interword space and maximum quad space are, respectively, twelve and twenty units. For the last two samples they are nine and twelve units.

INTERW)ORD INTER–

INTERWOR)D INTER–

tapes, and ribbons as required, entering control information on the control keyboard, and hyphenating words when necessary.

As stated above, the MT/SC employs an operator-controlled hyphenation method. Since even the best automatic hyphenation schemes produce less than 100 per cent accuracy and since the output station is monitored in any case, the system is designed to call on the operator to make hyphenation decisions when required. The machine prints the end-of-line word that is to be hyphenated after tabulating to the right of the column from the end of the line above the line in question. By means of a TYPE key on the control panel (Fig. 8), the operator causes the word to be printed a second time, one character at a time. When the desired break point is reached, the operator inserts the hyphen appropriately by means of a HYPHEN key. When the machine is restarted, the next line will print with the word hyphenated at the selected point (for an example, see Fig. A-4). If the operator chooses not to hyphenate the word or if it cannot be properly divided, the machine will justify the line by inserting additional quad spacing in the line.

• *Justification procedure*

As previously mentioned, considerable flexibility can be exercised over the tightness of lines and frequency of hyphenation. This flexibility is centered in the control keyboard in the MIN IW, MAX IW, MAX QUAD, and LINE EXPAND factors. If hyphenated text is desired, NO is indicated for LINE EXPAND and text is read into the machine until the total amount of text is sufficient to fill the column width, with spaces set equal to MIN IW, in units. Often there will be a word which begins before the column limit is reached and which, if completed, would overflow the column width. An attempt is made to distribute among the interword spaces of the line a space equal in length to the portion of the word which did not overflow. If this results in interword spaces which do not exceed MAX IW, the line has been justified and is then printed. Otherwise the word will be hyphenated by the operator as described above. After the hyphenation decision has been made, another attempt is made to justify the line, this time by distributing the space in the word between the hyphenation point and the overflow point among the interword spaces. If this results in interword spaces not exceeding MAX QUAD, the line is printed. Otherwise the interword spaces are set equal to MAX QUAD and the remaining space is distributed equally (within one unit) as interletter spaces between all letters of the line. Thus the machine justifies a line by successively trying the following methods until one is found which will work:

1. Expand interword spaces, without exceeding MAX IW.
2. Hyphenate the overflow word, and then expand interword spaces, without exceeding MAX QUAD.
3. Expand interletter spaces.

The operator can set upper and lower limits on interword spacing by entering appropriate values for MAX IW and MIN IW. Normally, all interword spaces should lie between these limits. However, if a word printed for hyphenation is not hyphenated, or if the operator incorrectly places the hyphen beyond the line-end limit, MAX IW may be exceeded. By entering an appropriate value for MAX QUAD, the operator can control the size of interword spacing that will be tolerated before letterspacing begins.

If YES is entered for LINE EXPAND, the procedure is simpler:.

1. Expand interword spaces, without exceeding MAX QUAD.
2. Expand interletter spaces.

This allows an operator who is willing to accept somewhat open lines to avoid hyphenation decisions entirely. (In a test, the entire text of the front page of a newspaper was set in this manner without a single hyphen and in fewer lines than the original, which had been partially set on manually operated linecasters and partially from wire service paper tape.) Some examples of text set with different combinations of these four variables are shown in Fig. A-4.

In modes other than justify, all interword spaces are set equal to MIN IW. In tabular work, it is frequently useful to set MIN IW equal to the width of a numeral.

• *Summary*

The entire procedure is thus carried out in two parts. The operator at the input station is responsible for original entry of the copy; for entry of the proper keyboard (prefix key) codes at the proper points; and for text correction and preparing any correction tapes. The operator at the output station is responsible for set-up, including type font selection, pitch and leading settings; for entry of the console control codes (format, spacing, etc. by means of the control panel of Fig. 8); and for monitoring the output copy and making the hyphenation decisions.

Received September 14, 1967.
Revised manuscript received May 14, 1968.