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The IBM SELECTRIC® Composer

Philosophy of Composer Design

Abstract: The IBM SELECTRIC Composer is a new kind of printing machine, much like a typewriter. This paper outlines the philosophy of design of the significant systems and mechanisms within the Composer and the primary elements needed to satisfy composition requirements, i.e., good print quality in a variety of classical type styles and sizes; variable vertical line spacing; justification; and an output of final copy that can be judged subjectively by printing experts and laymen alike.

Introduction

Equipment used in the offset printing industry has advanced significantly during the past twenty years; however, machines designed for preparation of copy for camera reproduction have not kept pace with this progress. Typewriters have been used frequently, and have served well, except for composing work requiring the styling and proportionality of classical type.

Composer design has utilized the IBM SELECTRIC Typewriter speed of operation and has capitalized on operator familiarity with keyboard controls. Most important, however, the Composer has adopted (almost intact) the SELECTRIC Typewriter's excellent printing system, with its compactness, stability, and type font interchangeability. Proportional horizontal spacing has been added, which permits type designers the freedom to adapt well-known designs to Composer use. A compact indexing mechanism has been developed for the paper feeding system to allow operator control of the line spacing from a very tight to a very loose fit, in increments of one point (1/72 inch, the printer's measure). For "justification" two mechanisms have been developed, the justifier (read), and the variable spacebar (write). The operator enters the "read" values into the spacebar controls after the first typing and is able to retype the line to its correct (justified) length.

Refinements have been made and new mechanisms developed to enhance print quality and give greater flexibility to the machine and, conversely, to give the operator more control over the appearance of the work. The keyboard design transfers two and one-half times as many event signals as the IBM SELECTRIC Typewriter, yet retains the SELECTRIC Typewriter's reliability and excellent subjective touch characteristics. Five modern languages may be typed on the same machine (when an optional component is added and different type elements are used), all having correct horizontal proportions and correct print velocity. The operator is able to backspace by character in order to correct errors—within the limits of machine memory, which is between 6 and 20 characters and depends on the width of the characters stored. Other operator aids available include provisions for centering copy, locating columns, and locating the first character in forms work, etc. An entirely new ribbon has also been developed especially for Composer applications.

The development of composition and printing

Eighteen centuries ago the Chinese were printing texts on paper. A thousand years ago the Chinese were printing texts using movable type, but they gave this up as impractical—too many characters in their language. In the fourteenth century movable type was again invented, this time by the Koreans, but they had the same problems as the Chinese. In the fifteenth century printing with movable type was invented for a third time; in western Europe of that time the happy combination of a relatively easy language, a will to learn, strong motivation, and a definite goal produced Johann Gutenberg's famous Bible.

- *Hot type (letterpress) composition*

Gutenberg's printing method was cold type printing. Type casting–hot type–machines, invented in the nineteenth century, use molten metal and a casting technique to produce a single cast letter or a cast line of type. (Cold type and hot type are catch-all names, but convenient at the moment for a general kind of classification.) A hot-type typecaster is long-lived, reliable, and permits a craftsman-operator to

produce a high level of quality printing. Final quality depends on the operations that follow the initial typecasting, but quality starts with the typecaster and the operator. In comparing their ability to perform against function requirements, typecasting machines are found to completely fulfill present-day requirements for high print quality at a reasonable cost. Machine capabilities permit utmost freedom in type design, type size, and the mixing of type styles. There need be no compromises in the aesthetic appearance of word groupings, spaces, and justification. Hyphens, symbols, letters, all maintain the continuity of the imaginary straight line running down the right side of the column of lines. A quick glance at a well-done paragraph leaves the impression of an aesthetically pleasing block of consistent grayness. At a scanning glance, recognizable groups stand out as easily-read words and phrases.

The well-known modern typecasters each cast complete lines of type that are accurately justified. Each letter is fixed on its own small, thin, rectangularly-shaped carrier. The carriers, called matrices, have the letter or symbol accurately embossed on one surface. Another surface is coded to identify that carrier (matrix) so the machine can return it to its proper place after the line has been cast and trimmed. Space bands that can be expanded are placed between words to fill the spaces. Quads (spaces of fixed width) are used for indenting, etc. Just before pumping molten metal into the casting container, all space bands are expanded horizontally to displace each line of letters and spaces until the limits of the container are reached. The lines are thus justified (each line having the same length as all the other lines). In the best quality printing, justification is achieved with a minimum of hyphenation because of the care taken in fitting the text to the allotted space, and large spaces between words are avoided.

A variation on the linecaster is the Ludlow Typograph. The line is set by hand, then cast automatically. The finished slug (cast line) is similar in appearance to the slug cast by the Linotype or Intertype. The Ludlow is generally used for large sizes of type as, for example, in newspaper headlines.

Monotype machines cast one character at a time. The machine assembles the cast characters into lines, but can also cast type for hand setting. The Monotype is actually two machines, a keyboard and a caster. The keyboard produces a coded paper tape used by the casting machine to control the casting operations. A Monotype machine is especially good for mathematics and scientific copy, and for work requiring exceptionally high print quality.

• *Printing techniques*

There are three principal ways of printing; each of them involves a printing plate. In the first method, the plate has the printing surface raised above the level of the rest of the plate. The ink is applied to the raised letters, then transferred to the paper. This is letterpress printing. In the second method, intaglio (gravure, etching, etc.), the design is cut into the plate. The whole plate is inked and the ink is then scraped off, with only the incisions remaining inked. The ink is then transferred to the paper. The third method—planographic printing—has all surfaces of the plate on the same level. The plate is treated so that the designs retain ink but the rest of the plate remains clean. Lithography and the offset process best explain this method of printing.

• *The offset process*

Probably two-thirds to three-quarters of the printing in the United States today is done using the letterpress method, i.e., raised characters. However, the method of most interest here is the lithographic/planographic method as used for offset printing, wherein thin aluminum plates are used as the transfer medium. A photographic negative is placed in direct contact with the plate and the plate is photoetched to image whatever was on the negative. When properly inked and soaked in water, the images retain ink and the clean portions retain water. This plate is then attached to a cylinder, inked and watered, and rotated against an intermediate cylinder that is specially treated to take only the ink of the images. This cylinder, in turn, is rotated against a third cylinder that carries the sheet of paper. It is the ink on the intermediate cylinder that is transferred to the paper. Of course this is an oversimplification of the offset printing process, but the important point is that the method begins with a photographic negative.

Any copy which can be photographed can be reproduced and printed with this process. The thing to be photographed may be "composed" copy produced originally by any of the methods described. It can be the typewritten page produced by a typist on a standard typewriter.

The place of the typewriter in the printing industry

A typewriter therefore can and does fit into the printing industry. But it fits only because of lithography, photography and offset printing. Many people believe that direct impression machines (typewriters) have no place in the "pure" printing industry; however, a relatively large volume of business is done by people who have nothing but direct-impression machines—machines which were not specifically designed for the printing industry's level of print quality. Some of these, however, do have certain features which, in recent years, have significantly raised the level of "typewriter" quality.

Principal requirements of composition: the basis for composer design

With the proven SELECTRIC Typewriter concept as a starting point, it was necessary to define precisely the requirements a printing system based on the SELECTRIC Typewriter would have to meet to produce true "composition" before work could begin on development. The philosophy was to first determine the standards of quality, variations in format,

and physical specifications a page of finished composition should have. Concurrently, the experience of the designers with small, operator-oriented, impact-printing systems was applied to identify each functional area of a SELECTRIC Composer. Finally, the effect of the output requirements on each area was determined and decisions were made as to where existing technology could be applied, where new design was necessary, and what objectives should be dropped or made less stringent in order to produce a design in a reasonable length of time. The result of this approach was that a number of projects were defined, each for the requirements of a particular portion of the machine. Development proceeded at this functional-area level, with periodic review among the design group's engineers to compare progress and stay close to the goals of the system as a whole.

• *Print quality*

What is print quality? Gutenberg defined this by execution—he, or someone working for him, designed characters that were pleasing to the eye regardless of how they were arranged. He found a combination of paper and ink that printed those characters without smudging and without having some appear darker than others. However, no one yet has been able to define print quality by specific measurements. Print quality is subjective, and as long as it remains so its development will be a qualitative art. But this does not mean that it cannot be controlled. For example, an estimate of how much vertical and horizontal misalignment can be tolerated among characters can be made, as well as an estimate of the *ideal* alignment, blackness, edge definition, etc. The problem, however, is to decide how far print quality can be permitted to deviate from the "ideal" and still be acceptable. The answer has been to sample a variety of commercial print-work and statistically evaluate its alignment. Even so, judgment of what and how to measure has been arbitrary, though undoubtedly reasonable. Is "black" blackness what is needed? Is a uniform dark gray effect really the objective? Certainly, alternating black and gray is something to be avoided as much as possible. Why not control the terminal velocity of the character, as the IBM EXECUTIVE Typewriter does, so that small line-area letters will have a low terminal velocity and large line-area letters will have a high terminal velocity, etc.? The letters would print with an impact proportional to their needs, and with a uniform "color." But the IBM SELECTRIC Typewriter with all the characters on the same type element, and *one* system for supplying mechanical energy for printing, poses a problem. A good ribbon with characteristics that have not been available before—something pressure-sensitive with a low threshold of release, so that all the black comes off with a light blow—might solve part of the problem. Or the characters might be grouped on a type font into two, three, four, or five different categories by line area and, somehow, two, three, four, or five different print mechanisms could be designed which might be selected automatically by pushing down a keylever.

The final point to be confirmed was whether classical type styles could be put on the IBM SELECTRIC Typewriter type element and transferred to paper with the SELECTRIC Typewriter print mechanism and a ribbon. The type design group chose to adapt a Roman type style to an eleven-point body. This type design, called Press Roman, was very successful—after the characters were rearranged to eliminate shadow printing from adjacent characters. After the success of the Press Roman, other styles were adapted: Bodoni, Aldine (old style Roman), Pyramid (square serif), Univers (sans serif)—not only in eleven-point, but twelve-point, ten-point, and even eight-point sizes in the same type styles.

• *Proportional spacing*

Eight-point Press Roman is quite a bit smaller than eleven-point Press Roman, and a three-unit, eleven-point "i" must have more space allotted to it than a three-unit, eight-point "i". The size of the basic unit in the large styles, then, must be larger than the basic unit in the small styles. The escapement system of this new machine had to be arranged so as to give greater proportionality and satisfy several different sizes of type and yet have the ability to be easily changed.

This requirement resulted in the adoption of a rotary escapement system. (In the typewriter industry, "escapement system" is the term applied to the mechanism that allows the carrier to move from one typing position to the next. The carrier in the IBM SELECTRIC Typewriter is the small casting which carries the typehead, the ribbon, and the print mechanism.) A rotary system would allow the possibility of gear coupling, and gear coupling permits "gear shifting" to change the coupling ratio. By using this concept and dividing the various type sizes into three groups, three different gear ratios could be used so that one unit of input would have one of three different units of output. By allotting an "m" nine units of space, an "e" five units and an "i" three units, etc., a degree of proportionality could be achieved close to that of the classical styles. By changing gears the nine-unit "m" would have nine smaller (or larger) units of space, in keeping with its smaller (or larger) size.

• *Justification*

Putting a proportional escapement system into a machine spurred the need to find a simple way of permitting the operator to justify a series of lines. (The Composer is essentially an operator-oriented machine.) Justifying may be achieved in two ways: by permitting the expansion of space between words or by putting somewhat more than the required space between letters, so that the line will end at a predetermined point. Where the line is too long, the last word or, if hyphenation is used, part of the last word, is removed until the line is too short again. Then the letter or word spacing is increased.

It was easy to demonstrate simple justification by increasing the word spacing. The simplicity of this method indicated that it would probably result in a simple mechanism that could count and could have a read-out arrangement. In order to do this the mechanism would need to "know" how long a justified line was to be in terms of units of the escapement system and how many spaces had been used between words. It must also compute how many units have been left over after the last word has been typed, i.e., how much space, in units, is left between the end of the last word and the end of the justified line. The remainder of the unjustified line could be divided equally among the word spaces and the line retyped, using the new word spacing. It would then be justified. (All justification in direct-impression systems requires a second typing, except automatic justification as in the IBM Magnetic Tape SELECTRIC Composer, etc.)

• *Variable line spacing*

Along with horizontal proportionality must go a vertical proportionality. For each change in type height (point size) the printer must change the spacing between lines. This is necessary because in close (solid) spacing the line height (including the interline space) is the same as the point size of the type. With solid spacing the descenders of one line will not quite touch the ascenders and capitals of the line below (i. e., if a "p" in the first line is directly over an "h" in the next line, the two characters will not quite touch). In hot type, solid spacing is the closest line-to-line relationship possible, but in a direct-impression machine one could choose a point size greater than the line height for which the machine has been set. For example, eleven point type with seven point line spacing would allow descenders in one line to overlap the taller characters in the next, producing an unacceptable appearance. Also, solid spacing is itself rarely used, since a line height greater than the type point size produces better readability. Hot-type printers increase line spacing by putting thin shims of lead between lines to space them out; this is called "leading." Two points of leading provide nearly 0.030 in. between descenders and ascenders.

Within the range of type sizes between six and twelve points, therefore, the machine should be able to offer each line spacing normally used with those sizes, from solid through normal leading, and more for special cases of extra leading. (All line spacing should be in the printer's measure, the point, which is equivalent to 1/72 inch.)

The SELECTRIC Composer

• *Type element-character size compatibility*

The SELECTRIC Typewriter's potential for good print quality has been realized and even extended in the design of the SELECTRIC Composer. The essential element, already designed into the SELECTRIC Typewriter, was the ability to manually change type fonts without changing print quality. This is an all-important feature. There is a significant limitation here, however. The physical size of the element, plus the limit on the number of character locations, limits the largest size of type that may be used.

Composer type elements have the characters arranged in such a manner that "shadow" printing from characters adjacent to the one being struck has been eliminated, even for the largest type sizes. The "side clearance" of all characters was calculated for the SELECTRIC Typewriter some years ago, but was recalculated for the Composer character arrangement to a different minimum value. When a character in the type font (on the spherical element) is in full printing contact with the paper, the next adjacent characters are also very close to the paper, i.e., the first character is in contact with the platen, and the horizontally adjacent characters are much closer to the platen than the vertically adjacent characters. The very tip of the character (the end of the hyphen, for example) closest to the print point is also closest to the platen. The perpendicular distance from the platen to the tip of the adjacent character (in this example, the hyphen) is called the "side clearance." Because the Composer was not designed to print on several thicknesses of paper, the minimum side clearance is small and wide characters can be used.

• *Print point stability*

The characters on the Composer type element were rearranged for another reason, also. The most frequently used characters have been located about the home position (the type element always returns to "home" after each print cycle). In this way the motion transients for the most frequent rotate and tilt* combinations have been minimized, and the type element is better able to be securely locked in place during printing. The tight locking stabilizes the typehead and hence the printing location of the character for better alignment of that character on the printed page. The type element locking device (detenting mechanism) has twice as much time as the IBM SELECTRIC Typewriter (and more) to do the locking. This was accomplished by two changes: The time for an operating cycle (select, print, and restore) was increased slightly without increasing the time allotted for each event in the cycle, and the selection time (rotate and tilt) was actually decreased slightly.

• *Machine speed*

With its single type element and small carrier the SELECTRIC Typewriter has an immediate advantage over the typebar machine: speed in transporting the carrier from print point to print point. The type element carrier weighs about one pound completely assembled. The paper carrier of the typebar machine weighs seven pounds and more; therefore, with

* The reader who is not familiar with the printing mechanics of the SELECTRIC Typewriter will find a brief description of the character arrangement and printing action of the type element in the paper by B. T. Crutcher and D. E. Sederholm that appears on p. 15 of this issue.

the same net force acting on each carrier, the SELECTRIC Typewriter carrier will move through the same displacement in a much shorter time. Another important factor concerns repeat characters, i.e., tt, bb, ss, etc. The cycle time for a repeat or single print operation is much less in the SELECTRIC Typewriter than it is in a typebar machine.

• *Keyboard*

There are other advantages to be gained from the operator's viewpoint. The Composer's designers extended the SELECTRIC Typewriter's keyboard philosophy to help the operator whose typing rhythm is erratic or whose key selection is faulty. The keyboard construction prevents the operator from depressing two different keylevers at the same time and thus getting the wrong output. The machine either blocks the action of the second lever or postpones it until the first cycle is complete. Erratic typing rhythm is filtered, even during fast bursts, because of the design of the tripping mechanism under the keylever. The several events that must occur to start a cycle have been arranged so that the action, once the tripping point has been reached, must proceed in a serial fashion and *all* of the events will occur. If these events had been arranged in a parallel manner, wear or maladjustment could have caused the cycle to be faulty in some respect (some of the events might not occur).

• *Interlingual character compatibility*

Interlingual character compatibility does not necessarily belong in a discussion of the keyboard, but its influence is reflected almost exclusively in the keyboard logic and layout. The standard arrangement of characters on a typewriter keyboard is not the same for all languages, and it was not considered practical to have only one available keyboard for the Composer. The case for compatibility, however, is complicated by the problems caused by inconsistencies among languages. These inconsistencies complicate character layout and require compromises in print velocity and escapement value assignment at the common points among the keyboards for different languages.

Once compatibility is achieved, however, machine flexibility is enormously increased. This achievement makes possible a simple and inexpensive machine capable of multilingual composition, within the limits of available keyboard configurations and type elements.

• *Ribbon*

The advances mentioned thus far are all mechanical improvements; however, these cannot stand alone. The various typewriter ribbons that were available were acceptable for some applications but not for all. A ribbon might cover well on the photopaper and leave voids on the direct-to-plate master. Or it might cover well on the master and smear on the photopaper. The range of application was too broad. However, while mechanical engineers were (qualitatively) investigating the physics of ink transfer, ribbon development work was changing and refining the ribbon-ink formulations. The two efforts to achieve better, cleaner coverage finally resulted in one ink. Just as letterpress ink is transferred to one sheet of paper, the ribbon carrying this ink is to be used on a single sheet of paper, without carbons. Print quality deteriorates immediately and visibly with the addition of several sheets of paper. The greater thickness of soft paper allows deeper penetration of the character, causing a drastic change in the pressure gradient across the face of that character. There is also some sliding between the character edges, the inked ribbon, and the paper. The combination produces ragged edges on the character, and changes in the density of the ink deposited. On some types of paper these effects are small and tolerable; however this cannot be assumed in practice with all type sizes and all papers.

Development

The above requirements were analyzed and became the basis used to design the IBM SELECTRIC Composer. The papers which follow report major contributions to this development. Each paper discusses a particular area of the machine or of the design program; design requirements, solution concepts and implementation are described. It should be noted, however, that these papers are not intended as a complete specification of the SELECTRIC Composer. An attempt is made to discuss only those areas that are significantly advanced and probably of most interest.

Figure 1 A sample of copy prepared using the SELECTRIC Composer.

This is a sample paragraph prepared using the IBM SELECTRIC Composer. The type style is 10 point Press Roman with two points of leading between lines. The column width is eleven picas. A handwritten draft of this copy was submitted to a Composer operator with instructions specifying type style, leading, and column width and a request for justification. The Composer-printed result was photographed and is reproduced here exactly as received from the operator.

Summary

The development program has succeeded in producing a machine that prepares composition of a quality approaching hot-type composition. (See Fig. 1 for an example.) The Composer appears in a familiar form and has the ease of operation of a typewriter. It can serve as a bridge between typewriters and "hot-type" machines, complementing the offset printing process and fitting easily into its own position among the tools of the printing industry. The papers to follow report on its development.

Acknowledgments

Many individuals, in addition to the authors whose papers appear with this one, have contributed significantly to the design of the SELECTRIC Composer from its inception and development to its release into production. Of these, W. O. Cralle and B. E. Toben made especially valuable contributions to the design of particular mechanisms in the SELECTRIC Composer and to the technical direction of the entire design effort in the development stage.

Received February 27, 1967.