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## LOW-COST SOURCE DATA TERMINAL FOR TECHNICAL TEXT\*

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### ABSTRACT

A low-cost source-data entry station, for the entry of technical text into computer files, has been assembled from commercially available hardware, specially constructed interfaces, and carefully tailored software. A keyboard is provided for entry of Latin and Greek alphabetic characters in upper and lower case, as well as numbers and about 100 special symbols. As the characters are entered, they are displayed on a CRT screen by a software character generator which can also display any character in superscript, subscript, italic, or bold face. Control keys are provided for specifying insertions, deletions, and other text modifications with direct display on the CRT screen. A facsimile recorder provides reasonably fast low-cost hard-copy output with adequate resolution. This paper describes the configuration of the hardware presently in use, as well as projections to a "commercially feasible" system which would consist of a PDP-8 computer with 8-K core, 32-K disc, one or more terminals (each consisting of a keyboard and a storage scope), a facsimile recorder, and the necessary interfaces. Hardware characteristics of the interfaces are described, as well as the overall system design of the software and the data structures used.

### INTRODUCTION

The usefulness of a digital computer in the processing of text has become widely recognized. However, hardly any of the applications so far implemented have included adequate provision for the incorporation of technical text—that is, of text which may include very many different nonalphabetic symbols and characters, and which may include displayed formulas and other constructions not readily handled "one line at a time" in the standard way.

The source of difficulty in processing technical text is not the output device, for photocomposers with the required capability (such as Linotron 505, Videocomp 830, Photon 713, and Fototronic 1200) are now available which can be driven from magnetic tapes written directly by almost any computer. Admittedly, these machines generally operate somewhat inefficiently on

\*Work done under auspices of the U. S. Atomic Energy Commission.

complicated text, but even the slower speed of operation that accompanies the increase of flexibility in handling technical text is acceptable and is far superior to any previous alternative.

Bottlenecks due to computer software are not especially difficult to overcome. It is estimated that one-half man-year should suffice for an experienced programmer with sufficient knowledge of graphics requirements to produce a program which will convert strings of technical text from any one specific, well-designed internal computer format to an output form that will meet the requirements of any specific photocomposer model.

Rather, the difficulty has been at the entry point, and seems to be centered in the need to provide adequate "feedback" to allow an operator to enter technical text reasonably rapidly and with a reasonably low error rate on a keyboard with a repertory containing several hundred different characters.

Providing feedback to the operator of a keyboard with a large character repertory seems to require character images generated by software rather than hardware; therefore, the keyboard must be operated on-line. Accordingly, we are not considering the design of an entry terminal for technical text as an isolated problem, but rather as a part of a complete on-line system including a computer, keyboards with feedback displays, a hard-copy ("proof-mode") output facility, and possible intercommunication links for transmitting data to and from other points of application.

### BACKGROUND OF THE PROJECT

The Nuclear Chemistry Group at the Lawrence Radiation Laboratory has published, since 1940, six editions of the nuclear data compilation, "Table of Isotopes." Each edition has approximately doubled in size, and the sixth edition,<sup>1</sup> which was published late in 1967, constitutes a volume of nearly 600 large pages of closely spaced tables and diagrams. Some two man-years were spent in transcribing the textual data for this latest edition onto paper in the desired form, using a modified typewriter with a few interchangeable type bars and with bold-face numbers in the upper-case position on the numeric keys. This edition had finally just gone to press when the authors realized that the entire input operation would have to be repeated "from scratch" for the next edition. The magnitude of this input effort, along with the lag time between the cutoff date for the inclusion of new references and the date of

publication, led them to examine the feasibility of keeping the data on a continuously updated computer file. The specifications for this file,<sup>2</sup> as they began to be developed, drew major attention for the first time at this Laboratory to the need for considerable improvement in our ability to enter technical text into computer-readable files.

Other potential applications at this Laboratory, for any technical text entry terminal which might be developed, were immediately evident. These included, in particular, a somewhat similar Nuclear Physics data compilation, "Review of Particle Properties"<sup>3</sup> (for which the file would be smaller in volume, but higher in acitivity), as well as technical papers being prepared for publication, source-language ALGOL, and various kinds of bibliographic and other information which was already being processed by computers for the Technical Information Group. Furthermore, it was foreseen that any results that might be obtained here could be of value in the design of similar systems at other institutions.

Our requirements for technical text input capability, then, have included as a minimum the ability to enter the text strings of the "Table of Isotopes" into a computer file. Some of this text is shown as an example in Fig. 1. It is because of this orientation that we have at first rather neglected some other interesting format problems: for example, we have not yet taught our system how to handle complicated mathematical formulas such as displayed fractions.

In 1968, we designed and constructed a keyboard (see Fig. 2) by means of which we could generate text like that in the "Table of Isotopes." We used this keyboard to explore some ideas about keyboard design and arrangement, as well as to generate some text for testing output techniques. The keys of this keyboard are connected to the columns of a diode board, the rows of which determine the output code. The keyboard has 73 "character" keys, with expansion room for about 30 more (see Fig. 3). Upper and lower case Greek characters are superimposed upon 24 of the alphabetic keys. This first keyboard is interfaced to an IBM-526 keypunch in such a way that two card columns are punched each time a key is pressed, and the printing unit of the keypunch is used to provide some minimal feedback to the operator. We have found that this feedback is adequate for rather simple text.

We are actually using this keyboard for entering bibliographic data, some of which has been included in reports published by the Laboratory since the middle of 1969. These publications are produced by reading the cards from the IBM-526 into a large computer, which generates magnetic tapes for direct input to a Linofilm Photocomposer. We have also generated some samples of more complicated text in order to test output techniques. Among these samples we included the portion of the Table of Isotopes shown in Fig. 1, which we converted to magnetic tape form for the Linofilm Photocomposer (Fig. 4) and directly to graphic form via the CRT Microfilm Plotter and

the CalComp Incremental Plotter (Figs. 5 and 6). For this complicated text, however, we found that many iterations through the entire system (including CRT output, for example) were necessary for finding and correcting errors which occurred at the keyboard but escaped detection at that point because of inadequate feedback.

About this time, a small computer (PDP-8) with a disc and a storage scope became available for our use on this project, so we constructed a second keyboard (see Fig. 7) to be connected to that computer with the idea of using the storage scope for immediate feedback.

The storage scope has proved adequate for display of strings of text in order to provide immediate feedback (see Fig. 8), but it does not have enough resolution for "proof-mode" page composition, which requires a reasonably accurate representation of the appearance of an entire page, including relative character widths, justification of lines, paragraph indentations, columnar formats, and the like. Because of the complexity of the characters used (see Fig. 9) and the need to distinguish similar characters such as  $y$  versus  $\gamma$ ,  $v$  versus  $\nu$ , and boldface versus lightface, it is necessary to use an average character width at least 12 - 16 times the minimum resolution of the output device. Thus, in order to simulate an "average" 100-character line, for example (corresponding to a 38-pica line of nine-point type), 1200 - 1600 resolvable points across the screen are needed and a 1024-by-1024 CRT is inadequate.

We wondered whether some hard-copy output device could give us a solution to this problem while also satisfying other possible needs for copy to be proofread off-line. For example, the scientist responsible for the accuracy of the data in the Table of Isotopes needs to be able to review it after a typist has performed the initial data entry. We rejected, on the grounds that they are too expensive, such devices as high-resolution CRT systems (for example, Stromberg Datagraphix 1060, \$275,000), low-cost photocomposers with magnetic tape input (for example, Linofilm, \$65,000), high-speed incremental plotters (for example CalComp 665, \$11,275), and multiple-stylus electrostatic recorders (for example, Varian Statos-5, \$18,500). Finally we discovered a 19-inch facsimile recorder which is reasonably fast, has a resolution of about 1800 points per scan line (by 100 scan lines per inch), costs less than \$2500 (plus interface), and seems to have further applications as a general-purpose graphical output device.

We proceeded to design interfaces and to develop software to combine the PDP-8, a keyboard, a storage scope for feedback, and a facsimile recorder for proof-mode output, into a technical text entry system. All of the hardware was obtained commercially, except the keyboard and the interfaces.

## DESCRIPTION OF PRESENT HARDWARE

Because we believe that a number of organizations have somewhat the same needs as our Laboratory, we have been strongly constrained, as a matter of overall project philosophy, to make our explorations within the area of commercially available hardware wherever possible. On the other hand, the small computer which has so far been available for our use was acquired for the benefit of other users as well; therefore, we have not always been able to proceed in exactly the way which our overall philosophy would most strongly indicate. However, actual departures have been relatively minor and of such a nature that it is fairly easy to project from the actual configuration to a "most commercially feasible" configuration. Furthermore, the philosophical disadvantage of being unable to completely specify hardware is heavily overbalanced by the practical advantage of having the major hardware components already available for our use.

The present hardware configuration consists of a PDP-8I Computer with 8-K core and 256-K disc. It is equipped (because of the requirements of the other users) with a "generalized display interface" and a "generalized serial input-output interface." Both of these interfaces were designed and constructed at this Laboratory. The display interface provides connections for a number of Tektronix "Type 611 storage display units" (storage CRT scopes), including digital-to-analog converters, an "Erase" function output, and "Erase Complete" return signal from the scope, and a "Write-Through" mode (display point on screen temporarily, without storing) which is used especially for cursors or pointers to particular positions within the display. The serial input-output interface provides connections for a number of Teletype-like channels of various speeds: by providing the proper clock-pulse generator, any channel can be made to operate at a specified speed up to about 50 kHz. A seven-track magnetic tape drive is also connected to the computer. The only additional hardware required by our project consisted of a keyboard and a facsimile recorder.

The keyboard which is presently connected to this system was constructed here, using reed switches obtained from Microswitch (a division of Honeywell). It is similar in external appearance to the first keyboard (which drove an IBM-526 key-punch). The main keyboard has two sections. On the left are 49 keys arranged in offset rows like a typewriter keyboard, including 36 letters and digits, 12 keys for commonly used symbols (including punctuation), and the space bar. Greek characters are superimposed upon 24 of the alphabetic keys (all except J and V), and upper- and lower-case Greek letters are engraved on those keys in reduced size above the normal (Latin) letters. On the right, there are 39 keys for additional symbols. If separate characters are assigned to upper and lower case, the 39 keys on the right and 12 keys on the left provide more than 100 different symbols.

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Across the top of the keyboard is a row containing four control function keys and ten control character keys. The four control function keys specify Greek, superscript, subscript, and Italic functions, all of which are available along with any of the characters. The other ten keys are "characters" in that they actuate the keyboard output in the same way as any of the normal character keys; however, they are assigned to control specifications such as tab, line feed, and editing controls. Shift and shift lock keys are also provided in the usual typewriter positions.

The 98 "character" keys are encoded, by means of a diode board, into seven parallel bits. The shift, Greek, superscript, subscript, and Italic functions correspond to five more parallel bits. These 12 bits, plus a pulse which occurs whenever a "character" key is pressed, provide the output from the keyboard. The 12 bits could be fed directly to the PDP-8 computer; however, because of the availability of the serial input-output interface, we convert the bits to serial form and send them out on two separate "Teletype" channels.

The facsimile recorder is an Alden\* Flying-Spot Component Helix Recorder, Model 319 DA, which for many years has been the standard machine in use throughout the country for receiving wire-transmitted weather maps. It records by applying an electrical signal to moist electrosensitive paper. A mechanical scanning system moves the point of application of the signal along each of a series of closely spaced lines across the paper. The scanning device consists of a straight "knife-edge" electrode above the paper which defines the scan line, and a drum with a single-turn helix below the paper which moves the signal across the scan line each time the drum rotates. The number of scan lines per second is determined by the speed of the helix drive motor, and the number of scan lines per inch (longitudinal resolution) is then determined by the speed of the paper drive motor. Our helix drive operating speed is 600 rpm, or ten scan lines per second, and the paper drive speed is 6 inches per minute, or 0.01 inch per scan (per 0.1 second). A return signal is sent from the rotating drum every time the helix starts a new scan.

The darkness of the recorded image on the paper corresponds directly to the signal level as it varies during the scan sweep. For some applications, such as weather map recording, a slowly varying dc analog signal produces varying intensity in the record: for these applications, a linear amplifier and low-contrast recording paper are used. For digital recording, on the other hand, a precise distinction between black and white is desired, so we use high-contrast paper and a high-gain amplifier, and the applied signal is a pulse train. The frequency of this signal determines the transverse resolution (number of points per scan line). The scan line is 18 inches long, so we use a signal frequency of 18 kHz, or 1800 pulses in 0.1 second, giving 1800 points across the scan line or 0.01 per inch. The longitudinal and transverse resolutions

\*Alden Electronic and Impulse Recording Equipment Company, Inc., Westboro, Mass.

are thus each 100 per inch, which equals the nominal working limit set by the electrical and mechanical characters of the electrodes and of the recording paper.

The 18-kHz pulse train requires that a 12-bit word be loaded into a shift-register buffer every 600 microseconds. The PDP-8 has no difficulty in operating at this rate. Determining the bit configuration to be written requires that the image be generated one scan-line at a time. For text output, this scan generation is considerably simplified by preparing the character images for the original character repertory in suitable form.

#### PROJECTED HARDWARE CONFIGURATION

Because the present project uses a computer that happened to be available, which was already provided with interconnection hardware that simplified the attachment of some of the input and output devices, it is necessary to make some projections in order to estimate the actual cost of assembling a similar system in a configuration that would be ideal from a commercial point of view. The projections listed here are based on experience with engineering and construction of the hardware we are now using, as well as similar systems developed for other applications at this Laboratory. Cost estimates for a "typical" basic system are as follows:

DEC PDP-8/L computer	\$ 9,150	
Additional 4-K core (including B08A unit)	5,500	
32-K disc (including KD8L)	<u>6,500</u>	\$ 21,150
Tektronix Type 611 storage display unit	\$ 2,500	
Interface (see description below)	<u>2,400</u>	\$ 4,900
Microswitch solid-state keyboard (Mono Mode, Type 2-1)	\$ 300	
Additional control keys	200	
Interface (see description below)	<u>400</u>	\$ 900
Alden Model 319-DA facsimile recorder (with helix drive, paper drive, marking amplifier, magnetic synch trigger, continuous blade drive, and accessories)	\$ 2,395	
Interface (see description below)	<u>1,355</u>	\$ 3,750
"Typical" total minimum system	<u>\$30,800</u>	
Each additional terminal (keyboard and storage scope, with interfaces)	\$ 5,800	

These costs are intended to apply to acquisition of the components at manufacturer's list prices, and include interface assembly labor. The system design allows for only a limited number of additional terminals, since core and disc space and computer time must be shared by all the keyboards. Four terminals would seem to be

a reasonable upper limit, beyond which additional computer capacity would be required.

#### Interface Descriptions

The interface for the Tektronix Type 611 Storage Display Unit consists of two 10-bit registers (for X and Y coordinates), with digital-to-analog conversion. Signals are provided for Erase, View, and Write-Through (display without storing) functions under control of the computer, and for the detection by the computer of the "Erase Complete" return signal from the display unit. Logic-board costs include \$700 for digital-to-analog converter and \$600 for display control functions.

The Keyboard interface provides 12-bit parallel input into the Accumulator, with interrupt when a key is pressed on the keyboard. Basic cost for the components of this interface is \$225.

The Facsimile recorder interface includes a three-cycle Data Break, Internal Variable Shift Register, and Output Register, at an estimated total component cost of \$755. The Data Break is used to control the transfer of words from core memory to the shift register and thus present them to the recorder one bit at a time. Interrupt occurs on "Transfer Complete" or on a Synch Trigger pulse from the Recorder helix drum.

Other costs to be added to these component costs include: (1) a pro-rata share of additional hardware costs including Mounting Drawer Bin, Power Supply, Cables, Connectors, and 10% Contingency (total \$1050), and (2) pro-rated assembly labor, design, and drafting charges (total \$825). These pro-rated additional costs are included in the cost estimates for the "typical" total system.

#### Alternatives

It is obvious that the DEC PDP-8 computers are not the only ones to which keyboards (etc.) can be attached. Since the speed of the PDP-8L is not being exhausted, it would be interesting to perform some experiments with a slower computer. As another alternative, the additional 4-K core might be omitted in the case of a one-key-board system which could avoid overlap of the basic operations (page display, line display with edit, and proof-mode output) each of which uses considerable in-core program space. Additional disc space (at the relatively low cost of \$3000 per additional 32 K, up to 128-K total) would be very desirable on multiple-keyboard systems, or for applications requiring direct access to larger amounts of text.

For multiple-terminal systems, a TV-type CRT screen (drive from parallel-head disc tracks) needs to be considered as an alternative to the storage scope. Here the software character generator (inside the computer) would write and update an image of the entire screen on the disc. Cost of the disc storage is about \$5000, plus \$300 per track. With standard TV resolution (about 200,000 bits per frame), only two tracks per CRT

scope would be needed. For resolution comparable to the Tektronix storage scope, on the other hand, about 10 tracks would be required, and other costs would increase because of the need for a higher-quality TV image and because of the higher bit rate (one million bits per frame).

The Microswitch Mono-mode keyboard provides 69 character keys, which would be enough for many applications. Keyboards are now being designed and packaged to order by many other manufacturers, and some of these can provide larger numbers of keys at a reasonable cost.

Unless the proof-mode output is to be used as the final product of this system, there is need for output (and perhaps also input) data channels for communication with various computers or other devices. It is interesting to note, in this connection, that the facsimile recorder interface contains most of the hardware required for an output data channel, and could probably be adapted rather inexpensively to allow the transmission of data from the PDP-8 to other computers. Availability of a magnetic tape drive, on the other hand, would provide considerably enhanced input-output capability for intercommunication.

#### USING THE TERMINAL

As we have seen, the editing of strings of text from a large and variable character repertory implies software-generated characters. Interactive manipulation of words or lines of text requires on-line display of the completely formed characters, which in turn requires either the storage or the rapid regeneration of the entire picture on the screen. For a small number of terminals, the most economical alternative seems to be a storage scope, with display stored on the CRT screen itself.

When a point has been stored on this kind of scope, it remains there until the scope is erased. Thus, it is easy to add points (or characters, etc.), but it is impossible to delete a portion of the display without erasing all of it. Because of this fact, we were not altogether certain at first that a scheme could be implemented for the interactive manipulation of text by means of this device. The key to success, as it has turned out, is the short time interval required to redisplay a screen full of characters. Thus, it is feasible to delete a particular character, for instance, by erasing the screen and redrawing all of the remaining characters; this requires less than a second. This time interval, however, is still long enough so that we must avoid performing the redisplay unnecessarily, and this fact has had considerable influence upon the methods we used for implementing the interactive manipulation of text with this terminal.

The handling of text at our terminal is analogous to the manipulation of a scroll: the characters that are visible (on the CRT screen) at any given time are in general only a portion of a long string of stored text which may be thought of as being continued to the left and right beyond the field of view. Both the left and right portions of

this unseen text are written on disc in 256-character "tracks," with leftover partial tracks (if any) remaining in separate left and right buffers in core.

During the manipulation of text, then, we always divide the entire string of stored characters into a left part and a right part, either of which may be empty. Each of these parts is structured in a simple three-level storage hierarchy. At the highest (most accessible) level we have the few characters which appear on the screen, at the lowest level we have 256-character tracks on disc, and in between are the residual partial tracks which remain in core.

Let us describe the operations the user can perform. We start from the middle, assuming that several hundred characters have been entered and that the text has then been divided (somehow) into a left string and a right string of approximately equal length, so that all the levels of the storage hierarchy are nonempty, including the "left line" of about 20 characters which is displayed near the top of the CRT screen and the "right line" of about the same length near the bottom.

A character can be added to the string by typing on the keyboard in the normal way. The character is added at the end of the left line, and it immediately appears on the screen.

A character can be deleted either from the end of the left line ("delete left") or from the beginning of the right line ("delete right"). In either case, the screen is erased and the display is re-created with the deletion having been performed.

A character can be moved from the end of the left line to the beginning of the right line ("move right"), or vice versa ("move left"). Here again, the CRT screen is erased and a new display is generated.

In all these cases, the text string in storage is modified. The small left or right "line display" storage areas in core can easily overflow or become depleted, and so text is transferred between these areas and the lower levels of the storage hierarchy as required.

Except when characters are being added, the display on the screen reflects the current status of the left and right "line display" storage areas. The regeneration of the display, therefore, restricts the speed of deletions and of moves to about one per second. For this reason, we also have provided a way for the user to delete or move several characters at a time with only one regeneration of the CRT display.

When characters are added, they enter the left line and are eventually stored in the lower levels of the left string. The new characters appear on the screen at the end of the left line, and then on additional lines down the middle of the screen, but the display is not erased until the screen is full.



Initial entry of text is handled by the program in the regular way, except that the right line and the right string at all levels remain empty. At the beginning, the left string is empty too, but as text comes in the left line overflows into the intermediate "partial track" area, and as full tracks are generated they are moved out to the disc. As soon as a "move right" operation occurs, the right string becomes nonempty. A sufficiently large number of these operations will empty the left string and place all of the text in the right string; so that any new data entered from the keyboard will be placed at the very beginning of the text.

In order to speed up the process of locating the desired point within a large body of text, a "page display" mode is provided in addition to the "line display" mode just described. In this mode, no editing is allowed, and the right and left line display storage areas are emptied and pushed back into the track buffers. These are then rearranged so that exactly two full tracks are contained in core, with the rest of the text on disc. These two tracks (512 characters total) are displayed on the screen, with a movable cursor between them. (The cursor is a small mark which is sent to the CRT in "write-through" mode so that it is not stored and must be regenerated several times a second.) The user can move left or right one page at a time: each such operation causes one of the old pages to be written from core to disc and a new page to be brought in, followed by a display of the two tracks currently in core. He can also move the cursor about, within the two-page display. When he returns to "line display" (edit) mode, the text immediately to the left of the cursor is brought into the left line display area and the text to the right goes to the right line area, and the display is recreated as before.

All of the displays described so far use fixed formats, with fixed-width characters and a fixed number of lines on the screen. Line feeds, tabs, etc., do not have any effect on the display except to insert special indicators which appear also as fixed-width characters. Words are broken arbitrarily at the end of the line as well. In short, these displays are strictly "documentary" in function, so that the user can tell exactly what characters are in the string. Even the space bar prints a special indicative symbol.

To better exhibit the ultimate appearance of the text, a "view mode" display is also provided, wherein the characters have variable widths, spaces do not print, and a new line begins at a line feed or between words.

## APPLICATIONS

One the text has been stored on the disc, it can be written line-by-line on the facsimile recorder at a rate of about 80 characters per second, or the entire file of 32,000 characters in about 6.5 minutes. After proofreading it at his desk, the user may wish to return to the console and make further corrections. Finally the text (in the form of a 12-bit code for each character) is ready to be used in some way.

For some purposes, the hard-copy output via the facsimile recorder will be the final output from the system. Although the characters generated on the facsimile recorder in the standard "proof mode" are not of the highest graphic arts quality, they are certainly better than the usual (all upper-case, fixed character width, unjustified) computer line printer, and are perhaps somewhat better than typed copy. However, in most cases this hard copy is not the final output; rather, the text entered into the computer is intended for further use in some automatic system, for information retrieval, automatic indexing, language translation, or some other purpose. A somewhat different case is the entry of source-language ALGOL, where the further processing to be performed by the computer consists of compilation and execution of the specified algorithm.

Often the further processing is beyond the capability of the small computer, either because of large storage and file requirements or because of the extent and intricacy of the programs involved. If a seven-track or nine-track tape drive is provided, the text can be transferred from disc to tape and thence to another computer. As an alternative, if the output interface to the facsimile recorder is adapted to provide a data output channel, then the text can be transferred to any computer system with a compatible input channel.

Furthermore, with input from tape or some other reasonably high-speed channel, the facsimile recorder can also be used as a general-purpose graphical output device which can plot some kinds of data faster than a digital incremental plotter. In particular, we use our recorder to plot larger, higher-quality computer-drawn letters and symbols. A page 18 inches wide and 27 inches long, corresponding to a 6x9-inch page after photo-reduction, is formatted on a large computer using characters from the repertory designed by A. V. Hershey.<sup>4</sup> Using that storage capacity of the large computer, we convert the data to scan-line format and transmit it in that format to the PDP-8, which sends it directly to the facsimile recorder. The facsimile plotting time for 5000 characters (67 lines of 75 characters each) is 270 seconds or 4.5 minutes, as compared with 20 minutes for the CalComp 665, or about 10 - 12 minutes for the Linofilm Photocomposer. Thus the facsimile recorder, with input from external sources (via magnetic tape and small computer, or otherwise), can be used as a reasonably high-quality photocomposer. This use alone might justify its acquisition by an institution whose report printing requirements amount to a few hundred original pages per week.

We expect to use intercomputer links for typesetting compound fractions and other mathematical material which may be too complicated to analyze on the small computer. We will enter the data in the form of linear strings of text with function codes and delimiters to specify the mathematical nature of the material. Our small computer text entry system will handle it only in this linear string form, and will generate output for analysis by a large computer. The large computer

may produce photocomposer output, but for proof-reading of the results of the text analysis, we will probably want to simulate the photocomposer by generating the characters and converting them to scan-line format to be plotted on the facsimile recorder.

Another interesting application is the capitalization of existing files of one-case text, such as material which has been keypunched and which contains no upper- and lower-case indications. Such text is processed by a fairly simple program that converts all of the characters to 12-bit form, flagging them as lower case except for certain instances such as the first nonblank character following a period, which makes the correct decision on more than 90 percent of the words in the text. The resulting text is scanned by a human operator in order to correct the errors and oversights of the automatic conversion. This procedure fills a need which exists today, but its importance may be expected to decline as equipment for the entry of text in upper- and lower-case comes into general use over the next few years.

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Re<sup>186</sup> (90 h):

I: 1,  $\mu$ : -1.728 atomic beam (ArmL65)

$\beta^-$ : 1.071 ( $\dagger$  77), 0.933 ( $\dagger$  23) mag spect,  $\beta\gamma$  coinc (PortF56)  
others (MalyL64, JohnM56, StefR51, MetF51, GranP49a, LangeL49,  
BeacL49a, BashE63a)

$\gamma$  with  $\beta^-$ :  $\gamma_2$  0.13716 cryst spect (MarkI63)

$\gamma_2$  0.1372 ( $\dagger_{\gamma}$  100,  $e_K/\gamma$  0.44,  $K/L_{I+II}/L_{III}$  91/100/58),  $\gamma_3$  0.632 ( $\dagger_{\gamma}$  0.37),

$\gamma_4$  0.768 ( $\dagger_{\gamma}$  0.4i) mag spect, mag spect conv, scint spect (MalyL64)

$\gamma_2$  ( $L_{II}/L_{III}$  1.24) mag spect conv (SwanJ53, SwanJ53b)

$\gamma$  with EC:  $\gamma_1$  0.1227 ( $\dagger_{\gamma}/\dagger_{\gamma}(\gamma_2)$  0.073,  $e_K/\gamma$  0.53,  $K/L_{I+II}/L_{III}$  91/100/76)

mag spect, mag spect conv, scint spect (MalyL64)

others (RiceM55, PortF56, JohnM56, NielK58, ENesM63a, StefR51, MetF51,  
AjzF56, AntoN53, ThosB64)

$\gamma\gamma(\theta)$ : (LindqT57d, KinW59, BodE61a, LerjC61, VervJ63)

$\beta\gamma(\theta)$ : (DulH63, NoyeT56)

$\beta\gamma$  polariz( $\theta$ ): (DelM61, DeuJ60)

Isomeric level of Re<sup>186</sup>:  $t_{1/2}$   $7.0 \times 10^{-5}$  s delay coinc (Brank64)

prod: Re<sup>187</sup>( $\gamma, n$ )  $\gamma$ : K X-rays ( $\dagger_{\gamma}$  80), 0.10 ( $\dagger_{\gamma}$  1), 0.13 ( $\dagger_{\gamma}$  1) scint  
spect (Brank64)

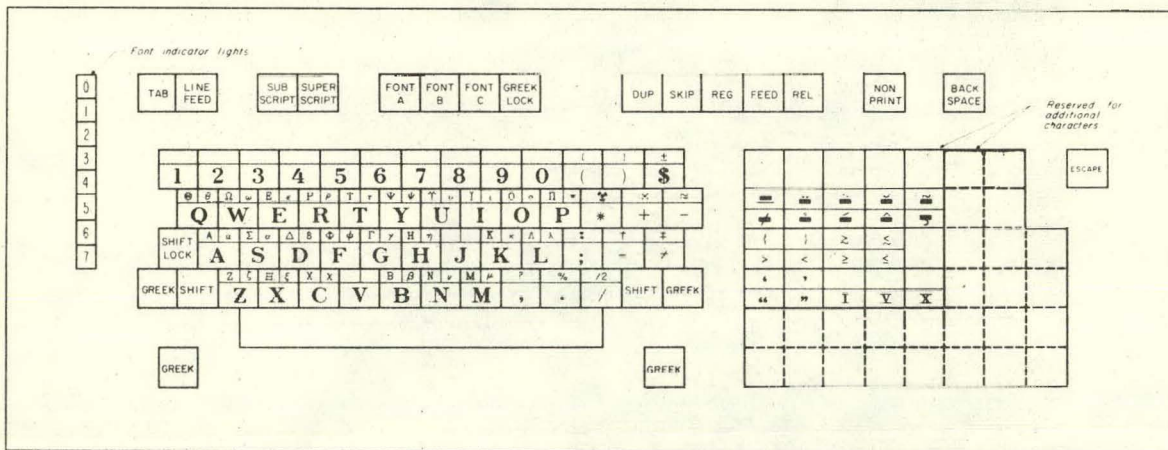
XBL 703-465

Fig. 1. Portion of a page from Tables of Isotopes, 6th ed.  
(John Wiley and Sons, Inc., New York, 1967).



XBB 6810-6032

Fig. 2. Keyboard constructed in 1968, which drives an IBM-526 keypunch via a relay-box interface.



XBL6810-7082

Fig. 3. Layout of 1968 keyboard.

Re<sup>186</sup> (90 h):

I: **1**,  $\mu$ : **+1.728** atomic beam (ArmL65)

$\beta$ : **1.071** ( $\delta_{\gamma}$ 77), **0.933** ( $\delta_{\gamma}$ 23) mag spect,  $\beta\gamma$  coinc (PortF56)

others (MalyL64, JohnM56, Stefr51, MetF51, GranP49a, LangeL49, BeacL49a, BashE63a)

$\gamma$  with  $\beta$ :  $\gamma_2$  **0.13716** cryst spect (MarkI63)

$\gamma_2$  **0.1372** ( $\delta_{\gamma}$ 100,  $e_K/\gamma$  0.44, K/L<sub>I+III</sub>/L<sub>III</sub> 91/100/58),  $\gamma_3$  **0.632** ( $\delta_{\gamma}$ 0.37),

$\gamma_4$  **0.768** ( $\delta_{\gamma}$ 0.41) mag spect, mag spect conv, scint spect (MalyL64)

$\gamma_2$  (L<sub>III</sub>/L<sub>III</sub> 1.24) mag spect conv (SwanJ53, SwanJ53b)

$\gamma$  with EC:  $\gamma_1$  **0.1227** ( $\delta_{\gamma}/\delta_{\gamma}(\gamma_2)$  0.073,  $e_K/\gamma$  0.53, K/L<sub>I+III</sub>/L<sub>III</sub> 91/100/76)

mag spect, mag spect conv, scint spect (MalyL64)

others (RiceM55, PortF56, JohnM56, NielK58, ENesM63a, Stefr51, MetF51, AjzF56, AntoN53, ThosB64)

$\gamma\gamma(\theta)$ : (LindqT57d, KinW59, BodE61a, LerjC61, VervJ63)

$\beta\gamma(\theta)$ : (DulH63, NoveT56)

$\beta\gamma$  polariz( $\theta$ ): (DelM61, DeuJ60)

Isomeric level of Re<sup>186</sup>:  $t_{\pm}$   $7.0 \times 10^{-5}$  s delay coinc (BranK64)

prod: Re<sup>186</sup>( $\gamma, n$ )     $\gamma$ : K X-rays ( $\delta_{\gamma}$ 80), **0.10** ( $\delta_{\gamma}$ 1), **0.13** ( $\delta_{\gamma}$ 1) scint spect (BranK64)

XBL 703-462

Fig. 4. Sample of technical text photo-composed of Linofilm, directly from computer-generated magnetic tape.

Re<sup>186</sup> (90 h):

l: 1,  $\mu$ : +1.728 atomic beam (ArmL65)

$\beta^-$ : 1.071 ( $\dagger$ 77), 0.933 ( $\dagger$ 23) mag spect,  $\beta\gamma$  coinc (PortF56)

others (MalyL64, JohnM56, StefR51, MetF51, GranP49a, LangeL49, BeacL49a, BashE63a)

$\gamma$  with  $\beta^-$ :  $\gamma_2$  0.13716 cryst spect (MarkI63)

$\gamma_2$  0.1372 ( $\dagger$ , 100,  $e_K/\gamma$  0.44, K/L<sub>1+2</sub>/L<sub>3</sub> 91/100/58),  $\gamma_3$  0.632 ( $\dagger$ , 0.37),

$\gamma_4$  0.768 ( $\dagger$ , 0.41) mag spect, mag spect conv, scint spect (MalyL64)

$\gamma_2$  (L<sub>2</sub>/L<sub>3</sub> 1.24) mag spect conv (SwanJ53, SwanJ53b)

$\gamma$  with EC:  $\gamma_1$  0.1227 ( $\dagger$ ,  $\dagger$ , ( $\gamma_2$ ) 0.073,  $e_K/\gamma$  0.53, K/L<sub>1+2</sub>/L<sub>3</sub> 91/100/76)

mag spect, mag spect conv, scint spect (MalyL64)

others (RiceM55, PortF56, JohnM56, NielK58, ENesM63a, StefR51, MetF51, AjzF56, AntoN53, ThosB64)

$\gamma\gamma(0)$ : (LindqT57d, KinW59, BodE61a, LerjC61, VervJ63)

$\beta\gamma(0)$ : (DulH63, NoveT56)

$\beta\gamma$  polariz(0): (DelM61, DeuJ60)

Isomeric level of Re<sup>186</sup>:  $t_{1/2}$   $7.0 \times 10^{-6}$  s delay coinc (Brank64)

prod: Re<sup>187</sup>( $\gamma, n$ )     $\gamma$ : K X-rays ( $\dagger$ , 80), 0.10 ( $\dagger$ , 1), 0.13 ( $\dagger$ , 1) scint spect (Brank64)

XBL 703-463

Fig. 5. Computer-generated microfilm plot of technical text sample.

Re<sup>186</sup> (90 h):

I: 1,  $\mu$ : +1.728 atomic beam (ArmL65)

$\beta^-$ : 1.071 ( $\mathcal{E}_\beta$  77), 0.933 ( $\mathcal{E}_\beta$  23) mag spect,  $\beta\gamma$  coinc (PortF  
others (MalyL64, JohnM56, StefR51, MetF51, GranP  
BeacL49a, BashE63a)

$\gamma$  with  $\beta^-$ :  $\gamma_2$  0.13716 cryst spect (MarkI63)

$\gamma_2$  0.1372 ( $\mathcal{E}_\gamma$  100,  $e_K/\gamma$  0.44, K/L<sub>I+II</sub>/L<sub>III</sub> 91/100/58)

$\gamma_4$  0.768 ( $\mathcal{E}_\gamma$  0.41) mag spect, mag spect conv, scin

$\gamma_2$  (L<sub>II</sub>/L<sub>III</sub> 1.24) mag spect conv (SwanJ53, SwanJ53)

$\gamma$  with EC:  $\gamma_1$  0.1227 ( $\mathcal{E}_\gamma/\mathcal{E}_\gamma(\gamma_2)$  0.073,  $e_K/\gamma$  0.53, K/L  
mag spect, mag spect conv, scint spect (MalyL64)

others (RiceM55, PortF56, JohnM56, NielK58, ENesM6  
AjzF56, AntoN53, ThosB64)

$\gamma\gamma(\theta)$ : (LindqT57d, KinW59, BodE61a, LerjC61, VervJ63)

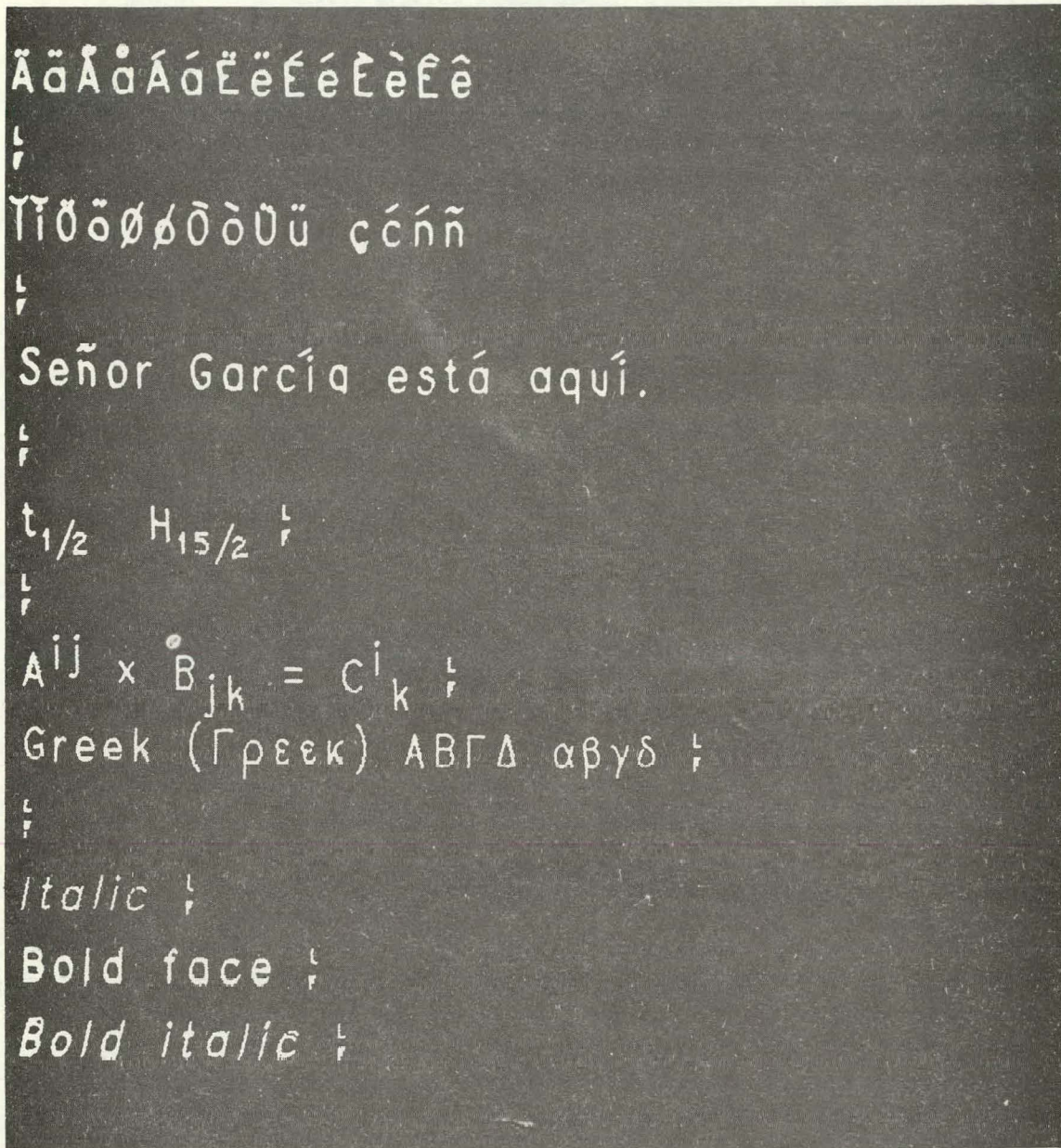
$\beta\gamma(\theta)$ : (DulH63 NoveT56)





XBB 6910-7027

Fig. 7. On-line technical text entry terminal, including keyboard and storage CRT scope.



XBB 6910-7029

Fig. 8. String of text displayed on storage CRT scope at on-line terminal.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
P	Q	R	S	T	U	V	W	X	Y	Z	Γ	Δ	Θ	Λ
Ξ	Π	Σ	Φ	Ψ	Ω	a	b	c	d	e	f	g	h	i
j	k	l	m	n	o	p	q	r	s	t	u	v	w	x
y	z	α	β	γ	δ	ε	ζ	η	θ	ι	κ	λ	μ	ν
ξ	π	ρ	σ	τ	υ	φ	χ	ψ	ω	,	;	:	.	?
0	1	2	3	4	5	6	7	8	9	-	+	*	x	/
(	)	≠	'	'	"	"	≈	≈	≈	±	I	V	X	‡
⊗	\$	=	[	]	%	‡	‡	‡	‡	‡	≡	→	←	↑
↓	^	∨	<	>	≤	≥	{	}	¬	°	-	-	˘	
˘	˘	/	/2	$\frac{N}{P}$	$\frac{N}{P}$	1	3	5	7	9	-	◊		

XBE 6910-7023

Fig. 9. Character repertory of on-line terminal.

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