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SOURCE DATA AUTOMATION TECHNIQUES STUDY FOR AFMPC

Leon McDowell

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Source data automation has often been defined as the efficient capture of data at the source, in addition to data handling. The speed with which computers are capable of manipulating data and executing instructions has increased significantly within this decade. However, the ability to input data to the computer has always been an area of concern. As a result, this deficiency has limited the potential throughput of current high-speed systems. The speed differential between manual data entry and computer processing has necessitated the development of source data automation techniques and devices in an attempt

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) to solve the input/output problem.

The spectrum of data entry techniques consists of the "old" keypunch operation at one end, followed by keyboard entry devices such as key-to-tape, key-to-disc and the CRT terminal; then the optical readers with voice input at the other end. A full progression from one end of the spectrum to the other has not been fully achieved at this time. A few applications still use the keypunch operation. However, it was forced to give way to the more efficient key-to-storage systems. Today, optical recognition technology is assuming a greater role in data entry. Voice input technology has progressed steadily in this decade. However, it is still largely developmental, and its use in data entry applications is somewhat limited.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

I. INTRODUCTION:

This report documents the results of an In-House Study in the area of Source Data Automation Techniques. The requirement for this study is contained in Program Management Directive (PMD) R-2144(4), dated 16 Jun 76. This PMD covers program direction on Project 1266 (Program Element 64708F).

The purposes of this study were to determine the capabilities which can be provided by the current state-of-the-art in source data automation and related technologies, and to underscore trends in future capabilities. The study was conducted in support of the Air Force Manpower and Personnel Center's (AFMPC) Microform System located at Randolph AFB TX.

The AFMPC maintains microfiche records of all active duty Air Force personnel. These records are maintained by keystroking input data into the computer-controlled microfiche records retrieval system. This input data is comprised of typewritten Air Force and Department of Defense documents which are created at base level and forwarded to AFMPC via the Postal Service. The AFMPC is interested in exploring the technical and economic feasibility of incorporating source data automation techniques into the system. It is anticipated that the data presented in this study will aid the AFMPC in assessing the cost/effectiveness of automating specific system functions and in establishing reasonable estimates in the areas of performance and cost for future planning purposes.

Data for the study was gathered from the following sources:

Literature Search - An extensive literature search was conducted and numerous technical articles from the various trade journals were obtained, along with many technical reports from commercial and military agencies.

Technical Survey - A survey was conducted in which a form letter was distributed among companies considered knowledgeable in any of the technologies related to source data automation, particularly Optical Character Recognition.

Travel - Selected agencies and companies were visited to obtain data as well as discuss some of the critical aspects of this technology. The Optical Character Recognition (OCR) Users Conference was attended in Hershey, PA during the summer of 1978. At that time, very valuable literature was obtained on existing OCR equipment and techniques.

RADC Programs - RADC/IRA, under the direction of Dr. Bruno Beek, has been involved in the development of voice input technology for many years. Numerous technical reports on the subject were acquired from that office in addition to technical papers written by IRA experts and others working in the area.

II. TECHNOLOGY DISCUSSION:

The electronic data processing industry has made significant increases in the internal data processing capabilities of the computer; however, it has failed to develop input/output techniques and equipment to the same degree of efficiency. As a result, this deficiency has limited the potential throughput of current high-speed systems. The speed differential between manual data entry (such as keypunching) and computer processing has necessitated the development of source data automation techniques and devices in an attempt to solve the input/output problem.

Source data automation has often been defined as the efficient capture of data at the source, in addition to data handling. It has been the subject of electronic data processing experts for many years. The speed with which computers are capable of manipulating data and executing instructions has increased significantly within this decade. However, the ability to input data to the computer has always been an area of concern.

The spectrum of data entry techniques consist of the "old" keypunch operation at one end, followed by keyboard entry devices and optical readers with voice input at the other end. A full progression from one end of the spectrum to the other has not been fully achieved at this time. A few applications still use the keypunch operation. However, it was forced to give way to the more efficient key-to-storage systems. Today, optical recognition technology is assuming a greater role in data entry. Voice input technology has progressed steadily in this decade. However, it is still largely developmental, and its use in data entry applications is somewhat limited.

The evolution of source data automation concepts usually begins with a discussion of source data capture in a form not suitable for direct entry into the computer thus requiring a transcription process for data entry. If data is captured at a remote location, the method of transfer to the processing site also becomes important. Therefore, source data automation may be discussed in terms of both the technique used in source data capture and the method of data transfer from the point of capture to the processing location.

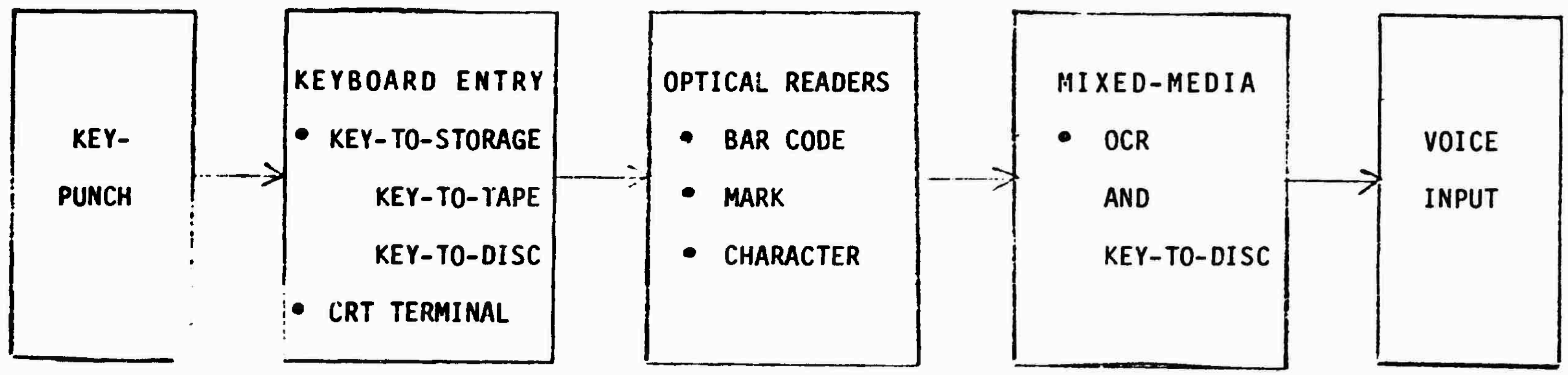
Reference 1 estimates that 25 to 50 percent of all data processing operating costs are consumed by the data entry process with the largest cost factor being personnel such as keypunch operators. Technological developments over the past 15 years have led to more sophisticated data entry systems designed to capture data more efficiently and economically than keypunching. Key-to-storage systems permit faster operator entry while performing preprocessing activities such as data format and verification checks. These data entry systems however still require operators and the associated labor cost. This reference, like others written on the subject, considers the key to efficient and economical data entry lies in the elimination of the data transcription step with its associated labor cost and its replacement with direct data capture at the source document.

III. TECHNICAL DESCRIPTION:

The source data automation technology spectrum is depicted in Figure 1. As noted, methods of source data capture and entry which represent varying degrees of automation may be divided into five technology categories: keypunch, keyboard entry, optical readers, mixed-media and voice input. Progression of the spectrum from left to right represents an increase in the efficiency with which the data is captured at the source. Further subdivisions, as appropriate in each of the categories, are also noted in the figure.

A. KEYPUNCH:

The most common form of data entry device is the keypunch. Data is received in printed, typed or handwritten



SOURCE DATA AUTOMATION TECHNOLOGY SPECTRUM

FIGURE 1

form either in its original format or on special punched card transcription forms. The keypunch operator must then punch the cards in a specific format. To assist the operator, a control card is initially made up to prescribe the fields to be punched and skipped. To assure accuracy, the data is usually entered a second time by a verifier to check for errors. With newer buffered keypunch machines, the keying operation is faster and limited card edit checks are performed.

From a system point of view, the keypunch is a very slow means of data entry. It requires a rigid format and is costly when used in a multi-keypunch installation. However, established usage of the unit record concept in existing system designs, the ease of punching small jobs and the ease of data insertion will keep the keypunch in operation. Reference 2 states that modern day keypunches which are buffered can be used for both punching and verifying. They are available in both the interpreting models (which print along the top edge of the card while punching) and non-interpreting models. There are 80 column keypunches supplied by Decision Data, IBM and Univac. IBM and Decision Data also make the 96-column keypunch. However, this reference suggests that this format is near extinction and as such does not recommend acquiring one.

The conditions which tend to favor the selection of a keypunch for data entry are:

(1) The need for a small number of data entry stations.

(2) The need for a relatively small number of program formats (10 or less).

(3) The ability to work effectively with 80 to 96 character records.

(4) The availability of strong editing procedures in the central computer for subsequent discovery of errors rather than relying on error discovery during the data entry process.

(5) The absence of a need for rapid and systematic searching of the recorded data records.

(6) The absence of a need for immediate printout.

These conditions suggests that if the data entry activity is relatively straight forward and not overly voluminous, then the keypunch might well be the most cost-effective data entry method.

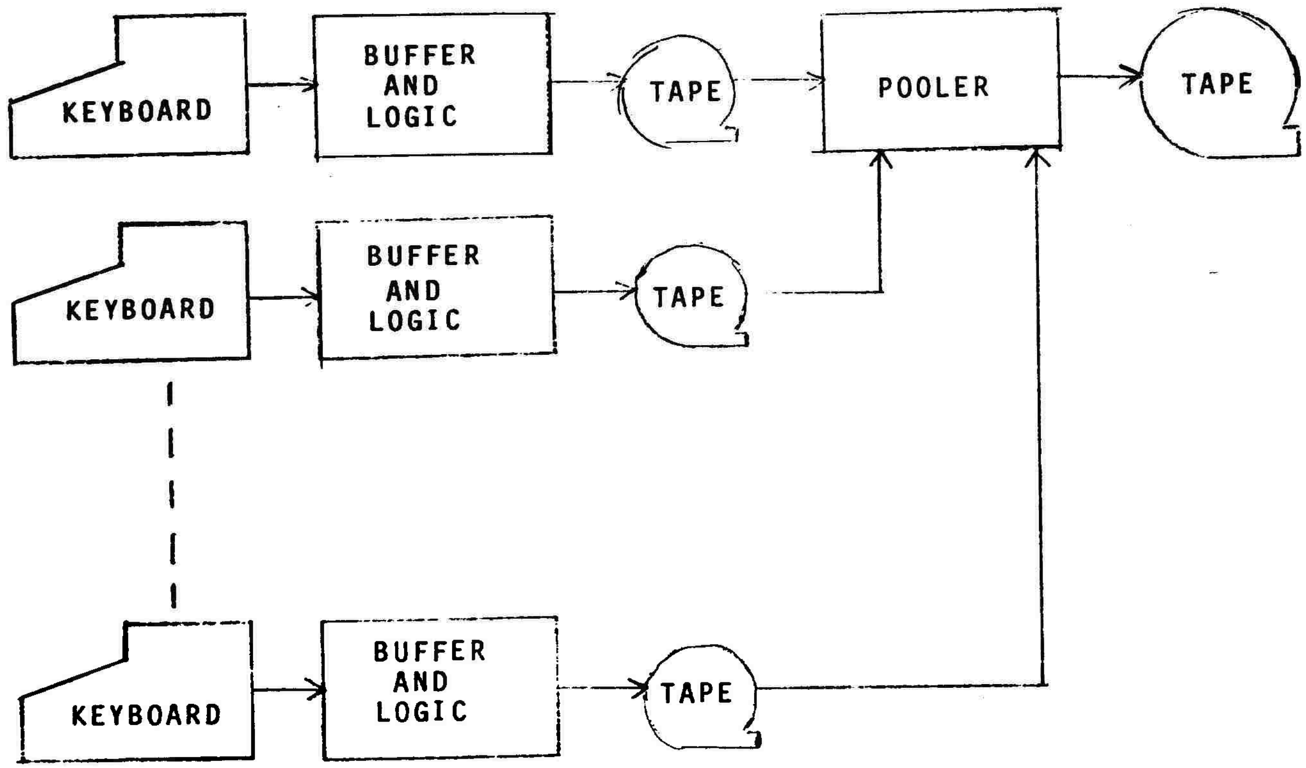
B. KEYBOARD ENTRY:

The need to increase the efficiency of the keypunch operation and lower data entry cost without changing data preparation procedures led to the development of keypunch replacement equipment. Key-to-storage and CRT terminal systems are the most widely used methods of keyboard data entry.

1. The Key-to-Storage System which includes both Key-to-Tape and Key-to-Disc Systems provides a more efficient means of data entry as compared to the keypunch system.

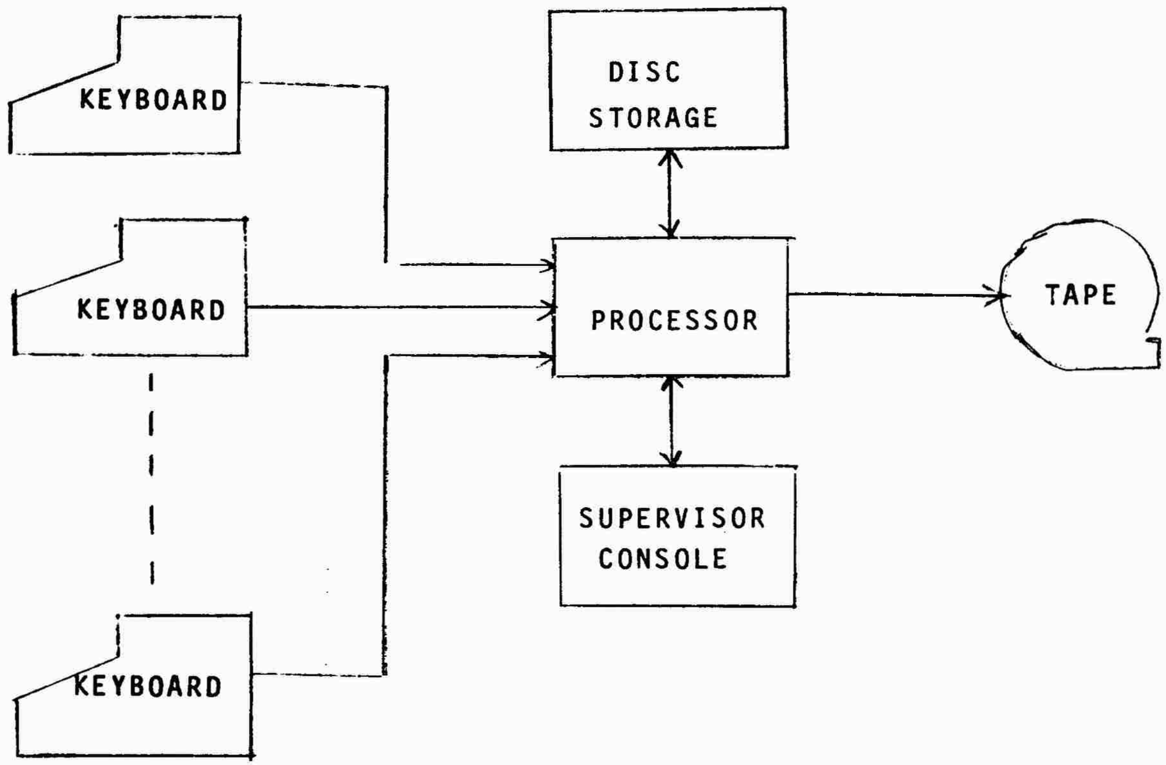
The Key-to-Tape System implies stand alone replacement of keypunch units. The basic elements of a key-to-tape system, as noted in Figure 2, are the keyboard, a tape transport, a buffer and associated logic. Some units use cassettes or cartridges as an intermediate medium but generally data is stored on half-inch computer compatible tape. The only essential difference between a stand alone key-to-tape and a keypunch unit is that the data is placed onto magnetic tape rather than punched cards. In order to reduce tape setup time, the tapes produced from a number of units are merged into a single tape by a pooler.

The Key-to-Disc System is an extension of the key-to-tape system in which the processor is enhanced by the addition of disk memory. As noted in Figure 3, each system consists of multiple keyboard terminals, a supervisory terminal, a small computer, a magnetic disc and a tape drive. The multi-keyboard stations connect to a shared processor. The disc memory contains the program library and operating system routines, and serves as a mass storage area for



BASIC ELEMENTS OF A KEY-TO-TAPE SYSTEM

FIGURE 2



<u>BASIC ELEMENTS OF A KEY-TO-DISC SYSTEM</u>

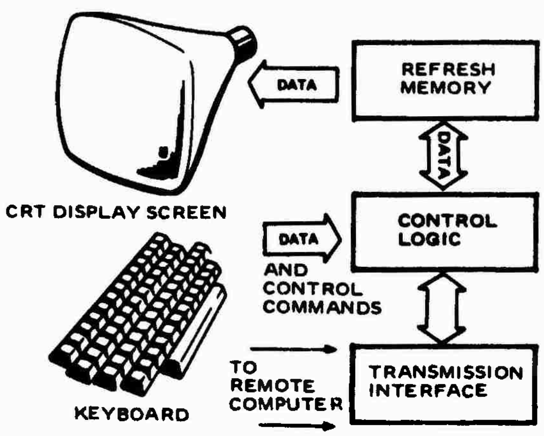
FIGURE 3

keyboard station input. After processing and formatting, the data is transferred from the disc to the magnetic tape. Because of the increased power of the key-to-disc processor, more sophisticated error checks and editing is performed. Reference 3 estimates that key-to-storage systems offer a 20 to 40 percent increase in data entry throughput with a substantial reduction in user costs. Depending on the system and the user, efficiency is obtained through increased operator speed, reduced error correction costs, increased flexibility, minimized overtime operation and the elimination of card and storage cost.

The shared processor systems offer both a price and speed advantage over most stand alone units provided that a number of operators are required. Since several keyboards share a processor, intermediate storage devices and tape drives, the cost of having a tape drive and control unit for each keyboard is eliminated, and the cost of a larger, more versatile processor and an intermediate storage device is substituted. Thus, for a small number of keyboards such a system would be more expensive; for a larger number, the price per keyboard drops as the number of keyboards increase. The break-even point varies with each system. However, Reference 4 suggested that at least six to eight keystations are required for this concept to be cost competitive with other methods of data entry.

2. CRT Terminal - The CRT Display Terminal is an on-line input/output device designed for two-way transmission of data with a control computer. Figure 4 depicts the functional units of a CRT Terminal, which are the CRT Display Screen coupled with a keyboard, a buffer memory for display refresh, control electronics, character generation and transmission interface.

The CRT Display is used to show input and output data. Therefore, one of the most important features is the screen capacity. Typical units are capable of displaying up to approximately 1,920 characters in a single display in a format of 80 characters per line and 24 lines per display. A cursor typically is used on the screen to show where the next character will appear. When the terminal is under the control of the operator, the cursor can be moved to any location on the screen and thus new information can be entered or old information deleted, and/or updated. The edit functions typically include: erase character, erase to end of line, erase to end of message, erase to end of display, insert character in line and display, delete character in line and display; and insert and delete line. The keyboard is usually a standard typewriter type keyboard with cursor control key and some additional special function keys provided to increase flexibility. The key cap explains the



FUNCTIONAL DIAGRAM OF A CRT TERMINAL

FIGURE 4

function performed by the system when it receives the unique code that is generated by that particular function key.

The refresh memory is usually large enough to store one "page" of data or a full-screen. However, a concept known as paging allows many more lines of information to be stored in the memory than can be displayed on the screen at any one time. Display Terminals with this feature require additional local memory for storing extra lines or pages of non-displayed data. The stored data can be displayed on command, a page at a time, or rolled back and forth in front of the display window (viewing area). Although a listing on a CRT is normally limited to 24 lines, "paging" permits data lines well in excess of 24 to be stored and displayed.

The control electronics provide the necessary sequence, timing and operational signals to let the display unit perform its various functions.

The character generator accepts coded characters (typically ASCII) from the computer and keyboard, and converts them to a pattern that can be "drawn" on the face of the CRT Display. Typical units are capable of generating up to 64 different alphanumeric characters including upper and lower case alphabets, the standard numerals and other special symbols.

The transmission interface connects the display unit to the communications computer system. It usually conforms to the ASCII code and discipline, meets the electrical and logical requirements of the standard EIA RS 232 specification, and connects to a modem or acoustic coupler at speeds between 110 and 9,600 bits per second. In some cases where the terminal-to-computer distance is not too great, the modem can be eliminated and the terminal can be connected to the computer directly.

CRT Display Terminals used on line for data entry provide a direct man-machine interface. With the appropriate systems software, the computer can prompt the operator with request or replies, and can detect errors during data entry. The operator can usually verify the data on the screen and therefore reduce significantly the input error rate problem. Therefore, the use of a CRT Display considerably eases data editing and correction. Arguments against displays, such as their not being necessary to operators for keying, would be valid if everything were entered perfectly. In the real world, however, where errors occur and corrections are needed during entry and verification, the display becomes a valuable aid. The existence of a display alone does not assure efficient operation. The data must be presented in an easily readable format that defines data fields. For purposes of controlling operator entry of data, the software system can be designed to present formatted displays with predetermined fields for the operator entry of data. Data generated by the system would be categorized as a protected field (operator cannot change data). The data entered by the operator in the appropriate fields (operator can enter/change data) is unprotected. During transmission, only the unprotected fields are transmitted.

C. OPTICAL READERS:

Optical Readers are devices which employ a scanning process to search a document for marks, an array of code bars or alphanumeric characters and converts the optical impulses obtained via reflected or transmitted light to an appropriate electrical signal for further processing. As suggested above, Optical Readers can be categorized by the type of symbol read. The three principal groupings are Optical Mark Readers, Optical Bar Code Readers and Optical Character Readers. The Mark and Bar Code Readers correlate the position of marks and code bars respectively, while the character reader identifies each character by comparing its features with those of pre-stored characters.

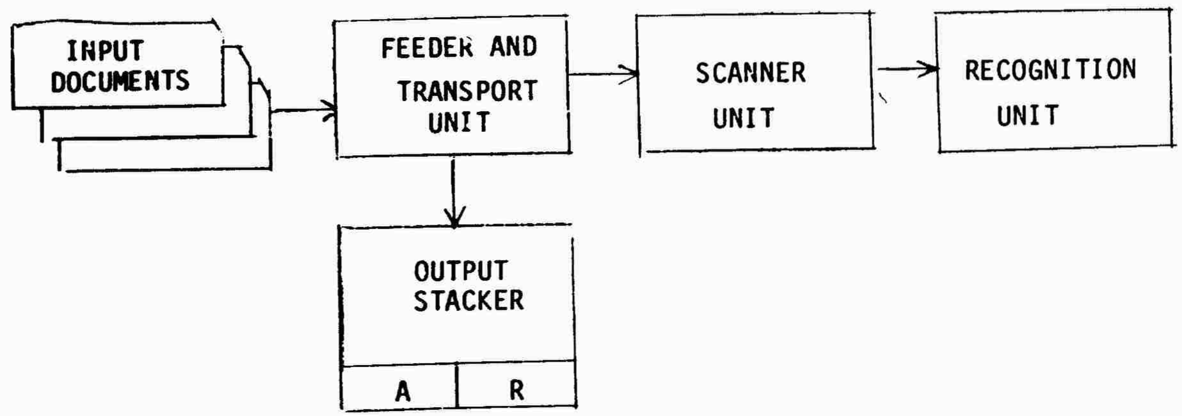
1. Optical Mark Reader - The Optical Mark Reader is the simplest type of optical reader and is used primarily for test scoring, inventory control, data collection or other

"mark the correct box" applications. Some of the mark readers handle conventional 80-column cards while others are capable of handling full-page documents. They typically read data in one of two ways. The first is by interpreting rows of marks in exactly the same way as holes in a card are interpreted. Thus, one column of marks can be used to represent one character. Some readers are designed to interpret data coded on conventional punched cards consistent with the Hollerith code. The second technique used by mark readers transmits a binary image of the marks to the computer which is then interpreted by software. They may interface directly or over a communications line with a computer. They may also operate off-line, feeding data onto magnetic or paper tape for future computer entry.

2. Optical Bar Code Reader - Optical Bar Code Readers are electronic reading devices which optically sense special combinations or arrangements of bars and correlates these bars to previously defined characters. The type of code used varies, but in most cases they cannot be formed by hand and are not easily readable by humans. Usually, special devices are required to produce the bar code imprinting. The most widely used code pattern is the Universal Product Code (UPC). Bar Code Readers like Mark Readers may interface directly to computers or operate off-line with tape recorders.

3. Optical Character Reader (OCR) - These systems are rapidly evolving as an economical means of inputting data into a computer system. The optical character reading method employed in OCR systems is similar to the reading method used by humans. When light is placed on a form containing data, we search or scan the form, and the optical image of the characters is reflected on the retina of the eye. These images are transformed into nerve impulses, and transmitted to the brain. The brain has been programmed through learning to identify and recognize a variety of characters. Optical character readers employ a scanning mechanism to convert reflected light pulses representing particular characteristics of the character to be read into electrical pulses. These electrical signals are then used to "recognize" the character by comparing these signals with matching sets of signals stored in memory in order to determine the identity of the character.

Figure 5 depicts the functional elements of an OCR System. The input documents are fed to the scanner unit by the feeder and transport after which the data acquired by the scanner is used by the recognition unit to identify the data. Depending upon the success of the recognition task, the feeder and transport unit sends the document to either the accept or reject bin of the output stacker.



A - ACCEPT BIN

R - REJECT BIN

BASIC ELEMENTS OF AN OCR SYSTEM

FIGURE 5

INPUT DOCUMENTS - The input documents may be of the turnaround type (utility bills, charges, etc.) which are printed or sometimes handwritten data. The quality of the input document and the data on it are important for proper operation of an OCR machine. Excellent reading performance can be achieved when forms on which data are printed conform rigidly to machine specifications. Reference 1 indicates that the quality of the input data involves a number of factors: The device used to print the data, whether it is a computer line printer, a typewriter, or a typesetting machine; the print ribbon used on typewriters; the ink used to print the forms; the paper and the design of the input documents. The printing mechanism is extremely important because the OCR units become increasingly expensive in proportion to their ability to handle misregistration and blurred characters, and skewd lines. Therefore, a precisely printed document can have a great effect on the cost of a reader capable of a given throughput. Most current readers require special typewriter and printer ribbons to assure sharp images resistant to deterioration and producing minimum reflectance on the paper. With regards to forms design, the most important considerations are to consider machine limitations of the reader to be used, i.e., font capabilities, registration tolerances and skew, and to minimize space between OCR fields to reduce unnecessary scanning.

Font types are especially significant to the OCR field since they govern the nature of the input medium. OCR readers fall into three broad categories. They are the single-font, the multi-font and the omni-font reader. A single-font reader "reads" a single printed or typewritten font. A multi-font reader is capable of reading a variety of fonts, one at a time. An equipment adjustment is usually necessary in changing from one font to another. The omni-font reader is capable of reading multiple fonts which are mixed together by performing a character set analysis immediately prior to reading.

A significant problem faced by the multi-font and omni-font readers is the wide variation in type sizes as well as type styles. The size of the area that the letter occupies must be defined in order to determine all aspects of an individual shape. This is difficult when type sizes vary. The problem is also encountered by readers that must deal with proportional spacing, since the size of the area containing the character is not predictable. Single-font and most multi-font readers deal with fixed pitch fonts (fixed spacing) rather than proportional spacing and have a limit on allowable type sizes in order to provide enough decision points to accurately identify the character.

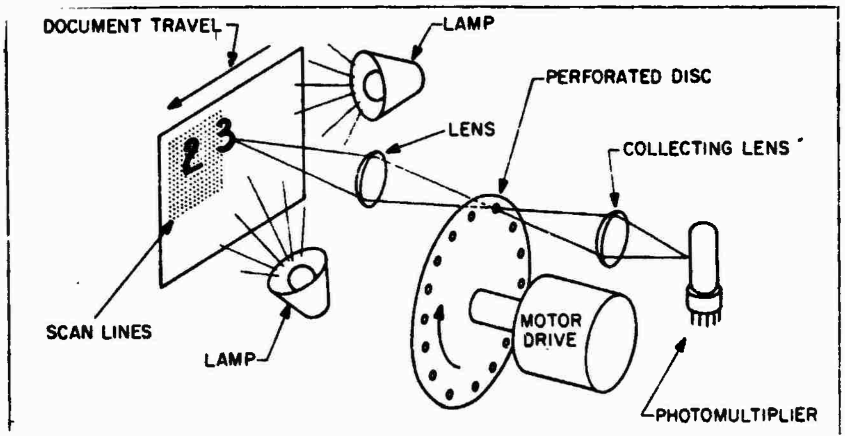
Reference 5 reflects some problems experienced by a military organization. The article discusses the incorporation of an OCR capability by the U.S. Marine Corp. The keypunching operation was replaced by OCR typewriters with a USASI type font for data preparation prior to entry in the computer. With regards to OCR typewriters, the author emphasizes that the OCR font is only one consideration which led to the replacement of the older nonelectric typewriters. Ribbons and embossing density are critical. Reusable cloth ribbons "splash" when struck by the key, and the scanner reads the splash mark as part of the character. Key pressure must be accurate so that the typed character is free from shadows caused by hitting the page too hard or unblackened areas in the letters caused by hitting the page too lightly. Another critical parameter is vertical alignment. If vertical alignment is not maintained (e.g., six lines per inch) by the time the scanner is halfway down the page, the scanning aperture will be skimming the top or bottom of the characters, the line will be rejected. The printer should be one with a proven record of satisfactory performance in preparing OCR forms.

FEEDER TRANSPORT/OUTPUT STACKER - The function of the transport unit is to move the forms from the input hopper past the scanner read station and then to the output stacker. This unit represents the most critical and costly element of a reader. Reference 1 states that there are essentially four types of transports each associated with a different type of OCR device. Transports used for handling cards or small paper forms (up to 4 x 9 inches) are associated with document readers. Transports for handling variable size forms from card size to 11 x 14 inch paper are associated with page readers. Transports for handling continuous paper rolls (cash register or adding machines tapes) are used in journal type readers. Finally, transports for handling microfilm are used in microfilm readers. Although significant improvements have been made in transport mechanisms in recent years, the ability to properly feed and align paper in the read unit remains a problem which manufacturers are attempting to solve by developing new technologies. The disadvantage of mechanical paper handling techniques is that they tend to jam even when high quality paper is used. Reference 1 reports that most OCR units employ one of two types of feeder mechanism. The first is a friction feeder which exerts pressure on the stack and pushes the forms through a set of rollers that separates the top form from all those below it. The other type is a vacuum feeder which lifts the top form off the input stack. The form is then moved past the scanner on a conveyor belt and/or a set of rollers.

SCANNER - The scanner has the function of converting the printed information on the document into electrical signals that will enable the recognition system to recognize the printed characters. As noted previously, an OCR system can fall into two categories: Page Readers which are capable of reading the entire page and Document Readers which read only a few lines. Therefore, the kind of scanning system suitable for an OCR depends on the size of the area to be scanned. The most common types of scanners used today are the mechanical disc, flying spot, laser, linear and area solid state arrays.

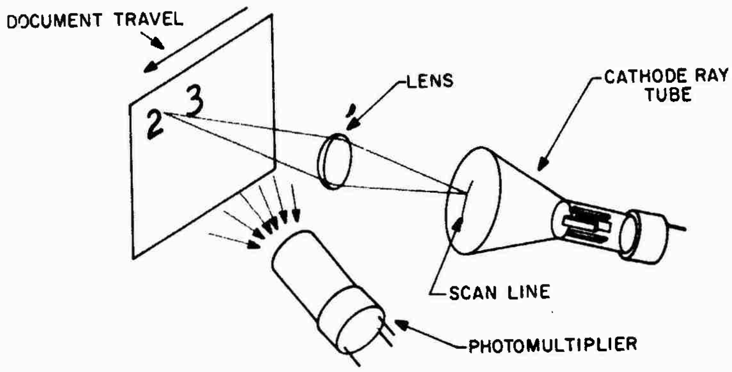
The Mechanical Disc Scanner as depicted in Figure 6 uses a light source which is reflected from the source being scanned. The reflected light is collected and focused on to a rotating disc containing multiple apertures. The selective apertures in the disc allow only a portion of the area being scanned to impinge on the photomultiplier at one time. The document movement combined with the spinning disc results in a video output representative of the character shape. Although this method of scanning has the advantage of a lower cost, it is relatively slow in comparison to other methods.

The Flying-Spot Scanner is used extensively in page readers. It is an example of selective illumination in which the light spot on the CRT screen is focused on the document as indicated in Figure 7. By deflecting the CRT beam in short vertical movements that are displaced horizontally to one another, each character on the line is covered in ten to twenty cycles of scan. Figure 8 shows that the



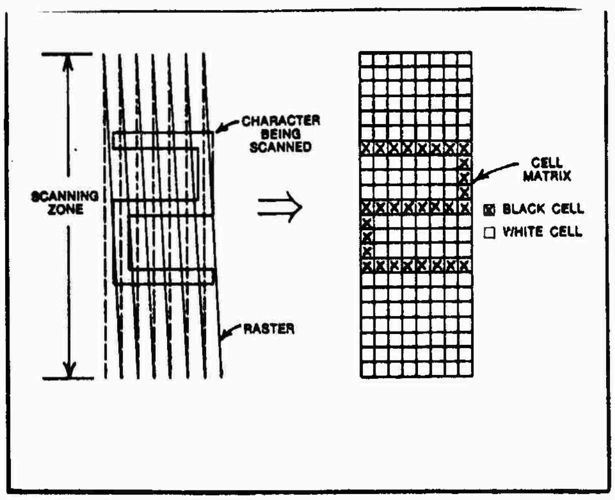
MECHANICAL SCANNER WITH ROTATING DISC

FIGURE 6



CRT SCANNER

FIGURE 7



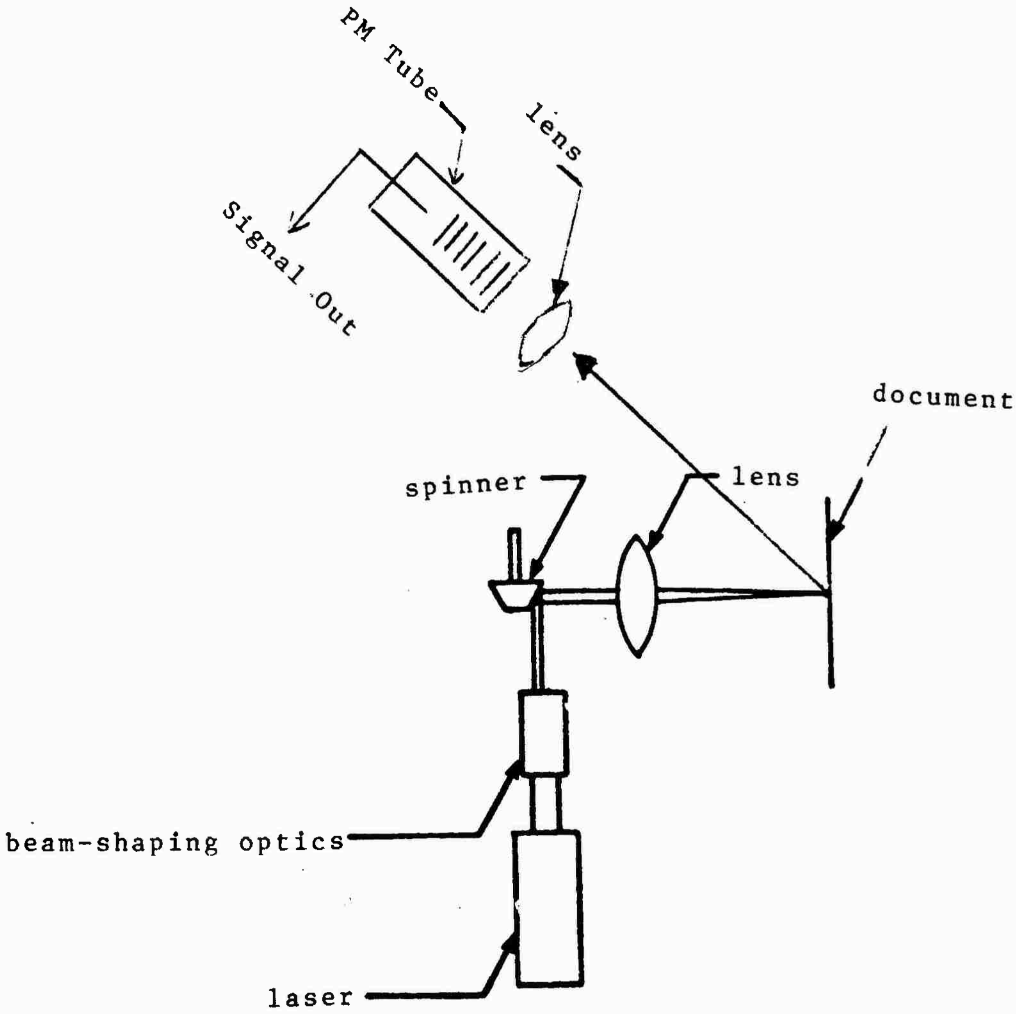
SCANNING A CHARACTER

FIGURE 8

scanning system slices the character many times vertically in a TV raster like manner and also divides each vertical scan into cells, so that the character is in effect described as a two-dimensional matrix of black and white cells. The scanning raster height is typically larger than the height of the character to allow for vertical misregistration of the characters. This method of scan is the most versatile in terms of flexibility. The Flying Spot Scanner can scan in any pattern desired, and can jump from one part of the page to another with relative ease. This is important when rescanning has to be done. Its disadvantages are that it is somewhat expensive and bulky, has limited resolution, and suffers from geometrical distortions and defocussing when spot is deflected over large angles.

The Laser Scanner provides a monochromatic source of light that is of much higher intensity than the CRT scanner, and results in an improved signal-to-noise ratio in the detection system. Thus, lower contrast characters can be recognized with a greater confidence.

The concept of the Laser Beam Scanner utilizing the spinning mirror as the deflection mechanism (as opposed to the galvanometer approach) is depicted in Figure 9. It is very similar in operation to the flying spot scanner. However, in the case of this scanner, a laser is used to generate the scanning spot. The scanning spot is obtained



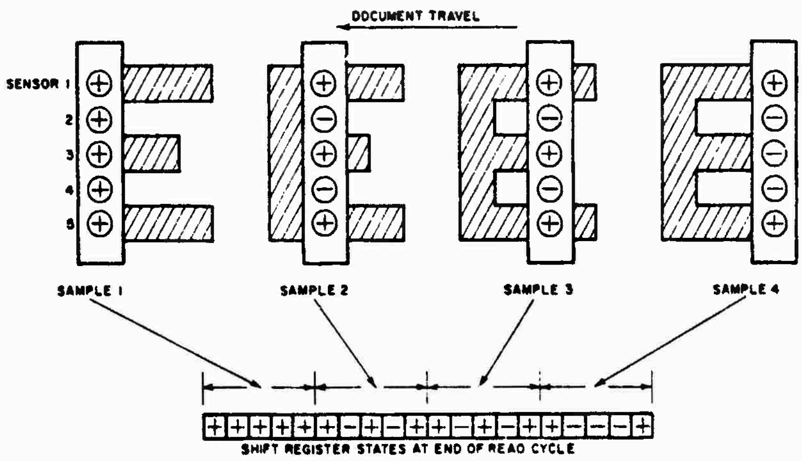
LASER-BEAM SPINNING MIRROR SCANNER

FIGURE 9

by first passing the laser beam through a set of optics. The function of these optics is to generate a spot of light that is uniform in intensity. The beam is then directed onto a scanning spinner. The spinner deflects the beam through a given angle at a uniform angular velocity. The beam then passes through an objective lens and a field flattening lens. Thus, as the beam moves through a given angle, a focused spot moves across the width of the document. During each line scan interval, the document is moved in the direction of its height, a distance equal to the width of the scanning spot. In this way, the entire document can be scanned. As with the flying spot scanner, the light reflected off the document is focused onto the face of a photo detector and the resulting signal fed into the signal processing electronics. The advantage of this scanning method is its high resolution. The disadvantage is its low speed (less than the mechanical scanner).

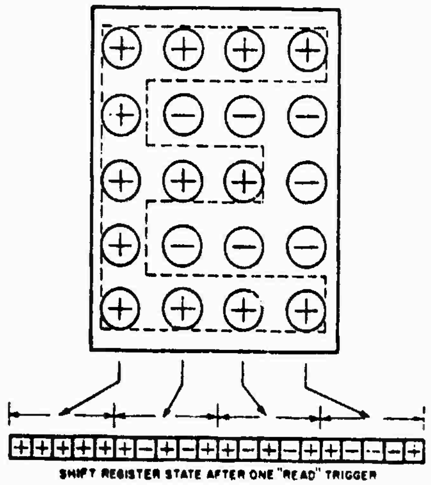
The Solid State Scanner technique can be designed around either linear or area arrays. The linear array as indicated in Figure 10 uses a single vertical array of about 10 to 50 sensors. A bright line focused onto the document reflects onto the sensor array. As a character moves through the optical system, a timing circuit "strobes" the character's image as it appears on the array. This produces a series of pulses that represent vertical segments of the character and the white field around it. The data for each segment is loaded in a shift register. Therefore after the character has been scanned, the shift register is loaded with data representing all the segments. Linear arrays generally break a character down into five to ten vertical segments. The larger the number of vertical segments, the smaller the chances of a misread character. However, using a larger number of vertical segments to step up reader accuracy slows down the data entry time for each character. So, OCR sensor-array systems have to play off recognition accuracy against reading time. The area array eliminates the speed and accuracy limitations of the one-dimensional OCR system. Instead of looking at a number of vertical segments of each character, arrays look at the entire character at once (Figure 11). State-of-the-art two-dimensional photosensor arrays look at as many as 500 to 1,000 points, simultaneously, in about the same length of time it takes to read only one or two vertical segments in a linear array.

<u>RECOGNITION UNIT</u> - The most commonly used recognition methods are matrix matching, stroke analysis, feature extraction and curve tracing.



SOLID STATE LINEAR ARRAY

FIGURE 10



SOLID STATE AREA ARRAY

FIGURE 11

In matrix matching, the electronic signals representing the scanned character are stored in a shift register that is connected to a series of resistor matrices. Each resistor matrix represents a different character. The output of each matrix is connected to a second register whose voltage outputs are representative of what should be obtained if the referenced character were present. The register voltage representing the character to be identified is compared to the register voltage of each resistor matrix contained in the character set. The recognition circuitry then determines which character is being read by deciding which matrix produced the maximum correlation with the "unknown" character.

In the Stroke Analysis Technique, recognition is based on analysis of the strokes or line formation of each character in comparison with information stored in the form of a truth table on all characters in the set.

Feature extraction involves the detection of certain features such as the major shape elements (lines, curves, etc.) via decision tree.

Curve tracing involves the tracing of each character's outline curvature by movement of the scanner beam or by logical decisions of the recognition unit. This technique is most suitable for the recognition of hand print numerics.

Optical Character Readers may be classified by the type of input form processed. The document reader can handle forms up to 4 x 9 inches and read up to five lines of data in fixed locations on a document with a single pass. A numeric character set in a single font is usually employed in Document Readers. The Page Reader is capable of reading numerous lines of data and a variety of printed forms up to 8½ by 11 with data in various locations on the page. This reader requires a scanner or a transport capable of precise positioning. The speed of searching and scanning and the capabilities for selective reading govern throughput more so than the speed at which the paper moves.

The two basic modes of operation for OCR equipment are the direct read mode and the re-type mode. When the generation of source data can be closely controlled, i.e., type font used, quality of printing, size of document, etc., the direct read mode is used whereby source documents are read directly by OCR equipment. When the generation of source data cannot be controlled, the retype mode is used whereby some or all of the source data are retyped on standard pages using the appropriate type font.

D. <u>MIXED-MEDIA</u>:

This system consists of an OCR system operating in conjunction with a key-to-disc unit. The key-to-disc portion is used to correct optical reading errors. It is a standard commercially available system with special software for combining OCR and keyboard data. Most mixed media systems let the OCR portion of the system read input data. The key-to-disc portion of the system handles rejects from the OCR pass or source documents recorded in non-OCR readable font. The combining of keyboard-to-disc and optical readers into one data entry system represents the proper evolution in design of a complete data entry system. Such a system permits the user to re-enter via keyboard all OCR unreadable documents thus reducing significantly the total number of rejects.

E. VOICE INPUT:

Voice data entry permits the operator to converse with the computer in his most natural form of communication - voice. Reference 6 states that in a previous report, RADC conducted a study to compare voice input with keyboard and graph light pen methods of data entry. The results indicated that for certain types of applications, voice input offers considerable advantages over other means of data entry. In data entry tasks where the operators' hands/eyes are busy, voice input allow the operators to concentrate on that task instead of having their attention diverted by a keyboard or CRT terminal. Also, in some applications where operator movement is crucial, voice input provides the operator freedom of movement as the task requires. This reference also states that although there are considerable advantages of entering data by voice, limitations are imposed by such factors as speed, accuracy, environmental noise, operator experience and degree of hand/eye occupation.

Most of the work done to date on voice data entry has been on the highly restricted form of spoken input known as "isolated words". Single words are spoken in isolation with distinct pauses before and after each word which act as boundary markers to show where a word begins and ends. Then the pattern of speech wave between those time markers can be analyzed without having to consider the effects of surrounding words. Thus, machine recognition of isolated spoken words is similar to human recognition of typed or handwritten words separated by clear spaces. Machine recognition of continuous speech is more complex, and is analogous to human recognition of typed or handwritten sentences without having the appropriate spaces between words.

Just as different individuals have different handwriting, different speakers have different "voice signatures," such that from the standpoint of the machine the same words are expressed differently by different speakers. The equipment may be designed to handle only one speaker's voice, or to adapt to many voices; thus, a distinction is made between "speaker-dependent" and "speaker-independent" systems.

Reference 6 states that most of the automatic speech recognition systems in operation are speaker-dependent systems. Each speaker must "train" the system to recognize a particular speech pattern. Also, speech recognition is influenced by environmental noise among other things, i.e., variation in pronunciation due to tired vocals, emotions, etc. Therefore, most speech recognizers have confined their applications to carefully spoken isolated words in fairly quiet rooms; thus, easing the recognition task.

Although much progress has been made in the field of voice input technology, particularly continuous speech recognition, the need for further major improvements is required. The experts agree that the problem of voice input is not entirely solved. Where current technology offers several commercial devices for isolated word recognition, there are still "gaps" that must be filled before speech recognizers will achieve their full potential as tools for conversing with machines. Reference 6 provides a current status of the problems to be solved in the voice input technology area before this method of data entry can be efficient and effective. The problems are noted below:

1. Words must be spoken in isolation which cause a considerable reduction in speed as well as a loss of the "naturalness" of voice communications. Also, the problem of

connected speech recognition is extremely difficult and unlikely to be solved for larger vocabularies in the near future.

2. Intra-speaker and inter-speaker variability presents a major problem. Intra-speaker variability can cause recognition rates to decrease if each speaker's reference patterns are not updated periodically. Experiments have shown that voice characteristics change slowly with time. Inter-speaker variability requires that every speaker establish and use his own reference patterns. This has a direct impact on systems cost.

3. Other problems include a variation in speech pattern when an individual becomes annoyed, operator training and orientation, and a difference in speech pattern being used during vocabulary training of the machine and during actual use.

RADC/IRA has a laboratory director's fund effort underway. The objective of this effort is to investigate techniques of voice data entry using Automatic Speech Recognition (ASR) equipment in conjunction with other automatic data entry equipment, such as keyboards and dynamic character pens. The research will focus on methods of combining rather than comparing these automatic data entry aids to provide high data throughput, low system error rates and an efficient man-machine interface.

IV. SOURCE DATA AUTOMATION EQUIPMENT PROFILE:

A source data equipment entry guide was compiled by the Operations Research Division of the Air Force Data Systems Design Center located at Gunter AF Station AL (Reference 7). This document represents the most complete and comprehensive summary of the description of source data automation equipment discovered during the literature search and data collection phase of the study. Although the report was published approximately three to four years ago, it is felt that the performance of source data automation equipment has not changed substantially since that time; perhaps only the prices require adjusting due to inflation.

The Data Entry Guide is intended to serve as a reference for "state-of-the-art" Source Data Automation (SDA) equipment. The reader should be able to use this guide as the first step in selecting SDA equipment (i.e., choosing an equipment category that may offer a solution to his data entry problem).

The equipment profiles for the different SDA methods contain descriptions, characteristics, typical applications, and representative equipment. They present the basic information necessary to select equipment categories meeting the requirements of source data entry application.

The Data Entry Guide is divided into three chapters - Keyed Devices, Reader Devices, and Special Input Devices.

Each chapter is further subdivided into equipment categories or profiles (such as keyboard-to-disk, optical character readers, voice recognition systems, etc.). Within the equipment profiles, the following information is supplied:

A. A general description of the equipment category including its definition, characterisitcs, and options (normally available).

B. Operator requirements normally associated with the equipment.

C. A cost range for the equipment.

D. Typical applications of the equipment.

E. Advantages and disadvantages of the equipment.

F. A list of representative equipment including features and specifications.

The SDA document warns that the guide is not intended to supply comprehensive specifications for every data entry device (or system), but rather as a sample to introduce the reader to the types of SDA equipment available. It further cautions that when consideration is given to implementing a SDA System, attention should be given to all equipments available and not just the ones in the SDA document. There are several reference sources (such as Auerbach, Data Pro and Data Entry Today) which cover specific data entry devices in greater detail.

The SDA equipment guide is quite comprehensive. It is recommended that all potential procurers of SDA equipment obtain a copy of the guide from AFDSDC/DMB, Gunter AFS AL.

V. ECONOMIC CONSIDERATIONS:

A sizeable portion of the cost of a typical data processing operation is contained in the data entry area. References 1 and 2 indicate that the range of operating cost consumed in the data entry process can vary from 25 to 30 percent on the low end, and may go as high as 40 to 50 percent depending upon the specific application and system configurations. These estimates pertain to data processing installations in which the data is input via keyboard thus requiring a large number of operators and the associated labor cost. For keyboard entry methods, the operating cost is directly proportional to the data volume to be processed. For OCR methods, the relationship between operating cost and volume is not directly proportional to volume. Nevertheless, the basis for determining the cost effectiveness of a particular data entry method lies primarily in the volume of data to be input. As noted previously in the report, OCR systems are assuming a greater role in the data entry process whereas voice input is still largely developmental. Consequently, only keyboard entry and OCR techniques will be considered from an economical standpoint. In the majority of cases, OCR systems are used as a direct replacement for keypunching operations. Whether or not it would be cost-effective to convert to OCR cannot be answered satisfactorily without first examining the specific application, present cost incurred in data preparation, input accuracy requirements, and more importantly the volume requirements. Simple cost/performance comparison can be made between OCR and other methods of data entry by comparing labor and equipment costs. Reference 1 presents the following formula for making the evaluation:

$$F = \frac{a}{b+c} \text{ ; where}$$

F = number of character processed per dollar.

a = total characters processed per month

b = monthly equipment rental and overhead cost.

c = monthly personnel costs.

Since data entry system cost/performance is normally specified in terms of cost per character rather than character per cost, the reciprocal of the value "F" in the formula will be used to present the results of the following analysis which establishes an approximate relationship between the cost per character versus volume for keyboard entry and OCR systems.

In order to establish the above relationship for a typical keypunch operation, the following assumptions were made:

1. Operator Speed - 5,500 keystrokes per hour.

Reference 7 states that most sources (e.g. reference 10) rate the average keypunch operator at 10,000 keystrokes per hour on unbuffered devices and slightly higher on buffered devices. However, this speed does not take into consideration such factors as card and document handling, coffee breaks, error correction time, etc. These factors restrict the sustained average speed in a typical commercial application to approximately 5,500 keystrokes per hour. Use of double entry for purposes of verification is not considered.

2. Keypunch Rental Fee - $100 per month.

Reference 7 indicates a range of $35-$200 per month for lease of an unbuffered unit ($60-$260 for a buffered unit). Reference 10 which is a later reference (1977) indicates a keypunch rental fee of $90 per month.

3. Number of Operators - Variable.

The number of operators required to input the data is dependent upon the input volume. Therefore, a different number of operators will be required and subsequently computed for each input volume considered.

4. Operator Salary - $1,250 per month.

This estimate includes fringe benefits and overhead.

5. Number of Supervisors - 1

6. Supervisor Salary - $1,500 per month.

This estimate also includes fringe benefits and overhead.

7. Hours per Day - 7

8. Days per Month - 21

9. Characters per Document - 100

10. Input Volume - Variable

An input volume will be considerd which varies from 1,000 documents per day to 10,000 documents per day in increments of 1,000 documents per day.

Table I is a summary of all the calculations for the volume range considered. For a volume range of 1,000 documents per day, the following values were computed as noted below:

1. Number of Operators = $\dfrac{1000 \text{ Doc/Day} \times 100 \text{ Char/Doc}}{5500 \text{ Char/Hr} \times 7 \text{ Hr/Day}}$

2. "a" = 3 (operators) $\times 5500(^{Char}/_{Hr}) \times 21(^{Days}/_{Mo}) \times 7(^{Hr}/_{Day})$

3. "b" = 3 (stations) $\times ^{\$100}/_{Mo}$

4. "c" = 3 (operators) $\times ^{\$1250}/_{Mo} + 1$ (Supv.) $\times ^{\$1500}/_{Mo}$

5. $F = \dfrac{a}{b+c}$

In order to establish the relationship for a key-to-disc operation, the following assumptions were made:

1. Operator Speed - 7150 keystrokes per hour.

Reference 7 states that the sustained average speed over a long period of time for a key-to-disc operator is approximately 7,150 keystrokes per hour.

TABLE I - KEYPUNCH COST/PERFORMANCE DATA

VOLUME (DOC/DAY)	NO. OF OPERATORS	a CHARS/MO	b DOLLAR/MO	c DOLLAR/MO	F CHAR/DOLLAR	1/F DOLLAR/CHAR	1/F CENTS/CHAR
1,000	3	2,425,500	300	5,250	437	0.00228	0.228
2,000	5	4,042,500	500	7,750	490	0.00200	0.200
3,000	8	6,468,000	800	11,500	526	0.00190	0.190
4,000	10	8,085,000	1000	14,000	539	0.00186	0.186
5,000	13	10,510,500	1300	17,750	552	0.00181	0.181
6,000	16	12,936,000	1600	21,500	560	0.00178	0.178
7,000	18	14,553,000	1800	24,000	564	0.00177	0.177
8,000	21	16,978,500	2100	27,750	569	0.00175	0.175
9,000	23	18,595,500	2300	30,250	571	0.00175	0.175
10,000	26	21,021,000	2600	34,000	574	0.00174	0.174

2. Key-to-Disc Rental Fee -

Reference 7 indicates the following average lease cost per month per unit for shared processor systems:

4 Station System - $250.00 (Estimate)

8 Station System - $213.00

16 Station System - $158.00

The remaining assumptions made for the keypunch operation are also applicable for the key-to-disc operation. Table II is a summary of the calculations made for the key-to-disc operation.

In order to establish the relationship on OCR systems, the following assumptions were made:

1. OCR THRUPUT - 1,500 pages per hour

The thruput of a page reader is dependent upon the number of lines to be read and the number of fields within each line. Therefore, the rate obtained with any OCR device is a function of the design of the form and the device reading speed in characters per second. The above estimate was based on data contained in Reference 10. For both single and multifont machines, the OCR thruput was given as 1,330 pages per hour at 0.8 effectiveness, and assuming 200 characters per page. Since this analysis assumed only 100 characters per page, the above thruput estimate of 1,500 pages per hour is considered to be a conservative estimate.

TABLE II - KEY-TO-DISC COST/PERFORMANCE DATA

VOLUME	NO. OF	a	b	c	F	1/F	1/F
DOC/DAY	OPERATORS	CHARS/MO	DOLLAR/MO	DOLLAR/MO	CHAR/DOLLAR	DOLLAR/CHAR	CENTS/CHAR
1,000	2	2,102,100	500	4,000	467	0.00214	0.214
2,000	4	4,204,200	1,000	6,500	561	0.00178	0.178
3,000	6	6,306,300	1,500	9,000	601	0.00167	0.167
4,000	8	8,408,400	1,704	11,500	637	0.00157	0.157
5,000	10	10,510,500	2,130	14,000	652	0.00153	0.153
6,000	12	12,612,600	2,556	16,500	662	0.00151	0.151
7,000	14	14,714,700	2,982	19,000	669	0.00149	0.149
8,000	16	16,816,800	2,528	21,500	670	0.00143	0.143
9,000	18	18,918,900	2,844	24,000	705	0.00142	0.142
10,000	20	21,021,000	3,160	26,500	709	0.00141	0.141

In any case, it is still sufficient to handle the daily volume range considered in this study.

2. OCR RENTAL FEE

The data contained in Reference 10 is used as typical values for the rental cost of single and multifont page readers. This reference states that the monthly rental fee for a single font machine is $5,700 and the monthly fee for a multifont machine is $16,000.

The values of the other parameters are the same as in the previous cases. Tables III and IV contain the calculations for the single and multifont machines respectively.

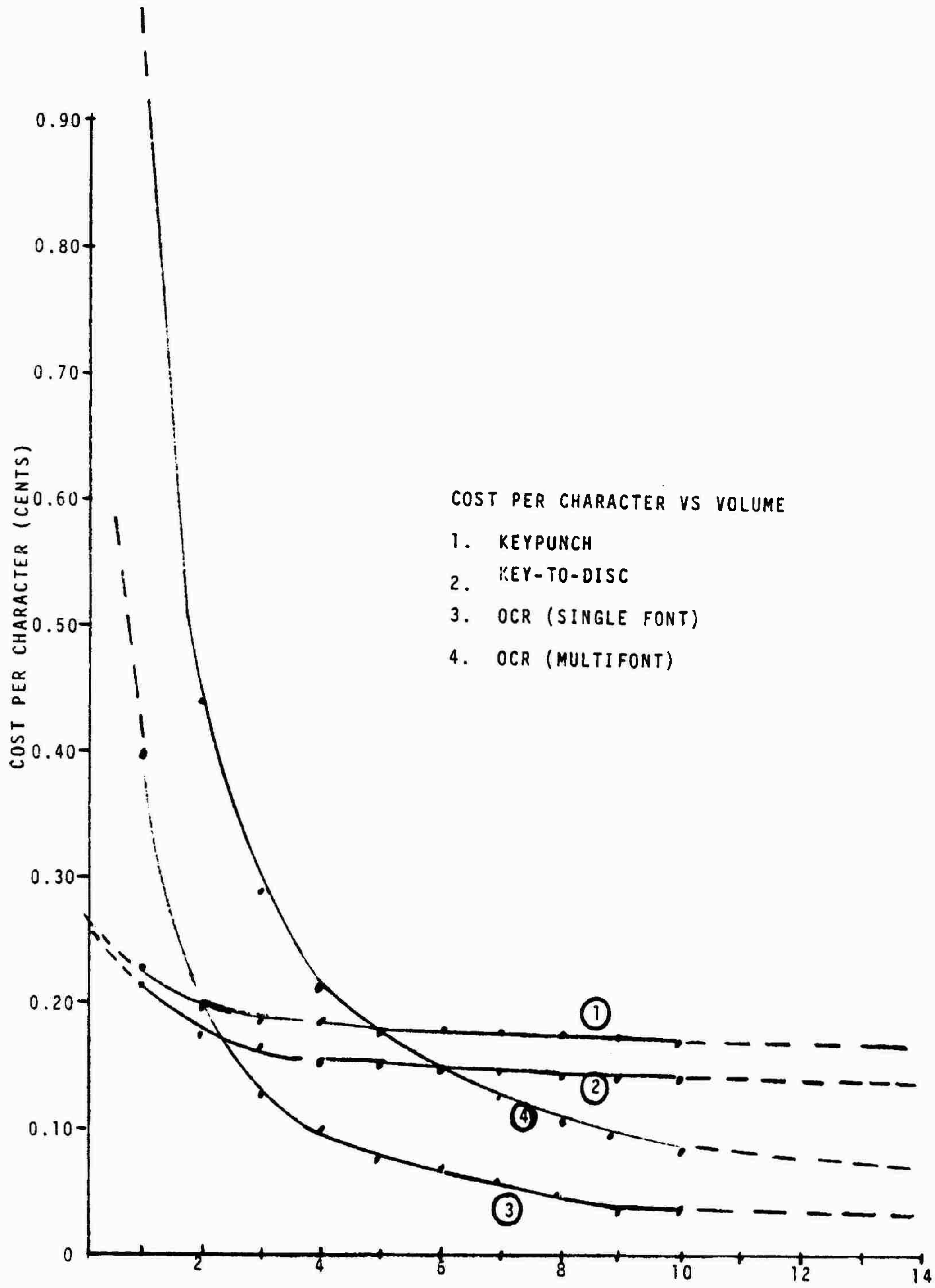
A graph depicting a comparison between these methods of data entry is shown in Figure 12. The results indicate that for low volumes (approximately 2,000 documents per day or less) the keypunch and key-to-disc data entry methods are more cost effective than either of the OCR devices. As noted in the figure, the cost per character processed via keypunch and key-to-disc is less than the cost per character processed on a single font OCR device (curve 3) for volumes less than 2,000 documents per day. The figure also indicates that for a multifont OCR device (curve 4), the breakeven volume when compared with the keypunch approach is approximately 5,000 documents per day. The break-even volume is approximately 6,000 documents per day when compared to a key-to-disc approach.

TABLE III - OCR (SINGLE FONT) COST/PERFORMANCE DATA

VOLUME	NO. OF	a	b	c	F	1/F	1/F	
DOC/DAY	STATIONS	$X10^3$						
1,000	1	2,100	5,700	2,750	249	0.0040	0.40	
2,000	1	4,200	5,700	2,750	497	0.0020	0.20	
3,000	1	6,300	5,700	2,750	746	0.0013	0.13	
4,000	1	8,400	5,700	2,750	994	0.0010	0.10	
5,000	1	10,500	5,700	2,750	1,243	0.0008	0.08	
6,000	1	12,600	5,700	2,750	1,491	0.0007	0.07	
7,000	1	14,700	5,700	2,750	1,740	0.0006	0.06	
8,000	1	16,800	5,700	2,750	1,988	0.0005	0.05	
9,000	1	18,900	5,700	2,750	2,237	0.0004	0.04	
10,000	1	21,000	5,700	2,750	2,485	0.0004	0.04	

TABLE IV - OCR (MULTIFONT) COST/PERFORMANCE DATA

VOLUME	NO. OF	a	b	c	F	1/F	1/F	
DOC/DAY	STATIONS	$X10^3$						
1,000	1	2,100	16,000	2,750	112	0.0089	0.89	
2,000	1	4,200	16,000	2,750	224	0.0044	0.44	
3,000	1	6,300	16,000	2,750	336	0.0029	0.29	
4,000	1	8,400	16,000	2,750	448	0.0022	0.22	
5,000	1	10,500	16,000	2,750	560	0.0018	0.18	
6,000	1	12,600	16,000	2,750	672	0.0015	0.15	
7,000	1	14,700	16,000	2,750	784	0.0013	0.13	
8,000	1	16,800	16,000	2,750	896	0.0011	0.11	
9,000	1	18,900	16,000	2,750	1,008	0.0010	0.10	
10,000	1	21,000	16,000	2,750	1,120	0.0009	0.09	



VOLUME (DOCUMENTS PER DAY X 10^3)

FIGURE 12

This difference is reasonable since the key-to-disc approach is more efficient than the keypunch approach. Consequently, a single font OCR device is more cost effective than keyboard entry methods (particularly keypunch and key-to-disc) in applications where the volume of characters to be processed exceeds 200,000 characters per day (2,000 documents per day x 100 characters per document). A multifont OCR is not cost effective until the volume of characters to be processed exceeds 600,000 characters per day (6,000 documents per day x 100 characters per document). Figure 13 shows the relationship between the monthly operating cost and volume for the various data entry methods. The monthly operating cost of keypunch and key-to-disc methods are directly proportional to the volume processed with the proportionality constant being slightly higher for the keypunch approach than for the key-to-disc approach. This figure also indicates that the monthly operating cost for both OCR devices is independent of volume (at least for the volume range considered). This relationship would hold until the volume requirements exceed the thruput capability of a single device. The acquisition of a second device would cause curves 3 and 4 of Figure 13 to be elevated to reflect the new operating cost. As expected, the break-even points for the monthly operating cost of the various data entry methods occur at the same volumes as noted in the

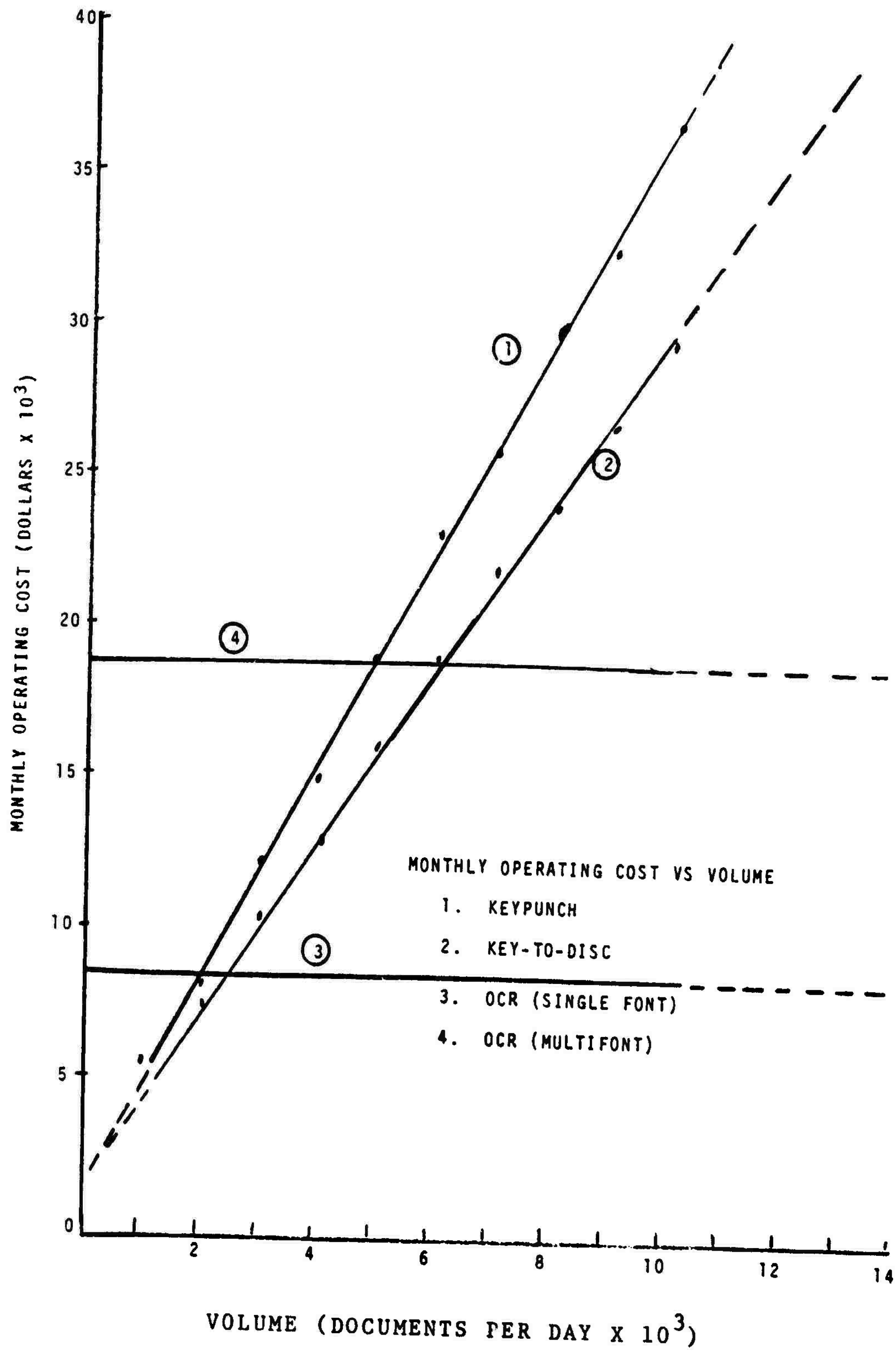

MONTHLY OPERATING COST (DOLLARS x 10³)
0
5
10
15
20
25
30
35
40
2
4
6
8
10
12
14
1
2
3
4
MONTHLY OPERATING COST VS VOLUME
1. KEYPUNCH
2. KEY-TO-DISC
3. OCR (SINGLE FONT)
4. OCR (MULTIFONT)
VOLUME (DOCUMENTS PER DAY X 10³)

FIGURE 13

previous discussion. The CRT terminal approach does not appear on the graphs of Figures 12 and 13. It is considered similar to the key-to-disc approach in that the CRT terminal would replace the keyboard in a key-to-disc system. The cost of this system would be somewhat higher since the hardware cost of the terminal should be more than the cost of a keyboard, and a more sophisticated software package is required. However, the data keystroking rate is approximately the same. Therefore, a curve reflecting the CRT terminal approach would fall somewhere between the keypunch and key-to-disc curves on Figures 12 and 13.

VI. SYSTEM CONCEPTS:

A discussion of Source Data Automation system concepts can best be accomplished by a consideration of the following factors:

SOURCE DOCUMENT CREATION - This process is typically accomplished by an operator typing in the required information in the appropriate data fields on pre-designed forms. Source document creation may also be accomplished (not necessarily cost effectively) in a manner similar to the process used by RADC/IS in the computer generation of Project Management (Johnson-Beers) forms. The software for the computer generation of the form on an Anderson-Jacobson printer is prestored. In addition, the software required for the identification of the various data fields for keyboard entry of the appropriate data during update is also stored in the computer system. This software facilitates the creation of a new form in addition to the update of a selected form.

DATA CAPTURE LOCATION - Data from the source documents may be captured at the location where the document was created, or at a central location. Therefore, in the former case, there would be as many data capture locations as there are source document locations, and in the latter, only one location would serve as the data capture facility.

SOURCE DOCUMENT TRANSFER - In cases where the data capture location is different from the location where the source document is created, the document must be transferred to the data capture location. This may be accomplished via the U.S. Postal Service or electronic transmission.

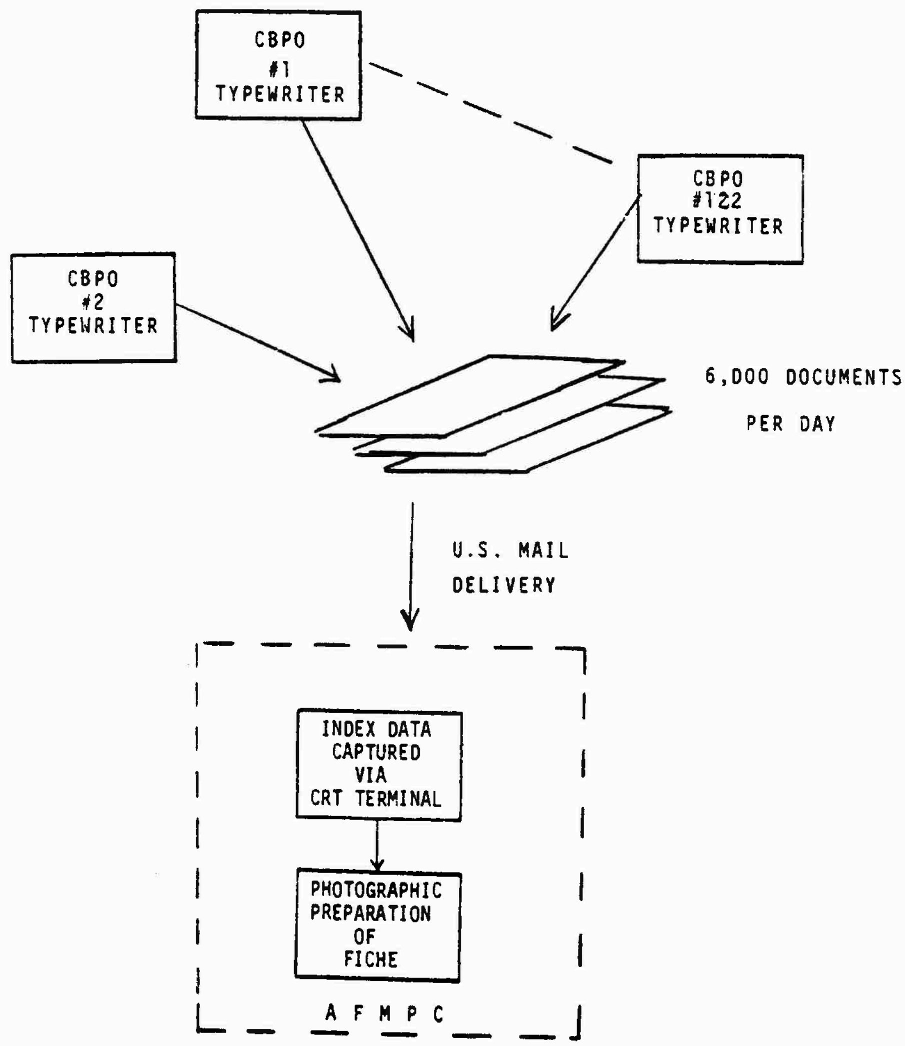
DATA TO BE CAPTURED - The type of data typically captured is source document index data. This data forms the basis of a digital index file which is used by the computer system to control the input and retrieval of all source documents in the document file.

DATA CAPTURE TECHNIQUES - Data from source documents may be captured either manually or automatically. Manual data capture typically involves an operator inputting system data via a keyboard. Automatic methods of data capture from source documents include the optical character recognition approach and voice input.

The existing AFMPC System will be described in order to provide a basis for comparison with other source data automation system concepts. Figure 14 depicts the concept of the existing system. Source (paper) documents are created at each of the 122 Consolidated Base Personnel Offices (CBPOs) in addition to other locations such as recruiting centers. The documents are created by an operator who types in the required information in the appropriate data fields of numerous predesigned forms with a standard typewriter. Reference 8 indicates the 257 different document types are authorized for entry into the microform personnel record. The amount of data typed on each document is a function of the purpose served by the document.

The data is captured from the source documents at the File Maintenance Facility located at AFMPC, Randolph AFB TX. Therefore, the documents created at the CBPOs are transferred to the AFMPC for processing via the US mail delivery service. The current estimate is that approximately 6,000 documents arrive daily at the AFMPC for updating the master records of extended active duty personnel and creating record files for new accessions.

The data captured at the File Maintenance Facility is the microform index data. This data is used to maintain an index file which is used to facilitate the search and retrieval of microfiche located in the microfiche file.



CONCEPT OF EXISTING SYSTEM

FIGURE 14

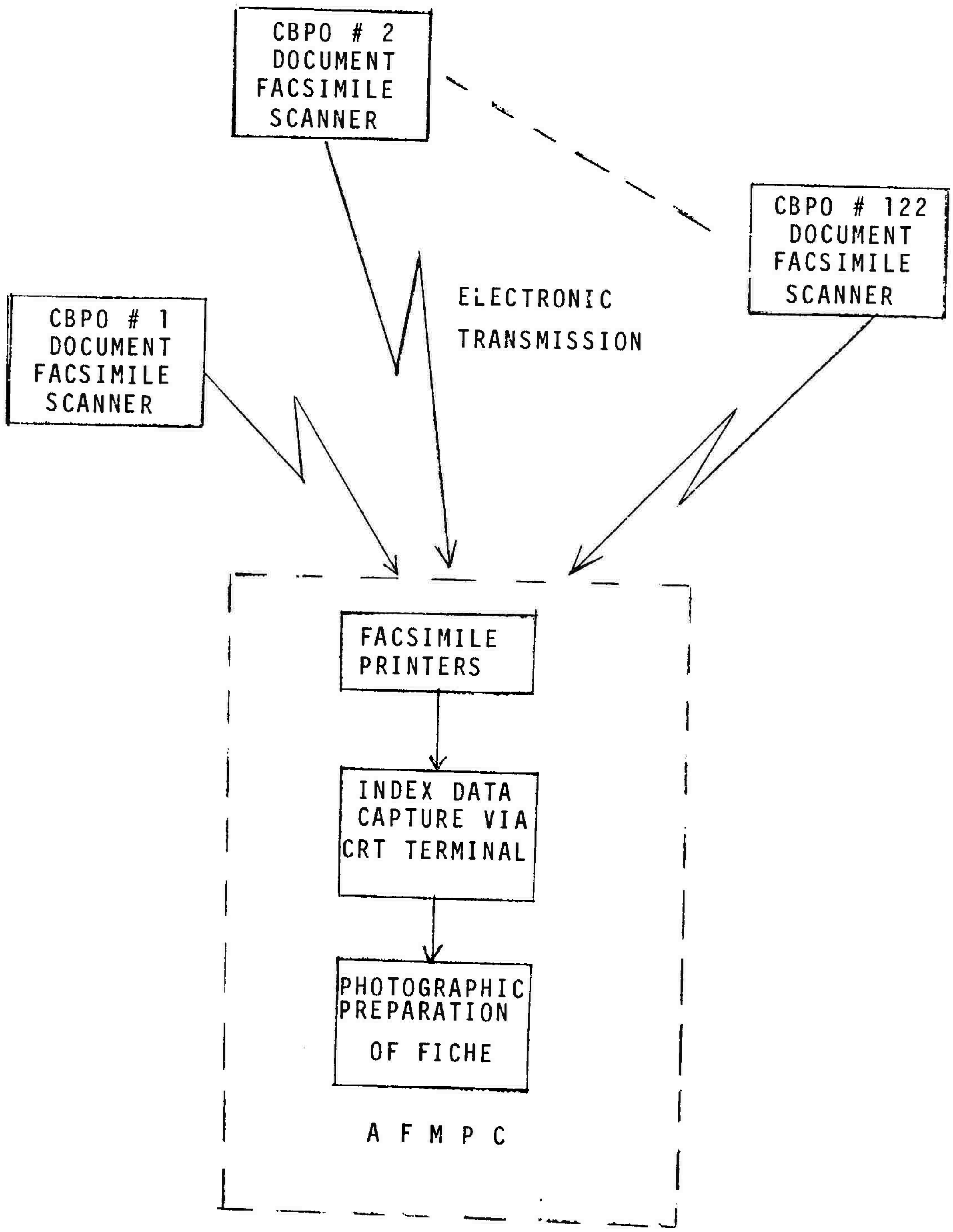
The data is captured via keyboard with a group of operators working in an on-line environment. CRT terminals are used to enter the index data into the system. Seven operators currently perform the indexing function and they have demonstrated their ability to handle the daily document volume during a single shift.

In summary, the microfiche file update process at the AFMPC File Maintenance Facility involves receiving update documents created at the various CBPOs and forwarded by U.S. Mail Delivery Service, extracting and entering the microform index data via a keyboard-to-storage technique which utilizes the CRT terminal, photographically recording the new document on film and automatically mounting the new document image on the appropriate fiche.

Four System Concepts are discussed. They represent a range of views. The first two concepts consider the automation of selected functions in the current system. Concept 1 discusses the document transfer function from the CBPOs to AFMPC and Concept 2 discusses index data capture at AFMPC. Although discussed as separate concepts, these two functions could have been combined and presented as a single concept. The last two concepts represent a more radical view in that the field paper record is eliminated. In Concept 3, a coded digital copy is substituted in its place. However, in Concept 4, the field record does not exist in any form and the data is provided by AFMPC.

CONCEPT 1 is depicted in Figure 15. It considers incorporating into the current system a higher degree of automation for the document transfer function from the CBPOs to AFMPC. The concept involves the creation of source documents at the CBPOs in the same manner as is currently done, the use of a document facsimile scanner to transmit the documents electronically to the AFMPC and a facsimile printer at the AFMPC for hard copy reproduction. The resulting paper documents would be processed as in the current system. This concept would eliminate the postal service time lag in delivery of the documents to AFMPC from the various CBPOs. However, there are two significant disadvantages associated with this concept. First, a significant cost in data communications and equipment is incurred, and second, the legibility of the small characters on the forms will be marginal on the hard copy reproduction.

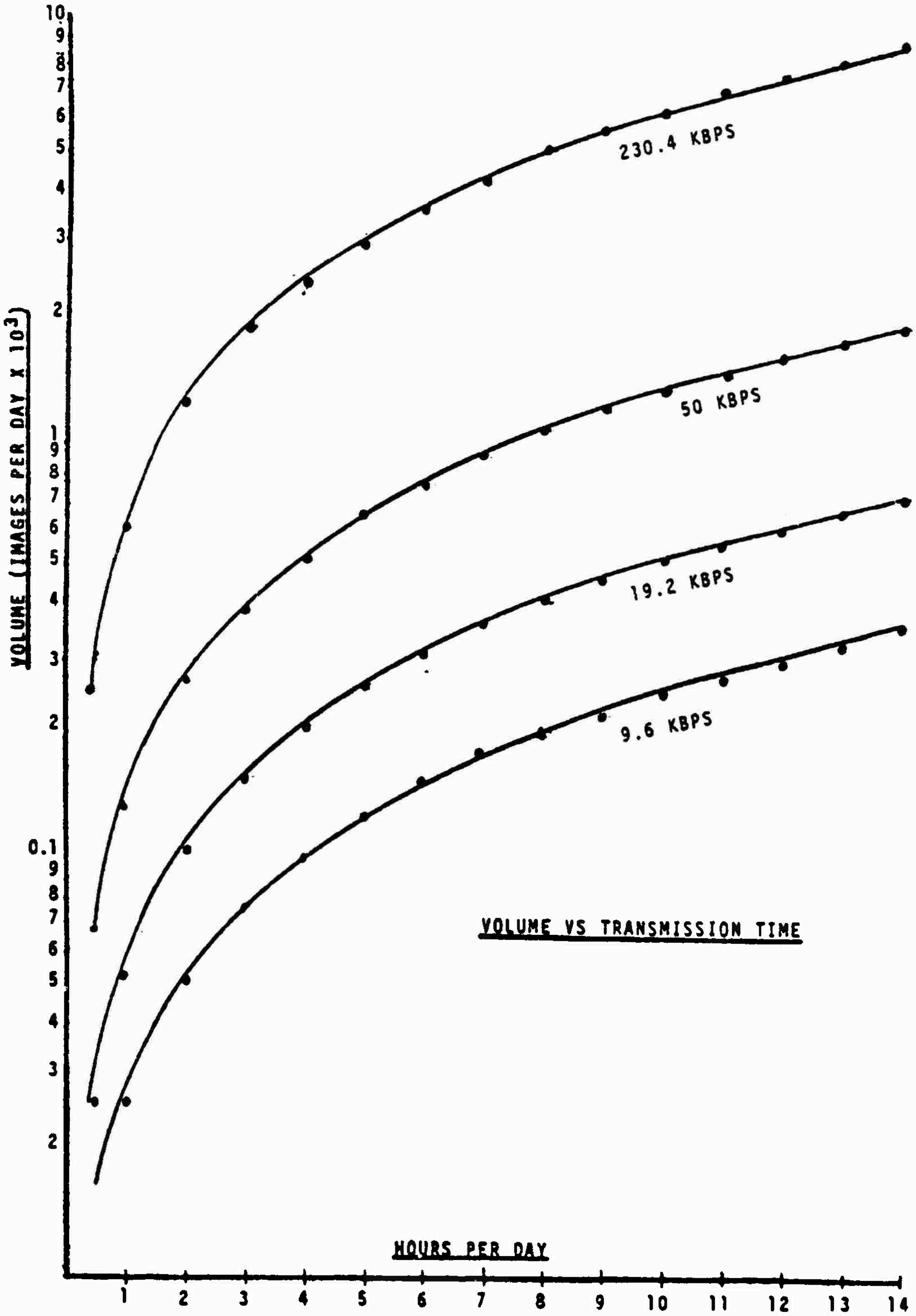
An estimate of the data communications cost incurred in this concept may be established from the volume of documents to be transmitted and the cost of the transmission link. The exact number of documents originating from the 122 CBPOs is not known. However, the current estimate is that approximately 6,000 documents arrive daily at the AFMPC to be used for updating the master personnel records of the extended active duty personnel and create record files for new accessions. This results in a daily average of approximately 50 documents



Concept No. 1

FIGURE 15

originating from each CBPO (a small percentage of the 6,000 documents originating from other sources such as recruiting offices, etc.). This represents an electronic traffic of 100 images (2 images per document) per day per CBPO. Based on Figure 16 which was taken from a previous study conducted by the author (Reference 9), a 9.6 KBPS line can transmit 100 images per day in four hours of actual transmission time. This graph presupposes that the 100 images have been scanned, compressed, stored as a contiguous block in a digital buffer, and transmitted without interruption. Considering a few seconds to load and unload each document, the total time is extended by only three minutes. Using a conversion factor of 21 days per month, the total hours of transmission time required per month is approximately 85 hours. Figure 17 which was also taken from Reference 9 indicates for a transmission time of 85 hours per month, it is more cost effective to lease a communications line. For purposes of estimating the monthly lease cost for a 122-CBPO network, an average distance of 1,000 miles between a CBPO and the AFMPC was used. Figure 18 (from Reference 9) indicates that the monthly lease cost for a 9.6 KBPS line at that distance is $1,300. Therefore, the monthly cost for 122 CBPOs would be $158,600. For comparative purposes, an estimate of the cost of postal delivery service can be established based on the current rates.



VOLUME (IMAGES PER DAY X 10^3)
10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
0.1
9
8
7
6
5
4
3
2
230.4 KBPS
50 KBPS
19.2 KBPS
9.6 KBPS
VOLUME VS TRANSMISSION TIME
HOURS PER DAY
1
2
3
4
5
6
7
8
9
10
11
12
13
14

FIGURE 16

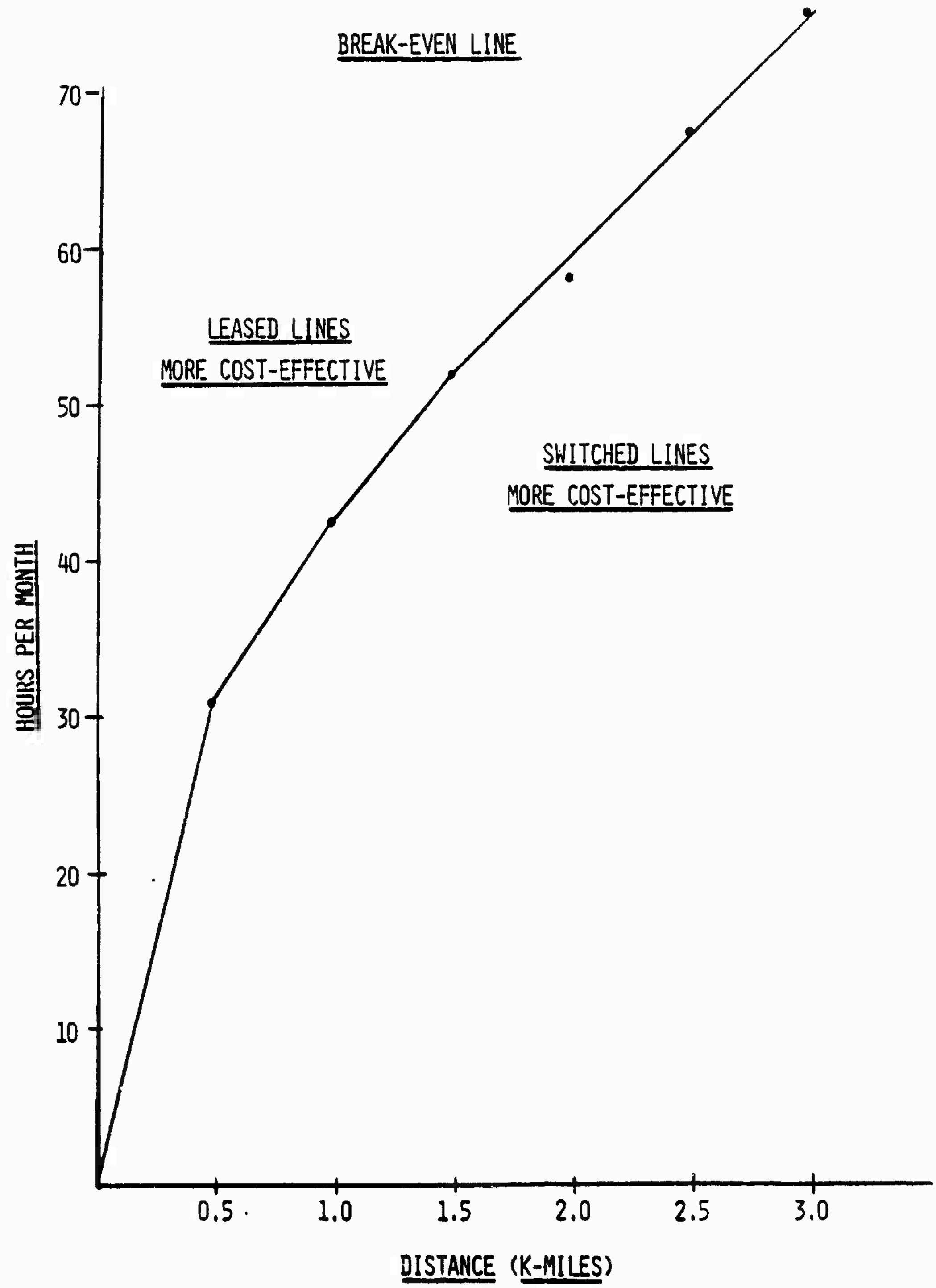
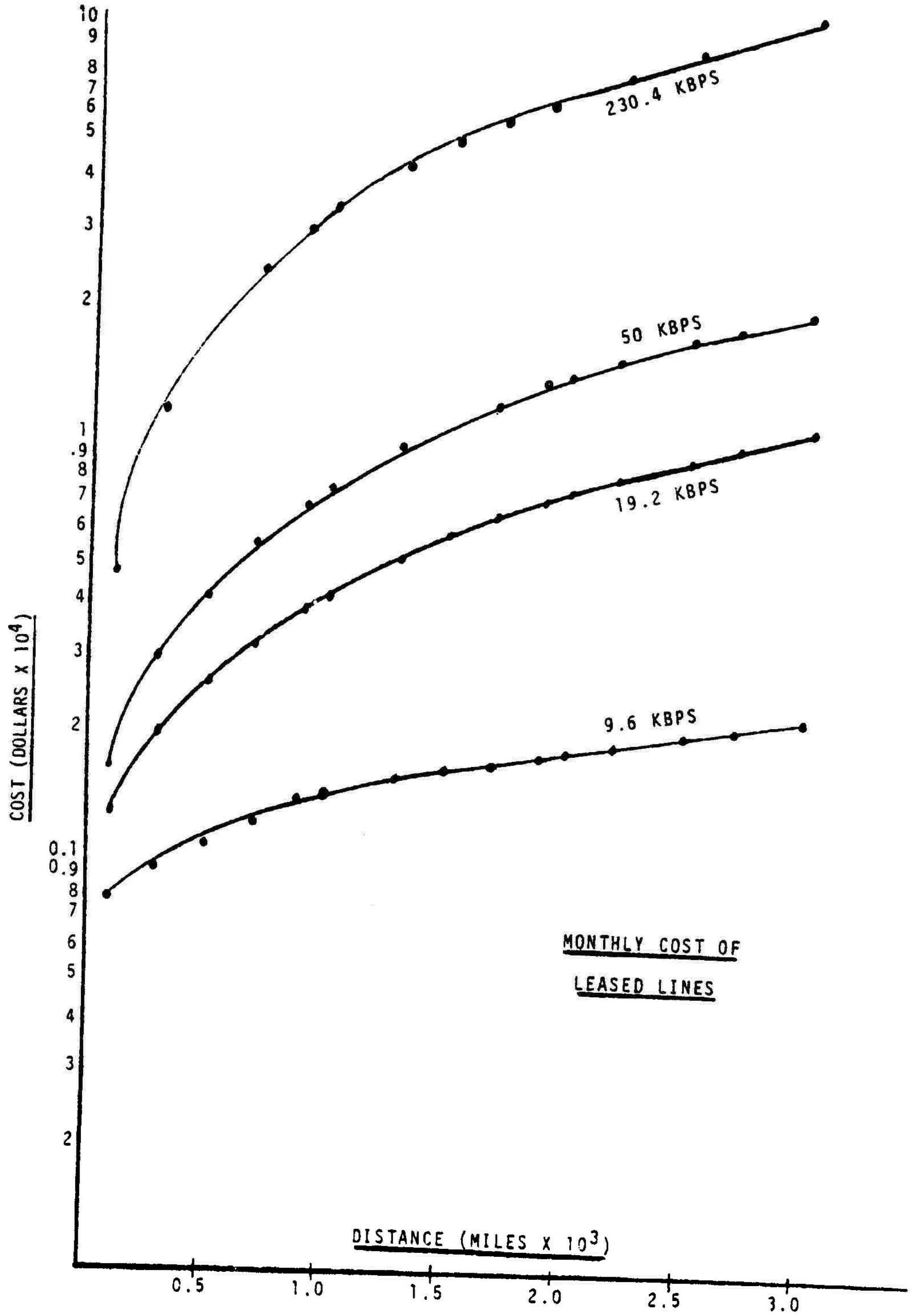

BREAK-EVEN LINE
LEASED LINES
MORE COST-EFFECTIVE
SWITCHED LINES
MORE COST-EFFECTIVE
HOURS PER MONTH
70
60
50
40
30
20
10
0.5
1.0
1.5
2.0
2.5
3.0
DISTANCE (K-MILES)

FIGURE 17



10
9
8
7
6
5
4
3
2
1
.9
8
7
6
5
4
3
2
0.1
0.9
8
7
6
5
4
3
2
COST (DOLLARS X 10^4)
230.4 KBPS
50 KBPS
19.2 KBPS
9.6 KBPS
MONTHLY COST OF
LEASED LINES
DISTANCE (MILES X 10^3)
0.5
1.0
1.5
2.0
2.5
3.0

FIGURE 18

U.S. Postal rates for first class mail are $0.15 for the first ounce and $0.13 for each additional ounce. Therefore, the cost (in dollars) of the postal service may be computed from the relationship:

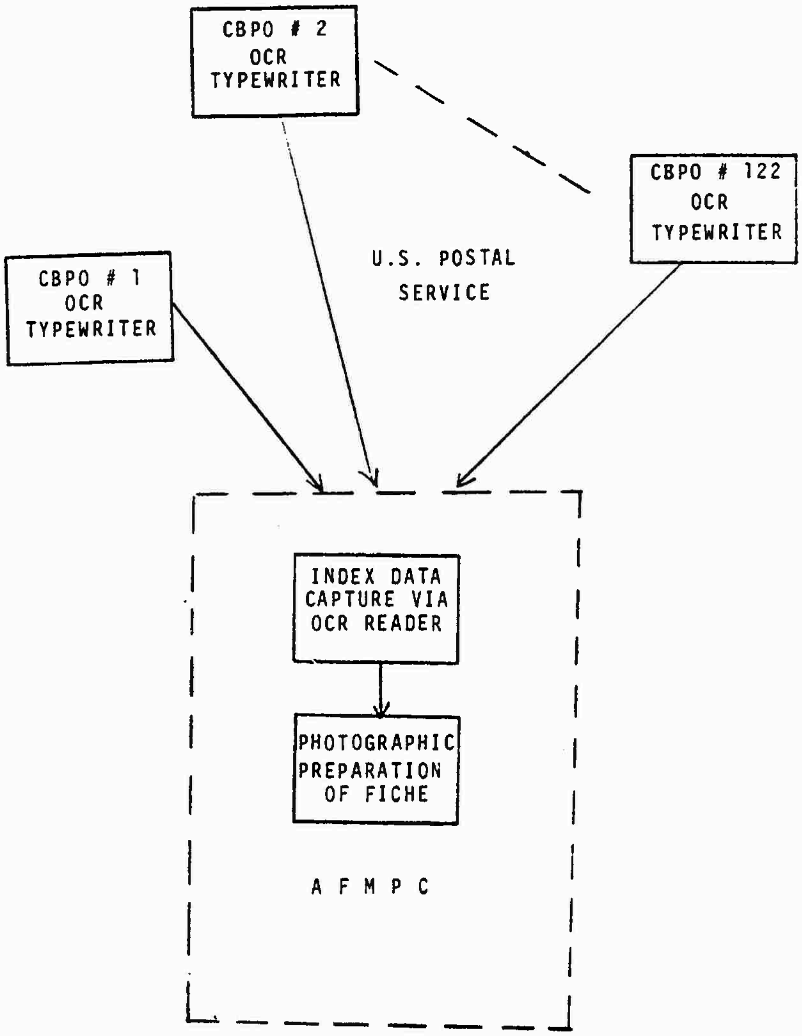
$$C = 0.15 + 0.13\,(n - 1)$$ where "n" equals the number of ounces

A document is estimated to weigh 0.2 ounces. Therefore, the estimated daily cost of postal delivery service for each CBPO to mail 50 documents is $1.32. Therefore, using 21 days per month, the monthly cost for all 122 CBPOs is $3,382.00.

The equipment cost estimate involves the cost of a document facsimile scanner at all the CBPOs, and the cost of document facsimile printers at the AFMPC. A cost estimate of $21,000 was used for the document scanner. This estimate was based on the price of a typical document scanner, e.g., model DDS 240 (240 lines per inch resolution), manufactured by Dest Data Corporation of Sunnyvale, CA. Therefore, the total cost estimate for 122 CBPOs is approximately $2.5 million. The estimate for the purchase price for a facsimile printer is $10,000 (based on GSA data on the DACOM printer.) A facsimile printer requires 90 to 120 seconds to produce hard copy document. Assuming a production requirement of 6,000 documents per day, 25 printers will be required at AFMPC to meet the daily workload. This results in a cost of $250,000.00. Therefore, the total equipment cost estimate is approximately $2.75 million.

The legibility deficiency associated with hard copy production was cited in the above mentioned study (Reference 9). The commercial facsimile printers available are adequate for reproducing typewritten letters where the character point size is in the neighborhood of eight points. However, for character sizes in the neighborhood of three to four point type, which is characteristic of the field identifiers on Air Force documents, the legibility of the hard copy products is at best marginal.

CONCEPT 2 is depicted in Figure 19. It considers incorporating a higher degree of automation for microform index data capture at the AFMPC File Maintenance Facility at Randolph AFB TX. This concept involves the creation of source documents at the CBPOs utilizing an OCR typewriter with a specialized OCR font, the transfer of those documents to the File Maintenance Facility at AFMPC via U.S. Postal Service, and the capture of microform index data via an OCR reader. This concept results in a minimum impact on the current system. A potential reduction in the number of operators would result since one OCR device is more than capable of handling the daily document volume. However, a major disadvantage associated with OCR technology is the

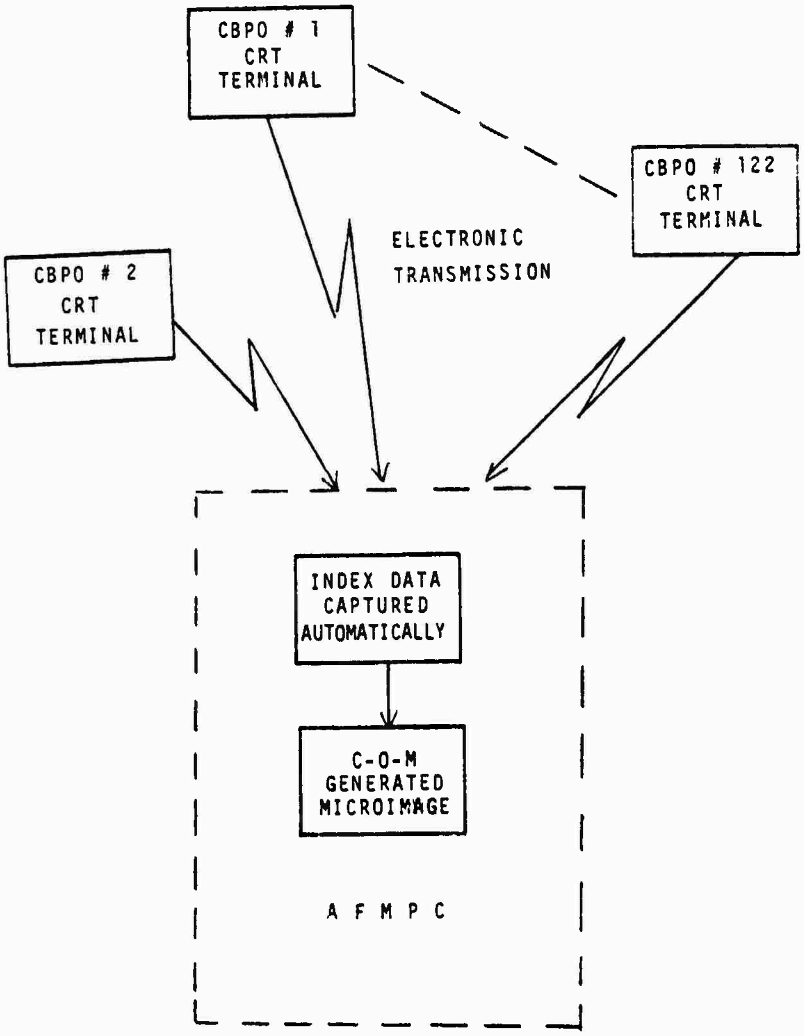


Concept No. 2

FIGURE 19

strict requirements and controls on forms, character set and font. A forms redesign with a specialized OCR font to facilitate the forms identification function, as well as a redesign of the data fields to facilitate the OCR scanning function would be required in order to incorporate this technology. The quality of input is critical to the success of the OCR device. Also, the restrictions on font, forms design and the document printer are necessary to obtain an acceptable thruput with a minimum of rejects due to "no reads," and more importantly, a minimum of substitute errors. The greater the extent to which the quality conditions and other restrictions are met, the simpler is the machine required. Therefore, a direct relationship exist between forms control and the price of an OCR device. Recall that in a previous section (Economic Considerations), it was stated that the monthly rental fee on a typical single font page reader was considered to be about $5,700.00. The author of Reference 10 from which this figure was taken is a representative of Recognition Equipment Inc. A recent telecon to Recognition Equipment Inc. (a leading manufacturer of OCR equipment) revealed that the purchase price of their single font page reader, model S80/88 is $235,300.00. This price represents a full-up configuration which includes two tape drives, a printer, a CRT terminal for re-entry of rejected data, a control computer, and a page numbering device. The above figure does not include maintenance. The monthly fee for maintenance would be $2,933.00. This telecon also revealed that the monthly rental fee for a three-year lease period ranges from $4,000 to $7,000 depending upon the equipment configuration. The five-year lease rental fee range is $3,200 to $6,500. The monthly rental fee includes the maintenance cost. The cross-over time for determining the cost effectiveness of an equipment purchase versus an equipment rental can be estimated by comparing the purchase price and monthly maintenance fee with the monthly rental fee. Based on an initial purchase price of $235,300 along with a monthly maintenance fee of $2,933, the cross-over time for that particular unit would be seven years when compared to a monthly rental fee of $5,700. Therefore, for an equipment life cycle of seven years or less, it appears that equipment rental is the more cost effective approach. If that time is significantly exceeded (e.g., 10 years or more), consideration should be given to equipment purchase.

CONCEPT 3 is depicted in Figure 20. This concept represents a radical departure from the current system in that the paper document is eliminated, and a coded digital version of the field record is retained at each field location for all assigned personnel. It involves the use of a CRT terminal



Concept No. 3

FIGURE 20

for "source document creation" at the CBPOs. All the background forms would be prestored in the system's mass storage unit. The operator, in conjunction with the CRT keyboard, would retrieve a specific background form and insert the appropriate information in the respective data fields. The data inserted in the data fields along with the data necessary to identify the form would then be transmitted electronically to the AFMPC. The output product at the AFMPC would be a microimage of all the transmitted images generated on computer-output-microfilm equipment.

The communications cost estimate for this concept was determined to be approximately 40 percent of the cost when transmitting in a facsimile mode as in Concept 1. Alphanumeric as opposed to facsimile transmission is employed. Unlike facsimile transmission, alphanumeric transmission is the transmission of the coded digital representation of the characters contained in the message. In facsimile transmission, the bit stream has no coded digital significance but rather each bit corresponds to a particular picture element in the original document. Alphanumeric transmission of alphanumeric data is significantly more efficient than facsimile transmission of alphanumeric data. For example, Reference 9 indicates that approximately one million bits are required to digitize a typical business document for transmission in a facsimile mode. Assuming the document contains about 300 characters and the digital code for each character consists of eight bits, the total number of bits in the coded digital representation of the data is 2,400 bits. Therefore, alphanumeric transmission of alphanumeric data is several orders of magnitude more efficient than facsimile transmission. However, for graphic data, pictorial data, or handwritten data (such as a person's signature), facsimile transmission is the more efficient if not the only transmission mode to be used.

The estimate of the data communications cost was established based on the quantity of bits to be transmitted. It is estimated that a CRT operator inputs an average of 80 to 100 characters per screen (document image). This corresponds to the data which is typed on the predesigned documents in the current system. Therefore, for 100 document images (50 documents front and back), the total number of bits to be transmitted per day on an average from each CBPO is 80,000 bits. The background data on the CRT screen which corresponds to the fixed data on the predesigned documents such as field identifiers is not transmitted. A low speed voice grade line (1200 bits per second) will suffice in meeting this daily traffic. Approximately 1.1 hours per day or 23 hours per month (using a conversion factor of 21 days per month) is required to meet the data load. Figure 17 indicates that for a distance of 300 miles or greater and a total transmission time of 23 hours per month, it is more cost effective to use the switched network than the leased lines. Figure 21 which was also taken from Reference 9 indicates that for a distance of approximately 1,000 miles and a daily transmission time of 1.1 hours, the cost for data communications is approximately $25.00 per day or $525.00 per month for each CBPO or $64,050.00 for all 122 CBPOs.

A reasonable cost estimate for the equipment could not be established. However, indications are that the cost will be significant. Factors which contributed to this situation are that the extensive software design cost is difficult to estimate based on a concept rather than a detailed system design and the mass storage unit required at each field location is estimated to cost at least $50,000.00.

In this concept, the "source document creation" function represents a sizeable software task. To produce a "software copy" of the multiplicity of complex forms currently used in the military personnel record for purposes of CRT terminal data entry will require extensive software development. It would appear that in order for this concept to be viable, a type of forms re-design would also be required as in the case of Concept 2. The objective of this forms re-design

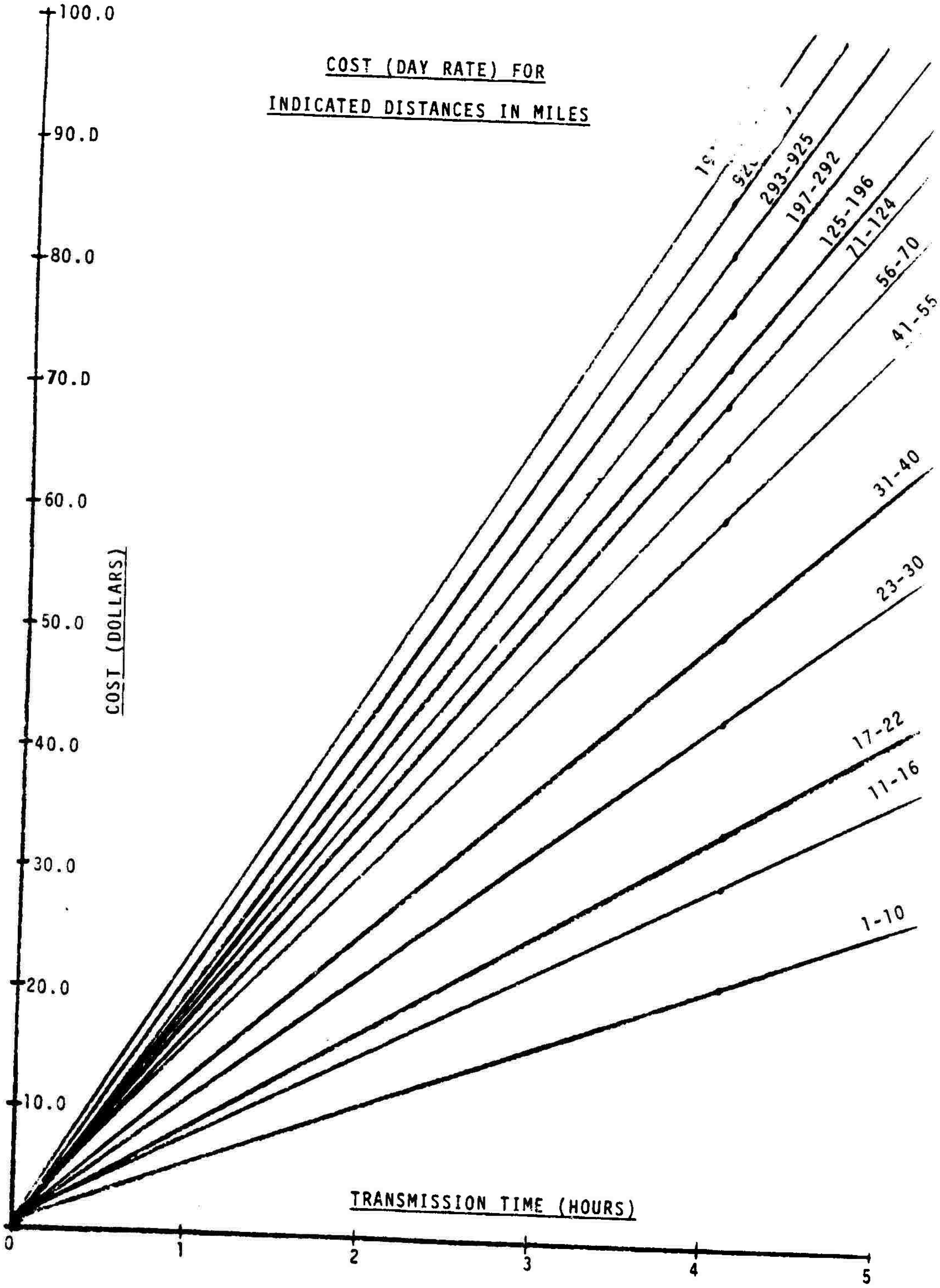

COST (DAY RATE) FOR
INDICATED DISTANCES IN MILES
COST (DOLLARS)
100.0
90.D
80.0
70.D
60.0
50.0
40.0
30.0
20.0
10.0
293-925
197-292
125-196
71-124
56-70
41-55
31-40
23-30
17-22
11-16
1-10
TRANSMISSION TIME (HOURS)
0
1
2
3
4
5

FIGURE 21

effort would be to reduce significantly the number of different types of document forms used and to simplify the document design. This would reduce the number and complexity of the different types of formatted screens that would have tc be generated for operator entry of selected data. One of the primary task performed at the CBPOs is the "records review" function. Therefore, in addition to the software required for source document creation, software must also be developed to provide the user the capability for conducting records reviews. Software development and/or modifications will also be required at the AFMPC to perform the automatic index data capture as well as other functions required to implement the concept.

The size estimate for the mass storage requirement at each CBPO was determined from data provided in Reference 11. The number of records maintained at the 122 CBPOs is 569,210 thus producing an average of 4,666 records per CBPO. Using a weighted average of four fiche per record for officers and airmen, and a weighted average of 13 images (pages) per fiche for both officers and airmen, an average of 150 characters per image and eight bits per character, the mass storage requirement estimate was 0.29 billion bits per CBPO.

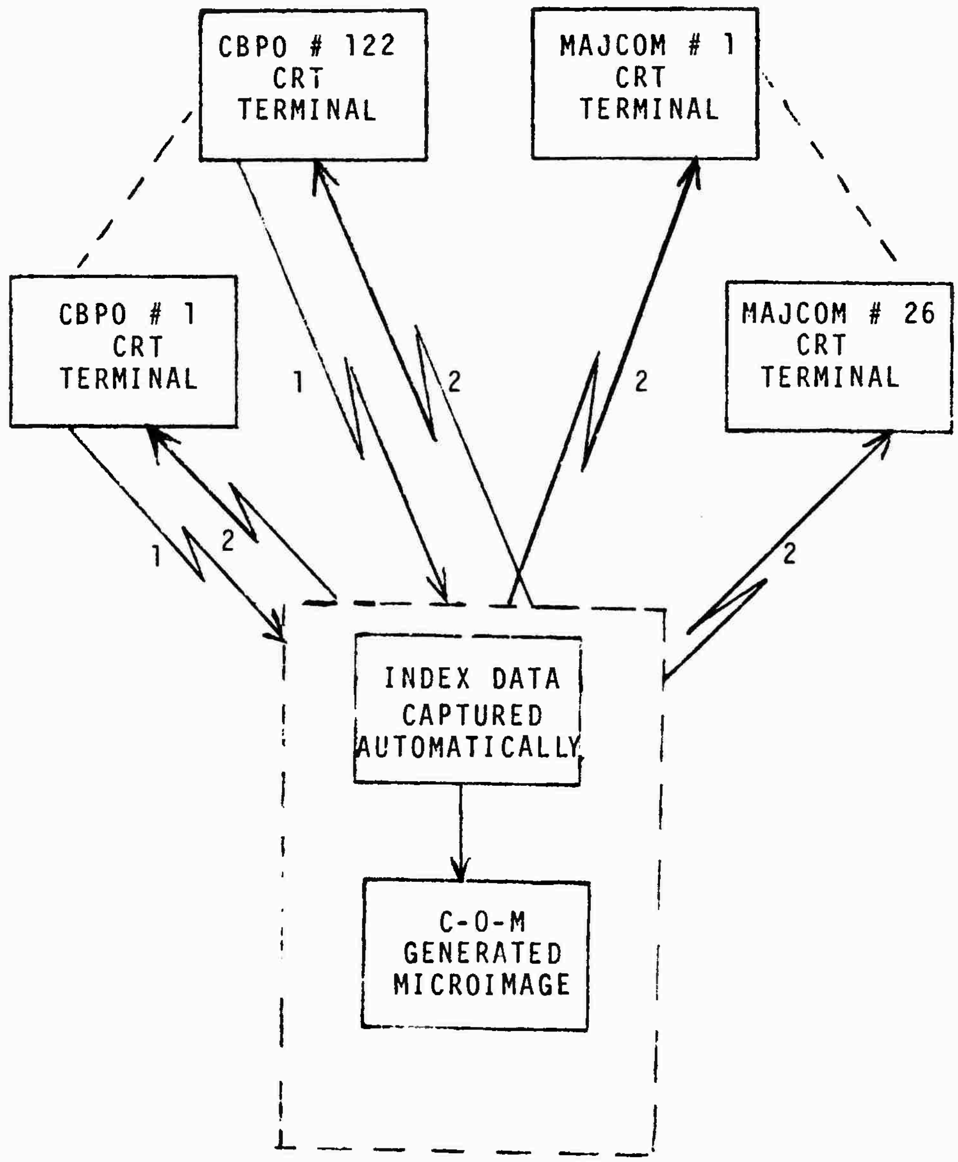
Recall that the two primary activities performed at the CBPOs are source document creation and records review. The primary activity at the MAJCOMS is records review. Therefore, the MAJCOMS were not considered in the previous estimates on up-date document flow since the bulk of the documents originate at the CBPOs. However, in discussing a concept in which the field record (paper or film) is eliminated and a coded digital version is substituted in its place, the mass storage requirement at the MAJCOMS must also be considered. The number of records maintained at the 26 major commands (MAJCOMS) is 95,753 thus producing an average of 3,683 records per MAJCOM. Using the same conversion factors, the mass storage requirement at each MAJCOM was 0.23 billion bits. These mass storage units are expected to cost at least $50,900 each. This estimate was based on the Digital Equipment Corporation System SM-30HHA-LA. This system consist of a dual RK07 cartridge disk-based PDP 1134A real time package. It includes the RSC-11 multi-user operating system, and a RK07 drive with a 28 megabyte (0.22 billion bits) storage capacity. Hardware maintenance cost for this system is $441.00 per month. Software support for this and other DEC Systems is provided on a per-call basis ($50 per hour, plus expenses), a weekly basis ($1,800 per week, plus expenses), for a six-month period ($5,500 per month) and for a 12-month period ($5,200 per month). A software support cost for at least one month will be included as part of the system costs ($7,200).

The CRT terminal is estimated to cost $15,000. It must be a high resolution device capable of displaying a full page document. A three-terminal configuration will be required at the CBPOs to support both the source document creation and records review functions. A two-terminal configuration should suffice at the MAJCOMS for records review.

An estimate of $137,500 was used as the cost of a computer-output-microfilm system. This estimate was based on the price of the Model 715 COM System manufactured by the 3M Company.

In summary, this concept involves each CBPO and MAJCOM retaining a coded digital record of all assigned personnel to facilitate the records review activity. It also involves the creation of source documents via CRT terminal at the CBPOs, the electronic transmission of those documents in an alphanumeric mode to the AFMPC for file update and the generation of a film strip of the update images via COM.

CONCEPT 4 which is depicted in Figure 22 indicates the relationship between this study and a previous study entitled, "Long Range Microimage Transmission Techniques Study for AFMPC," (Reference 9). In that study, a similar concept was considered in which the paper copies of the master record at the 26 MAJCOMS were eliminated. Further, no other form of the record was substituted in its place. CRT terminals were used to facilitate



1. UPDATE DATA
2. USER DATA

Concept No. 4

FIGURE 22

the records review and other user activity which involved the requests of data contained on microfiche from AFMPC. The requested data was provided to the 26 MAJCOMS via electronic transmission in a facsimile mode. Therefore, Concept 4 represents an extension of the concept discussed in the Long Range Microimage Transmission Techniques (LRMTT) Study. In this concept, data from AFMPC is provided to the 122 CBPOs in addition to the 26 MAJCOMS. One of the conclusions reached in that study was that the data communications cost between the 26 MAJCOMS and the AFMPC would be a significant factor in the recurring cost of the system. Consequently, the data communications cost in this concept will be exorbitant. Although the 122 CBPOs were not considered in the LRMTT Study, sufficient data was provided to estimate the data communications cost for a network which includes the 122 CBPOs in addition to the 26 MAJCOMS. Specifically, an estimate of the image traffic in support of the records review and other user activity was established for the CBPOs (as well as the MAJCOMS) in the Operational Requirements Section. The estimated average image traffic in response to user equests was 2,103 images per day for each CBPO. This consisted of 730 images per day of on-line traffic (corresponding to requests for which an immediate response is required) and 1,373 images per day of off-line traffic (corresponding to requests for which an immediate response is not required). The analysis conducted for the MAJCOMS in the LRMTT Study indicated that the user requests at each MAJCOM resulted in an image traffic of 835 images per day (290 on-line and 545 off-line). In order to satisfy these requests during a single shift operation, a 230.4 KBPS data link was required. Therefore, the on-line traffic portion (730 images per day) of the CBPO image traffic will require a similar link. Figure 18 indicates that the monthly lease cost for a 230.4 KBPS link transmitting over an average distance of 1,000 miles is approximately $35,000.00. Since the off-line requests do not require an immediate response, they may be satisfied via the U.S. Postal Service. The postal estimate for the off-line traffic was approximately $95.00 per month per CBPO. The estimate was based on the analysis used in the LRMTT Study for the MAJCOM off-line traffic along with the CBPO user request data provided in Reference 11. In the LRMTT Study, the monthly postal cost to satisfy 241 off-line requests per month at each MAJCOM was approximately $38.00. The off-line traffic for each of the 122 CBPOs corresponds to 604 requests per month. Therefore, the monthly postal cost for the CBPO off-line requests will be approximately $95.00. The total monthly cost of data communications via electronic transmission and the postal service for this concept is approximately $36,000 for each of the 122 CBPOs.

Whereas the 230.4 KBPS data link was required to satisfy the on-line requests during a single shift, a double shift operation would permit the user of a lower speed data link which would be less expensive. Figure 16 indicates that 50 KBPS data link can transmit the on-line CBPO traffic in a contiguous block in approximately six hours. However, as noted in the LRMTT Study, time will be required to retrieve the appropriate fiche from the file, load, and unload the scanner and scan the fiche. This operation will exceed a single shift. Figure 18 indicates that the monthly lease cost for a 50 KBPS data link transmitting a distance of 1,000 miles is approximately $7,000.00 per month. Therefore, the monthly cost of data communications using a 50 KBPS data link would be approximately $8,000 per CBPO (postal cost included).

In the LRMTT Study, cost estimates were also established for the equipment and manpower impact at AFMPC to implement a capability for responding to user requests from the 26 MAJCOMS. It becomes apparent that the cost estimates for the 122 CBPO network will be extreme. Due to the excessive cost indicated, this concept does not warrant any further discussion.

Table V is a summary of the monthly costs for the different concepts. All purchase costs have been distributed over an assumed equipment life span of 10 years in order to provide a common reference for comparison with monthly rental costs.

PARAMETERS	CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4
SOURCE DOCUMENT CREATION	TYPEWRITER	TYPEWRITER (OCR FONT)	CRT TERMINAL	CRT TERMINAL
DATA TRANSFER METHOD	ELEC. TRANSMISSION (FACSIMILE)	POSTAL DELIVERY	ELEC. TRANSMISSION (ALPHANUMERIC)	ELEC. TRANSMISSION (ALPHANUMERIC & FACSIMILE) AND POSTAL SERVICE
MONTHLY COST PER LOCATION	$ 1,300 PER CBPO	$28.00 PER CBPO	$525.00 PER CBPO	SEE NOTE 1
TOTAL MONTHLY COST	$158,600.00	$3,416.00	$64,000.00	
DATA REPRODUCTION	PAPER DOCUMENT RETAINED	PAPER DOCUMENT RETAINED	COM (FILM)	COM (FILM)
INDEX DATA CAPTURE	CRT TERMINAL	OCR	AUTOMATICALLY VIA COMPUTER	AUTOMATICALLY VIA COMPUTER
EQUIPMENT MONTHLY COST ESTIMATES				SEE NOTE 2
FACSIMILE SCANNERS	$ 21,350.00	N/A	N/A	
FACSIMILE PRINTERS	$ 2,083.00	N/A	N/A	N/A
OCR	N/A	$5,700.00	N/A	N/A
COM	N/A	N/A	$ 1,146.00	
MASS MEMORY SYSTEMS	N/A	N/A	$62,000.00	N/A
MAINTAINANCE				
HARDWARE			$65,268.00	
SOFTWARE			$ 8,800.00	
CRT TERMINALS	N/A	N/A	$52,250.00	
ADVANTAGES	1. ELIMINATES 3 TO 4 DAY TIME LAG. 2. CAPABILITY OF SIGNATURE CAPTURE.	1. REDUCTION IN NUMBER OF OPERATORS FOR INDEX DATA CAPTURE.	1. NO PAPER.	1. NO PAPER.
DISADVANTAGES	1. DATA COMMUNICATIONS COST VERY HIGH. 2. MARGINAL LEGIBILITY OF SMALL CHARACTERS.	1. REQUIRES FORMS RE-DESIGN.	1. EQUIPMENT & SOFTWARE DESIGN COST VERY HIGH. 2. DATA COMMUNICATIONS COST HIGH. 3. REQUIRES FORMS RE-DESIGN. 4. INABILITY TO CAPTURE SIGNATURE.	1. DATA COMMUNICATIONS COST IS EXORBITANT. 2. SOFTWARE DESIGN COST VERY HIGH. 3. REQUIRES FORMS RE-DESIGN. 4. INABILITY TO CAPTURE SIGNATURE.

NOTES: 1. The monthly cost of data communication is $36,000 for a single shift operation. If a double shift is used, the monthly cost estimate is $8,000.00.

2. The equipment cost at the CBPOs and MAJCOMS combined with the equipment and manpower cost impact at the AFMPC is too severe to warrant any further discussion.

TABLE V - SUMMARY OF CONCEPTS

VII. SUMMARY AND CONCLUSIONS:

There are numerous data entry devices and techniques that are provided by the current state-of-the-art in source data automation (SDA). These techniques range from the tried and proven method of operator keystroking of data via keyboard; to the optical reader devices which are currently assuming a greater share of the data input load, and voice input technology which is largely developmental and whose application is presently limited.

The selection of the most cost-effective source data automation method is accomplished primarily by examining the volume of data to be processed. For example, when considering the selection of a key-to-disc versus an OCR approach, the volume of data to be processed in conjunction with the number of fonts to be read determine which is the more cost-effective approach. For a multifont requirement, the break-even volume is approximately three times that for a single font requirement. This is due to the fact that the multifont OCR device is significantly more expensive than the single font unit. Therefore, as a general rule, OCR direct read may offer the greatest advantage in high volume situations. However, for low volume data input, key entry may offer the lowest cost based on the parameters analyzed and the system constraints selected. This is especially true if the hardware costs exceed the labor costs.

The current microform system contains a degree of automation in that the index data is captured via CRT terminals in an on-line environment. Consequently, the incorporation of any SDA technique(s) applicable to the microform system should provide a capability beyond that contained in the current system. The SDA techniques considered for automating selected functions of the microform system were found to have both advantages and disadvantages.

Concept 1 considered automating the document transfer function. Instead of forwarding the source documents created at the CBPOs to the AFMPC via the postal service, the documents would be transmitted electronically in a facsimile type of operation. A facsimile printer located at AFMPC would produce a paper document output which would be processed as in the current system. The advantages of this concept are that it can capture the signatures on the documents and it eliminates the three to four day time lag which is characteristic of the postal system. However, the cost of data communications will be significantly higher than the cost of document transfer in the current system, and the legibility of the small characters on the paper document which identify the various data fields will be marginal.

Concept 2 considered the use of an OCR device at the AFMPC facility for the capture of microform index data in conjunction with OCR typewriters with a specialized font for source document creation at the CBPOs. The processing speed of current OCR devices is such that only one device would be required to handle the daily workload of approximately 6,000 documents per day. This would result in a significant reduction in the seven operators now performing the function of index data capture using CRT terminals in an on-line environment. However, the chances of an OCR being successful as a means of inputting data in the microform system is dependent upon a redesign of all source document forms to facilitate an OCR device, and imposing tight restrictions and controls on quality during forms preparation. The greater the extent to which the quality conditions are met, the simpler is the machine required to achieve an acceptable reading performance, and excessive equipment cost may be avoided. The bureaucratic inertia associated with a forms redesign effort for DOD forms as well as Air Force forms appears as large and complex as the technological deficiencies which must be solved if indeed an OCR device is to be used successfully in the current environment without any forms redesign. Current assessment is that the successful utilization of OCR equipment as a data entry device will require a forms redesign and forms control in order to realize an acceptable throughput with a minimum of rejects due to "no reads," and more importantly, a minimum of substitute errors.

Concept 3 and Concept 4 represent a radical approach from a source data automation systems concept in that both considered the elimination of the paper record at the CBPOs and MAJCOMS. Both concepts have the two distinct disadvantages of being unable to capture the signatures that would ordinarily be on many of the original paper documents and both are extremely costly to implement and operate. A CRT terminal is used at the CBPOs for "source document creation." The data input by the operator is then transmitted electronically using a coded digital format typical of alphanumeric data transmission rather than the facsimile format. A sizable software effort is required to generate the document images at the CBPO. The software effort pertains to the applications programs required to duplicate the outline of the multiplicity of forms currently used in the personnel record, in order that the operator can enter the required data in the appropriate fields. A type of forms redesign to reduce significantly the number of different types of documents would reduce the number of formatted screens that would have to be generated for operator entry of data.

The difference between Concept 3 and Concept 4 is that in Concept 3 a coded digital copy of the record of all assigned personnel is substituted in place of the paper record at the CBPOs and MAJCOMS. Therefore, the major cost factor in Concept 3 is the cost of the mass storage systems required at each location. In Concept 4, no substitute is made for the paper record. The data requested in support of user activity is transmitted electronically from AFMPC to the respective CBPO or MAJCOM; thus, the major factor in this concept is the monthly data communications.

The SDA concepts discussed involve either a significant cost impact or a significant operational impact. The cost impact is associated with Concepts 1, 3 and 4. The operational impact resulting from a required forms redesign is associated with Concept 2. The impact of a forms redesign effort could be significantly reduced if only the high-use Air Force documents such as the selection folder material are redesigned. This would keep the effort within the Air Force and eliminate the requirement to involve DOD (and the other services) in the redesign decision process. It is very likely that the volume of high-use Air Force documents is sufficient to justify on a cost-effective basis the use of a single font OCR page reader. Although this concept appears to be the most viable of the concepts discussed (assuming a successful forms redesign), a thorough systems analysis should be performed to establish a more definitive systems concept from which more accurate cost estimates can be derived.

REFERENCES

(1) Auerbach Computer Technology Reports-1978-"Optical Character Recognition."

(2) Datapro Research Corporation, "How to Select and Use Data Entry Devices."

(3) Auerbach Computer Technology Reports 1978-"Key-to-Storage."

(4) L. Fedeilman and G. Bernstein, "Advances in Data Entry," Datamation, March 1973.

(5) E. H. Utley, "OCR in No Man's Land," Datamation, April, 1970.

(6) B. Beek, M. Manor, and J. Woodward, "Speaker Authentication and Voice Data Entry," 21st IEEE Midwest Symposium on Systems and Circuits, August 1978.

(7) Air Force Data Systems Design Center (DMB), Gunter AFS AL, "Source Data Entry Guide."

(8) PRC Image Data Systems Company, "Source Data Automation Requirements Study," October 1978.

(9) L. McDowell, "Long Range Microimage Transmission Techniques Study for AFMPC," RADC-TR-79-275, October 1979.

(10) H. F. Shantz, P.E., "Economic Consideration in Selection of OCR," Ocrua Summer Meeting, July 1977.

(11) PRC Image Data Systems Company, "Long Range Image Transfer System Requirements Study-Detailed Analysis," May 78.

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