riety of forms and purposes. The applications given are based upon conventional microfilming rather than computer output microfilming. A discussion with each application points out why the specific microform is most suitable to the specific application. In some cases, other microforms could have been used effectively but are typically uncommon.

A general flow chart is given for each application to assist in understanding it. For the sake of simplicity, however, not all detailed systems are illustrated.

16mm Roll Film Applications

Sixteen-millimeter microfilm is ideally suited for documents up to 12 by 18 inches in size. It offers lower recording cost, ease of handling, file integrity, and a variety of means for both indexing and locating specific images. It is economically reproduced, and a variety of equipment is available for its viewing and or printing.

Sixteen-millimeter roll microfilm has always been a popular format for business records. Rotary-type microfilm cameras provide reasonable quality at relatively high reduction ratios, and with automatic paper feeding, they provide the lowest possible microfilm cost per image.

Active Office Records. These systems are typically characterized by reduction ratios of 20 to 40:1, rotary camera microfilming, and use in only one location. They are often used for business records, such as checks, accounts-receivable ledger cards, shipment and receipt records, and general office files. When filmed in the duplex mode, both sides of the document can be microfilmed at the same time. With the duplex mode, the images appear in two tracks on the film requiring a higher than normal reduction ratio (approximately 32:1 to 40:1).

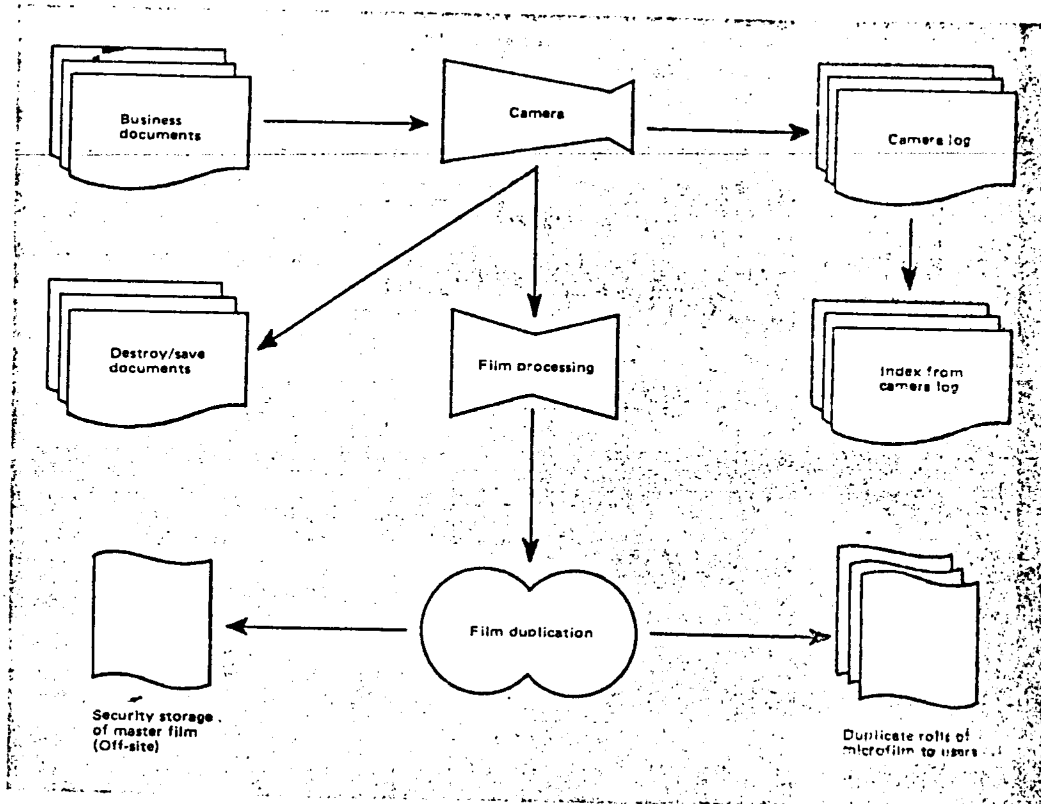
The use of these systems greatly reduces the bulk of records that must be stored in an office. Typically these microfilmed records require only occasional references. Document rearrangement required for the microfilm is usually minimal because most records have been arranged by serial number, by name, or by date. If a duplicate microfilm is made, it is usually for active use while the master is placed offsite for protection in a secure area. Figure 6 illustrates a typical 16mm roll film business records application.

Microfilm systems for business records are intended primarily to improve the use and handling of records rather than for archival storage. Higher reduction ratios are often used to reduce overall filming costs but with some loss of image quality. Reduction ratios are typically 24:1 or 32:1 but may run as high as 40:1 or even higher.

If archival retention of the microfilm is required because of permanent reference value of the records, a lower reduction ratio (e.g., 24:1) and archival processing and storage of the original silver halide microfilm is needed. In addition, more complete identifying and indexing information should be given at the beginning of the roll than is normally given in business applications.

Microfilm Jackets. In a 16mm jacket system, a copy of the roll film can be cut and the strips of microfilm inserted into the sleeves of a clear plastic jacket to make a unitized microform. The original of the roll film can be retained for security purposes. Unlike the microfiche, the jacket can be easily updated by inserting various frames or groups of frames produced as part of a continuing transaction. It has the advantage of low microfilming cost as in the 16mm roll system but combines information together into, in effect, a microfilm file folder. These advantages make it very popular with hospital microfilm systems for patient records. Following a patient's admittance or period of activity in the hospital, his records are microfilmed and added to his existing microfilm jacket. His patient number, which is permanently assigned to him, is used for indexing and filing the microfilm jacket. Upon

TYPICAL 16 mm ROLL FILM APPLICATION



Documents are microfilmed, the film processed and duplicated, the master stored off-site, and the documents either saved or destroyed. The camera log serves as an index for the microfilm system in this application.

Figure 6

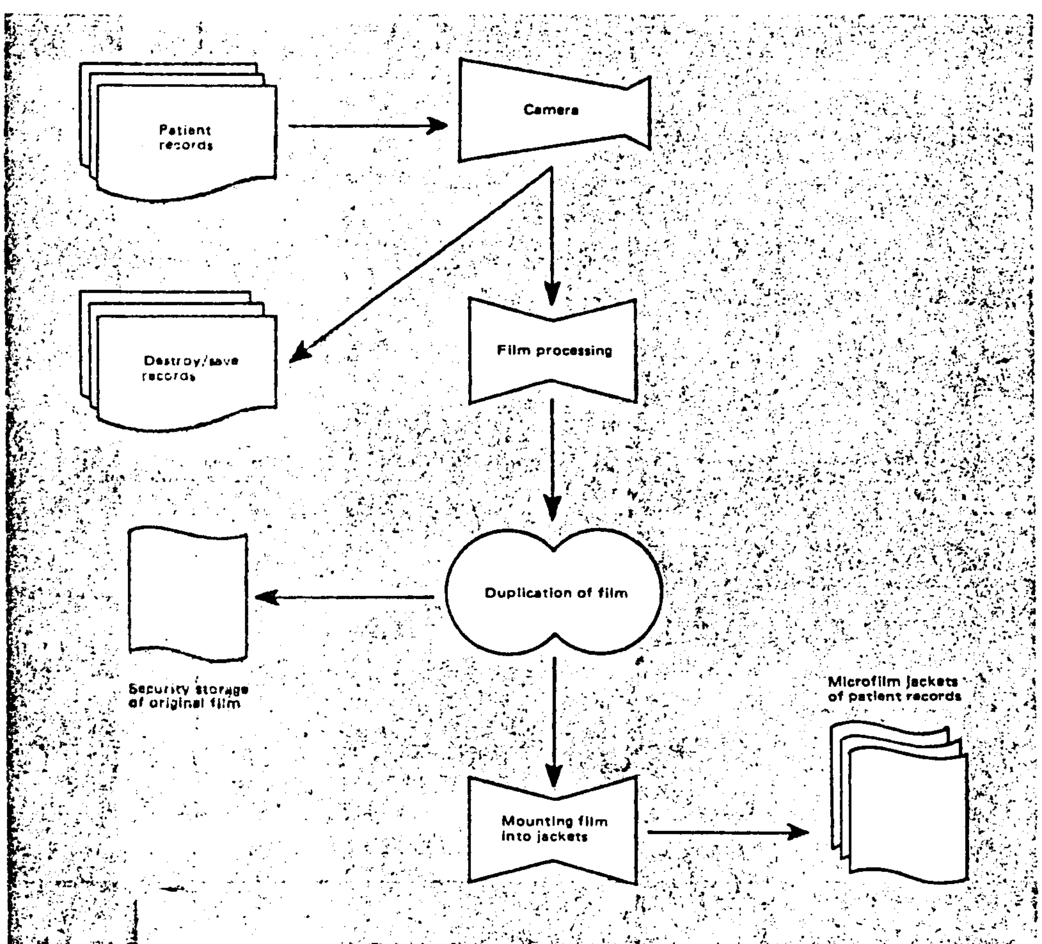
readmittance copies made from the microfilm jacket(s) may be placed in the patient's current admittance jacket, which provides the physician and hospital staff with immediate access to the patient's previous record. Figure 7 depicts such a jacket system.

The major disadvantage of this system is the time and cost involved in loading the individual microfilm frames or strips into the microfilm jackets. In addition, some image quality is lost in preparing duplicate copies of the master microfilm jacket for reference use.

Archival Microfilm Applications (16/35mm Roll Film)

An essential requisite for archival systems is preserving the image quality of the archival documents. Accordingly, low reduction ratios (14:1 - 18:1) are usually used with planetary microfilm cameras, and the film is processed and stored according to archival specifications. A major advantage of archival microfilming of important records is that once an entire collection is microfilmed it is readily reproducible. Because the purpose of the microfilming is to preserve the records for an undetermined period, careful identification of the records, sources, physical locations, dates of original generation, and other pertinent facts should be microfilmed at the beginning of the roll. An internal index is also helpful if it is placed at the beginning of the roll. This index may be made by grouping the material to be microfilmed into convenient sections or classifications, assigning a number to each section, and then using a flashcard to indicate each section. If other external indexes or tables of contents are used, their locations should be indicated by flashcard frames. Figure 8 provides an example of an archival system.

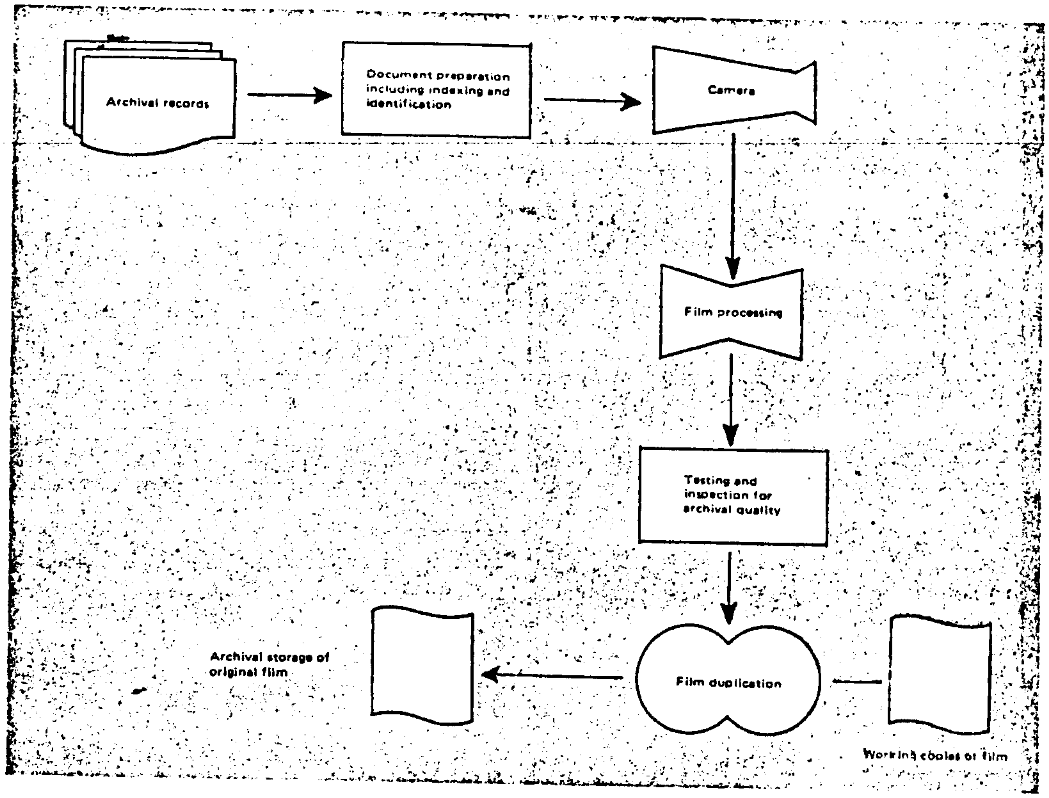
MICROFILM JACKET SYSTEM FOR PATIENT RECORDS



Hospital patient records are microfilmed, and, after processing, a copy of the roll film is cut up and inserted as strips into the patients' microfilm jacket, while the original of the roll film is stored for security purposes.

Figure 7

MICROFILMING ARCHIVAL RECORDS



Records are carefully identified, indexed as necessary, and then microfilmed. The original film is tested and inspected to insure archival quality prior to storage, and then duplicated to produce working copies.

Figure 8

Micropublishing and Library Applications

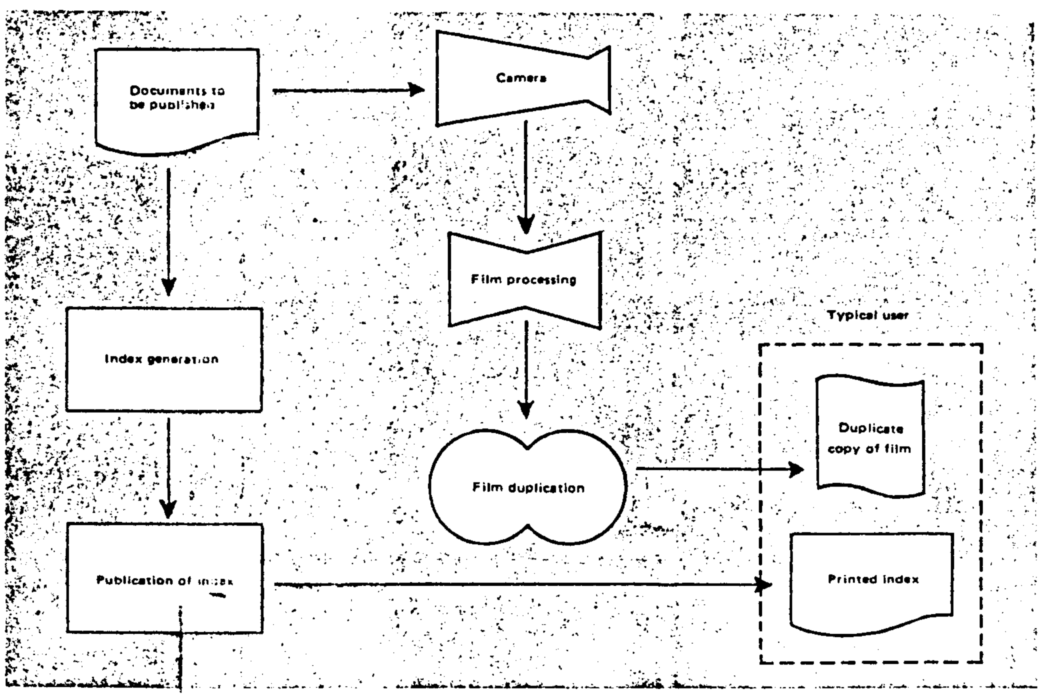
Micropublishing systems are primarily intended to replace the original paper copy with a microform copy or to provide a microform when no other alternative paper form exists. Such systems enable economical distribution of information, such as scientific and technical research records, military specifications, or manufacturers' catalog systems, and provide copies of records not otherwise available, such as historical newspapers or rare out-of-print books. In these cases the microform provides a low-cost means of reproducing large masses of information and distributing the information to many locations. Figure 9 depicts the steps of a typical roll film micropublishing application.

Several kinds of systems are typically found in these applications. In the case of newspapers, historical and current, reproduction masters (intermediates) made from the first generation silver microfilm are used to produce additional 35mm rolls of microfilm for distribution to various customers. The indexing is by date, or, in the case of arge national newspapers, such as *The New York Times*, a separate index to the volume, late, and page is available. The rationale of these systems is to justify the cost of original microfilming through duplication and distribution to a great number of users, as unit costs are reduced when many copies are made.

Roll Film. Micropublishing of highly active locuments is also common. More than 30,000 nilitary and Federal specifications and tandards, continually subject to change and updating are available from commercial micropublishers. In one such system the pecifications are microfilmed at random and are located by using various roll film retrieval methods for 16mm cartridge microfilm. Subscribers to the system periodically receive updated microfilms containing new and revised specifications. This system requires preparation of new indexes for each updating, and the user can locate either the older or the latest specification version. In other 16mm cartridge systems for specifications and standards, the material is arranged by Federal Supply Service classification groupings and updated by replacement cartridges containing internal indexes to the individual specifications and standards.

Microfiche. The 105mm by 148.75mm (or nominally 4 by 6 inches) microfiche is widely used for technical document systems where the document contains multiple pages (usually more than 20) and where there are multiple users of the documents. While 16mm film is usually issued only in roll-

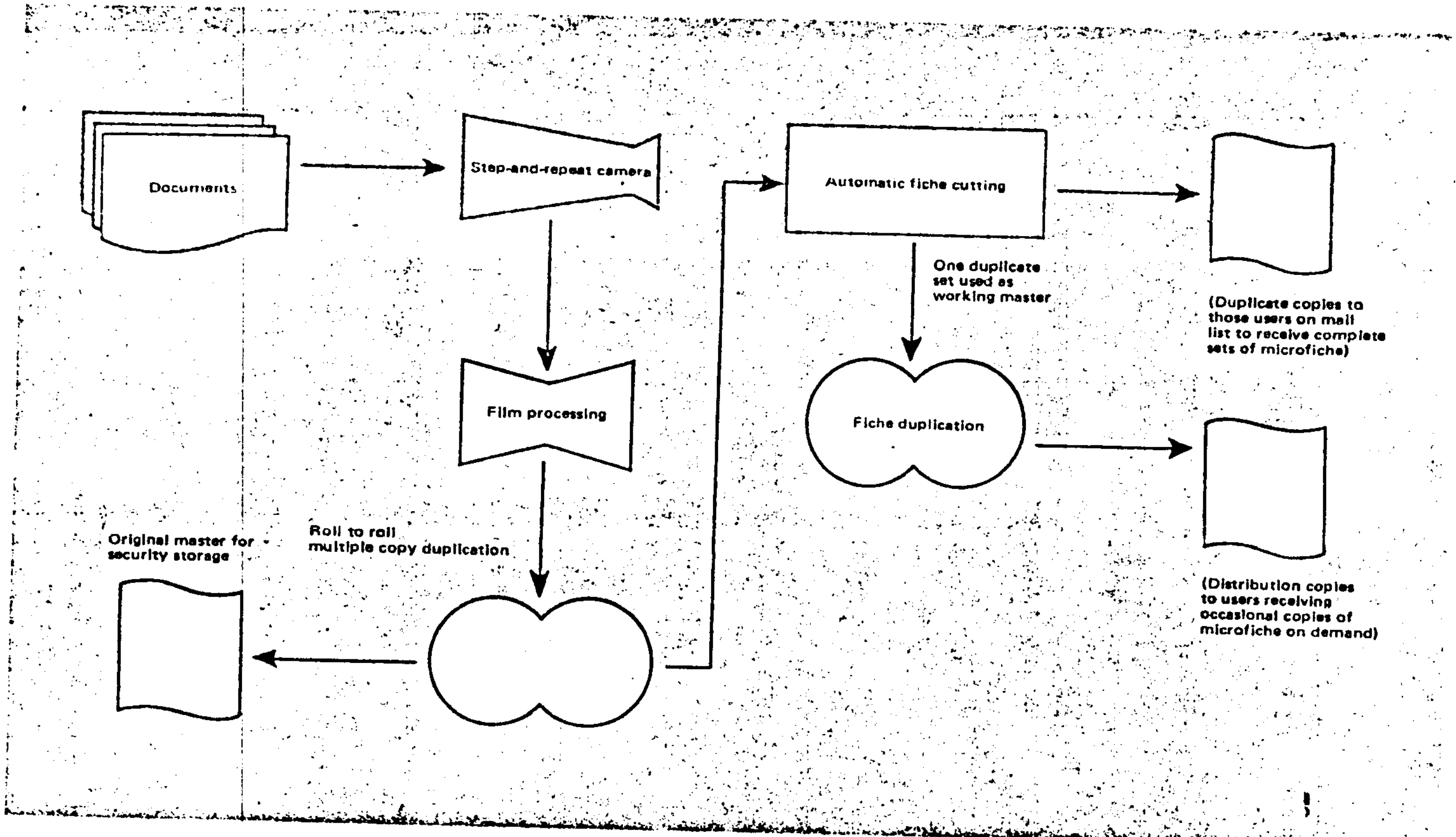
ROLL FILM MICROPUBLISHING APPLICATION



Detailed indexes are typically printed to serve as a contents guide to the microform package the user receives.

Figure 9

MICROFICHE MICROPUBLISHING APPLICATION



The step-and-repeat camera produces 105mm roll microfilm which is duplicated as roll-to-roll film. Individual sets are automatically cut for mailing list distribution. Any of these duplicate microfiche can serve as a master for on-demand duplication for occasional users.

Figure 10

length quantities, a microfiche of a 98-page document is reproduced and issued as a single sheet, thereby making it attractive in those situations that require various distributions of particular documents of a large collection. If a document is updated, a new microfiche is usually distributed to users to replace the obsolete document microfiche. If a user informs the central microfiche service of the types of documents in which he has an interest, automatic distribution of documents matching his interests can be accomplished to provide selective dissemination of information (SDI). (See fig. 10.)

The National Technical Information Service, Department of Commerce, microfilms and provides microfiche or paper copies of many of the technical reports produced by Government agencies. The Department of Defense, the Office of Education, the Atomic Energy Commission, and the National Aeronautics and Space Administration also have their own microfiche services to promote the wide and economical dissemination of technical information recorded on microfiche.

Micro-Opaques. A microform commonly found in older library collections is the micro-opaque, usually a 3- by 5-inch plastic or paper card with positive microimages. Micro-opaques were one of the first popular micropublishing formats, particularly desirable in library applications because they are easily handled and filed. They are, however, being replaced by other microforms.

MICROPUBLISHING WITH ULTRAFICHE

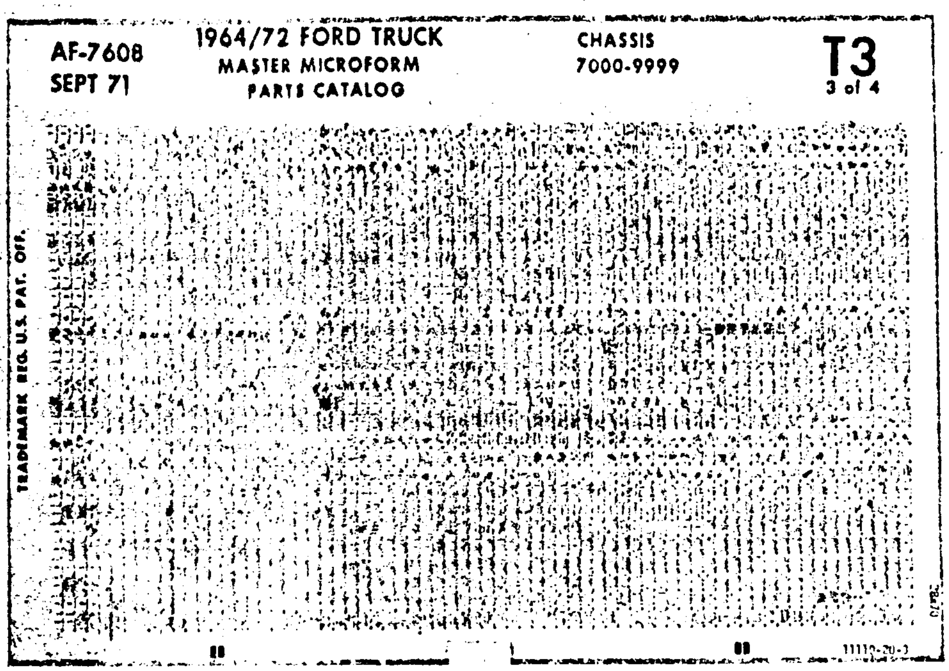


Figure 11

Ultrafiche. Packing more than 3,000 pages on a single 4- by 6-inch microfiche, which can be reproduced for less than a dollar, can solve updating problems in situations involving catalog-type information maintained by many different users and which must be updated periodically. The entire data base can be recorded on a relatively few ultrafiche, and periodically a complete updated version of the data base can be distributed on revised ultrafiche to the many catalog users. A typical application of this technology has been the Ford Motor Co. parts catalog, which is used by thousands of shop mechanics to identify appropriate parts from various models of Ford automobiles. Figure 11 depicts one of the seven ultrafiche, which together contain the information on more than 14,000 pages of parts catalogs. The key requirement for an economical ultrafiche system is a great number of reproductions made from the master ultrafiche. Because of the high cost of preparing the master and the relatively high cost of the viewing equipment, ultrafiche is seldom used in any other kind of application.

A unique indexing system is typically used with ultrafiche. The entire data base is grouped into a dozen or so ultrafiche. The user selects the appropriate ultrafiche and, placing it in the viewer, selects any frame at random. All frames on a particular ultrafiche contain the same index information at the top of every frame. This index information directs the user to the proper row for the kind of information he desires. Each row represents a general class of information within the ultrafiche. Every frame contains a second index along the side of the image, and this index is peculiar to the row in which it is contained. Selecting any column within the specific row, the user is then further directed to the proper column by referring to the vertical index in that row.

The indexing system is a series of successive approximations. The first is to the fiche in general, then to the row, and then to the column. The advantages of this system are its simplicity in usage, especially beneficial where a widespread untrained group of people use the system, and the ease of maintaining updated collections.

Engineering Drawing Applications

Thirty-five-millimeter microfilm provides the film area required for large engineering drawings. The cutting and mounting of the film into aperture cards (tab-sized cards) provides a convenient carrier for the chip of microfilm in addition to providing a means of labeling and identifying the engineering drawing number and other pertinent data. Since an aperture card is basically a unit microform, individual drawings can be selected for reference purposes. In addition, master aperture cards are easily assembled into a deck for further reproduction to produce additional aperture card decks. These decks can then be used for preparing documentation for bids, and they result in great savings when compared to the costs of producing full-sized engineering drawings for bid purposes.

Small viewers that magnify the image to half the original size are often used with engineering drawing systems because only a portion of a drawing is usually required for reference at any particular time. Larger 18- by 24-inch screen viewers are also available to view the entire aperture frame at a single time.

In some engineering drawing systems, it may be desirable to be able to correct printed paper copies of the microfilm rather than to revert to the original drawing for corrections. In this case maximum quality is required, which the 105mm microfilm width can provide. Using photographic enlargement techniques, the 105mm frame is blown back to its original size and exposed on high-quality photographic paper and developed. The copy is then corrected, deleting information by cutouts, and inking in new information on the enlargement. The enlargement has sufficient quality to be microfilmed and used for reprints of the updated information. The 105mm systems are typically used for construction and shipbuilding drawings where large drawings are common. This method of microfilming a corrected print may also be used in high-quality, 35mm engineering aperture card systems.

III. MICROFILM TECHNOLOGY

Understanding Microfilm

It is not too difficult to understand microfilm systems. One need not comprehend all the complex technical facets of microfilm, such as the chemistry of developing microfilm, the complexities of the lens formulas, or the physical nature of light. A knowledge of the steps required to produce microfilm and of the basic technology involved in obtaining distinct, readable images, however, will greatly aid the microfilm user and the system designer in avoiding or remedying the many potential problems of producing and using microfilm. Quality in microfilm is often coupled with additional cost, and some microfilm endeavors have had poor quality and hence marginal success because of tight budgetary restraints. On the other hand, procurement of the most expensive and modern equipment will not ensure success if the basics of microfilm technology are not understood and properly applied.

Microfilm comes in many formats, but several distinct characteristics separate it from similar media. To begin with, microfilm is usually a still photograph of textual material or graphic representations. Photographs of people, scenes, or similar nontextual material usually place the film media in some other category, such as a motion or still picture. Secondly, the photographic image is not readable without magnification. There are paper-based systems that reduce copy to one-half or even one-third of its original size but not below the range of eye-readability. Some publishers have even reduced material to one-fifth of its original size, necessitating a magnifying glass to allow reading. While this may be considered microtext, microfilm characteristically requires a projected image in order to be read satisfactorily. Primary characteristics are, therefore, a non-eye-readable textual or graphic image and a projection system for magnifying the microfilmed material so that it can be read.

Technological Characteristics

A brief discussion of some of the basic technological characteristics of microfilm systems follows:

Microfilm Polarity. The polarity of microfilm may be positive or negative. In positive images the images on film look similar to the images of the original document—for example, dark print on the paper appears to be dark on the film, and the light background of the paper appears to be light on the film. Negative images reverse the normal light images to dark and the normal dark images to light.

Most methods of producing film reverse the polarity of the image. The ordinary camera produces a negative image film of the original scene, which is then reproduced a second time, reversing the image into a positive image print. The microfilm camera film reverses the document's image from a positive to a negative polarity, producing negative "camera" microfilm. When the negative microfilm is projected on reversing photographic paper, the paper print produced is a positive. When a contact print is made, most films will produce a reversed polarity image, with the notable exception of diazo-type microfilms.

Choice of negative or positive film for reference in readers and reader-printers is largely based on personal preference. While many occasional users of film prefer positive film, negative film is usually preferred in high-volume continuous reference operations. The advantages of negative reference film in such operations include reduction of background light transmitted through the film and the fact that dirt and scratches on the film are less visible. In addition, most reader-printers make positive (black text on white background) paper prints from negative film and such hard copy is more desirable than negative prints.

Reduction Ratio. Reduction ratio refers to the linear relationship between the original size of the document and its reduced image on microfilm. A 10-inch page reduced 10:1 (one-tenth the original size) produces a 1-inch image on microfilm. But note that while the linear size is reduced in straight proportions, the area size is reduced by the square of the reduction in area. Doubling the reduction ratio places four times as much material in the same area of microfilm. Figure 12 illustrates this relationship between linear and area reduction.

The 8½- by 11-inch page reduced 20:1 or 24:1 gives an image about ½-inch high, ideal for the 16mm width film (approximately ⅝ inch). These reduction ratios for 16mm film are commonly used in microfilm applications where the document size is no larger than 11 inches in width. The 35mm microfilm, on the other hand, with a width greater than 1¼ inches, can handle a 30-inch document at 24:1 and is used extensively for newspapers and other large sheets of paper, such as engineering drawings. Drawings up to 38 by 48 inches can be handled in 35mm formats with a 30:1 reduction ratio.

Computer-output microfilm (COM) utilizes an effective reduction ratio rather than a true reduction ratio. This effective reduction ratio is the ratio of the dimensions of an equivalent page of printout prepared on a computer line printer to the image size on the film. This term is necessary since the actual size of the COM display photographed is considerably smaller than the normal page size. Since the COM-produced typeface is larger than the normal business size, reduction ratios as high as 42:1 or 48:1 are common in COM applications.

Higher reduction ratios can be obtained by a two-step process in which the original document is first photographed on microfilm, and the microfilm is further reduced in a second step. In all cases special technology and equipment is required for this second

RELATIONSHIP OF LINEAR REDUCTION TO AREA REDUCTION

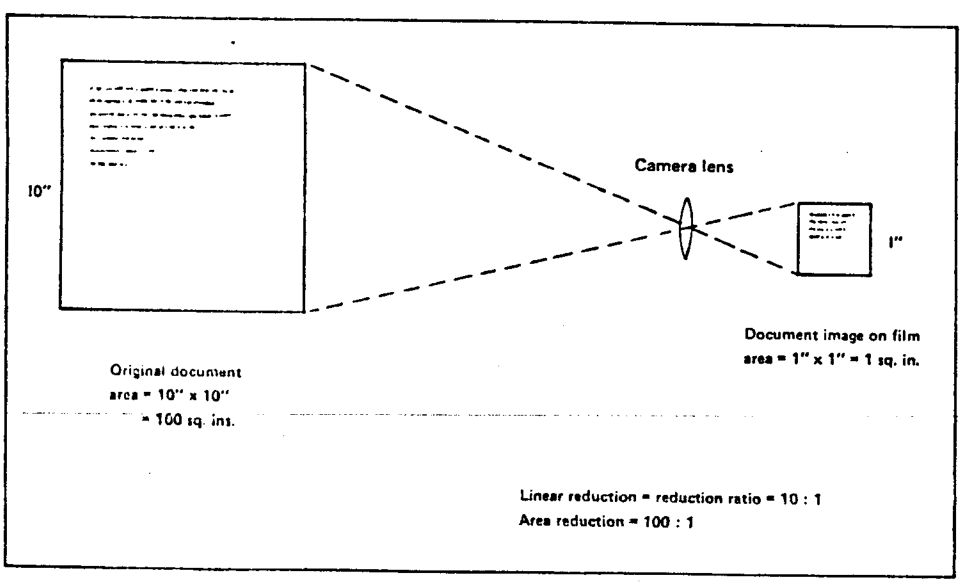


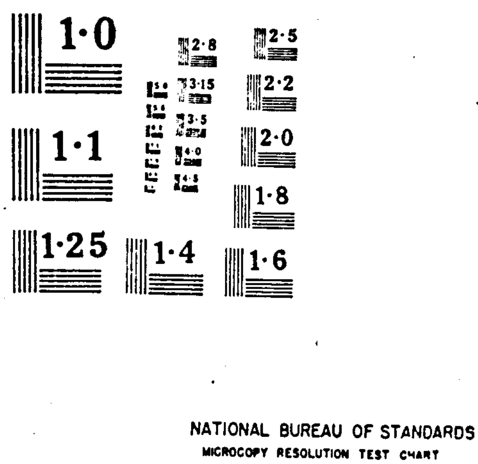
Figure 12

photographic reduction. Using this method reduction ratios of 100:1 or even 200:1 are not impractical.

Resolution. The degree of sharpness or acuity of the film is usually measured in terms of resolution, which refers to the ability of the film to satisfactorily record fine details, such as separate but closely placed lines. This ability is affected by many things, such as accurate focus, the contrast difference between the original image and its background, the exposure of the microfilm and its subsequent development, sharpness of the original lines, and the type and quality of the film used.

Resolution is usually expressed as the maximum number of line-pairs per millimeter the film system (camera, microfilm, and development process) can satisfactorily resolve, with measurement made by a micro-

DETERMINING RESOLUTION OF MICROFILM



RESOLUTION READ = Pattern Number x Reduction Ratio

Examples:

Film Reduction	Pattern No. Lines/mm.	Resolution Lines/mm.
16.1	7.1	113
24.1	5.0	120
30.1	4.5	135

Figure 13

scope. A series of resolution patterns, each consisting of five line-pairs in each direction, are photographed. The patterns range from line spacing of 1 line per millimeter to 10 lines per millimeter, with each pattern step increased about 10 percent. When photographed the actual patterns become smaller proportionally to the reduction ratio; i.e., at 10:1, the 4.5 lines per millimeter pattern becomes 45 lines per millimeter on film; at 24:1, the 3.6 pattern produces $24 \times 3.6 = 86$ lines per millimeter on the film. When read under the microscope, the larger patterns are usually clearly readable as five lines in each direction, but with examination of each pattern progressively smaller in size (but with higher line resolutions) a point is reached where the lines are no longer distinct. The resolution is expressed, therefore, as the last pattern that can be clearly discerned as five lines in each direction, and the value is determined by the pattern number multiplied by the reduction ratio used. Figure 13 illustrates a National Bureau of Standards chart used for determining film resolution.

Determining clarity or readability between one film portion or image and another is a very subjective process unless such resolution charts are used. A 10 percent change in resolution is difficult to judge but it will be reflected in resolution chart readings. Any change in the technical aspects of the microfilm camera operation or the development of the film may result in a falloff in resolution from the optimum quality. A significant drop in resolution indicates that a problem in the overall microfilm system needs correction.

Resolution charts may also be used for comparing the optical system of one microfilm reader with a second by using the same piece of microfilm and carefully reading the resolution chart when it is placed in the center and in the four corners of the screen of each reader.

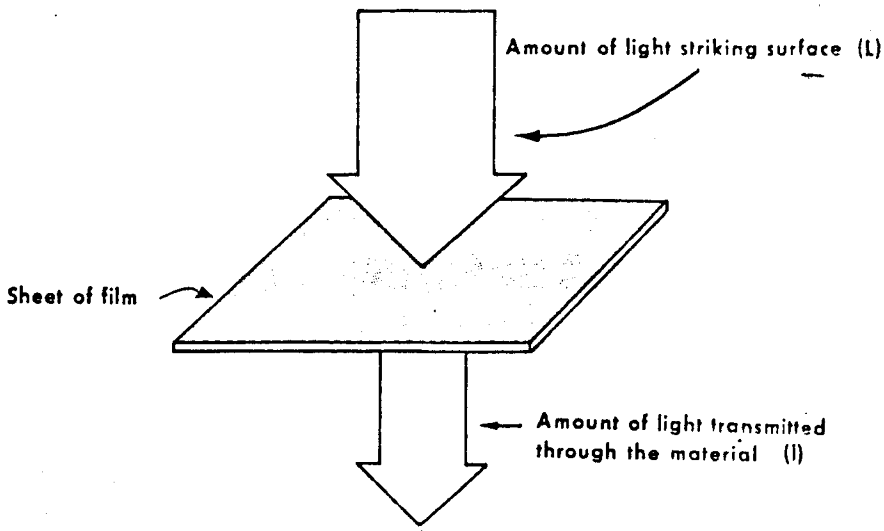
Density. Density refers to the degree of darkness of a microfilm image. There are several kinds of density measurements. The vesicular films, in particular, give a difference between the diffusion density (measuring the light diffused by the film) and the projection density, in which the density of the projected image is measured.

The percentage of light passing through a film is a measure of its density. If 100 units of light are falling on a film and 10 are transmitted, it can be stated that the light transmission is 10 percent. In photographic terms, this ratio is more commonly expressed as a logarithm of the ratio of incident light to the transmitted light, and this logarithm is the value of its density. The computing of film density values are illustrated in figure 14.

In microfilm systems we are concerned with the overall basic density of the clear areas of the microfilm, commonly called the base fog, and the background density, measured in the background areas of the microfilmed document. Control of this background density will provide optimum printing quality and good contrast between the textual material and the background. If the background density is too light or too dark, the contrast range will be less than satisfactory for viewing or will be beyond the capability of the microfilm printout device to handle the contrast properly.

Contrast. Contrast is a measure of the gray tones between the positive and negative areas within the image on the microfilm. Most film used in microfilm systems have high-contrast capability, that is, the light areas will appear very light and the dark areas very dark on the film, with no gray in between. High-contrast film is ideal for line drawings and textual material. Printed materials that include pictures which are halftones composed of very small black dots, will also reproduce well using high-contrast microfilm. Photographs (nontextual images) that have a continuous range of gray tones from black grays to brilliant whites will photograph on microfilm, but the result will be a loss of gray tones and a stark black and white rendering of the photograph. When these gray tones are desired, special

DETERMINING MICROFILM DENSITY



$$\text{Transmission} = \frac{I}{L}$$

$$\text{Density} = D = \log \frac{L}{I}$$

% Transmission	L/I	D = log L/I
50% (½)		0.3
25% (¼)	4	0.6
12% (1/8)	8	0.9
10% (1/10)	10	1.0
6.5% (1/16)	16	1.2

Figure 14

film and special processing of the microfilm are necessary to attain a lower contrast.

Types of Microfilm

Microfilm generally consists of a photosensitive emulsion coated on a clear base. The base material may be in various thicknesses from .002 of an inch (2 mils) to over .010 of an inch (10 mils). The thinner base is used in some roll film systems (including cassettes); the thicker bases make sheet film easier to use.

Silver halide, diazo, and vesicular films are the three types of microfilm in common usage today. Only silver halide film is typically used as camera microfilm for photographing paper records. The other microfilms are used to make duplicates of the master or original camera microfilm.

Silver Halide. This film type, similar to the film used in conventional photography, is characterized by high sensitivity to light, a wet process of development, and a reversing image. This film has good resolution and density properties, and it is the only film type currently accepted for the achival storage of microimages. It is the only microfilm accepted in commonly used cameras. The characteristics of the image produced are affected by the type of film emulsion, the exposure, and the subsequent wet development process.

Silver halide duplicates are also made from microfilm masters. With normal processing, a positive copy is made from a master negative. The copy also must be wet developed after exposure. In comparison to other microfilms, silver halide microfilm is more expensive.

Diazo. Diazo microfilm is used exclusively for making duplicate microfilms. It is exposed by contact printing with relatively large amounts of ultraviolet light, permitting the film to be used in normal light conditions for short periods of time without unintentional exposure. Diazo film is developed by passing the film through a heated gaseous ammonia chamber that develops the image to a certain point at which time the development stops.

The diazo process is basically a molecular coupling that does not require granular emulsion. Hence, duplicated diazo film is capable of extreme resolution not attainable with other types of microfilm. Depending on procurement conditions, diazo microfilm is one of the least expensive of the films available. The densities attainable with diazo film are not as high as silver, nor are the images considered to be archivally permanent. Nevertheless, diazo microfilm copies are very satisfactory for normal-use microfilm. Diazo microfilms are nonreversing, with a negative made from a negative master, or a positive made from a positive master.

Diazo coatings can be used in various colors, and often a sepia-colored diazo is used as a master for preparing additional duplicates. Sepia is particularly opaque to the ultraviolet used in the duplicating process; therefore, it is excellent for line copies. Use of an intermediate sepia copy film as a duplicating master also serves to protect the original silver halide film, which may serve as the archival or security copy.

Diazo microfilm's characteristics of low cost, extreme sharpness, relatively fast-printing speed, and nonreversing duplication make it ideal for high-volume reproduction of camera negatives. Simple duplication by exposure and immediate development in an ammonia chamber makes it attractive for user-reproduction of microfilm.

Vesicular. Vesicular microfilm is exposed by ultraviolet light and developed by heat. It is about twice as sensitive to ultraviolet radiation as diazo, but, except in special applications, it is not considered a camera microfilm. Vesicular images consist of microscopic bubbles (vesicles) formed in the emulsion during exposure and development. These bubbles reflect light to form an image instead of absorbing it. The film usually appears to be light tan or bluish gray, but the projected image is much like the image produced by silver or diazo microfilm. It is generally less expensive than silver microfilm and often competitive with diazo microfilm.

Vesicular film's greater sensitivity and simple in-line heat development make it ideal as a duplicating microfilm in many applications. High-speed duplicators producing as much as 500 feet per minute of ready-to-use film are commercially available. While vesicular film has less resolution capability than diazo, there is little significance to this difference in the majority of microfilm applications. Since it is a reversing microfilm, a positive image is produced from a negative master image. This reversing characteristic, however, is a highly desirable feature in computer output microfilm applications where the master microfilm is produced as a positive rather than a negative, and the vesicular duplicates are consequently produced as negatives. In addition, the dry heat developments of the microfilm make it attractive for computer room or office operations.

COMMON TYPES OF FILM

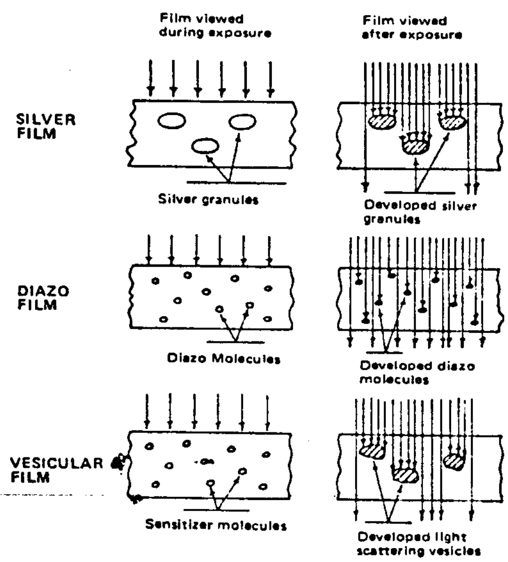


Figure 15

Figure 15 illustrates the exposure and development characteristics of the three major types of films.

Processing

All three types of microfilm must be exposed and developed to view the image. Silver microfilm is usually developed as a separate step, but often diazo and vesicular films, especially rolls, are exposed and developed in a single in-line process. To aid in understanding the characteristics of each of these films when used in a microfilm system, there follow further details concerning the processing of each type.

Silver halide microfilm requires a chemical bath to develop the latent image, a second bath to desensitize or fix the unexposed portions of the microfilm, a wash process to remove residual chemicals from the microfilm, and finally a drying process. The development stage is most critical because both time and temperature are important. In addition, the chemical strength of the bath must be maintained by replacement or replenishment. Replenishment is usually done through a system of adding chemicals to the development bath as microfilm is being processed. Variations in time, temperature, chemical strength, and, in some systems, chemical agitation will change the density of the developed microfilm. To prevent undesired changes these elements must be closely controlled and uniformly maintained.

An unstable image is visible after development, but the unexposed areas of the microfilm are still light sensitive. The fixing bath removes this sensitivity and produces a stable microfilm image.

Dyeback microfilm has a black coating on the back of the microfilm base to prevent the reflection of light from the base of the film into the bottom of the emulsion during exposure. This dyeback is dissolved during processing of the microfilm, and thorough washing is necessary to remove all traces of the coating. Some processors have a crubbing rack to rapidly remove the dye-backing.

In some cases a coating is placed be-ween the emulsion and the base. This un-lercoating, called antihalation undercoat, or AHU, disappears during processing. Both coatings tend to increase the sharpness of he film.

The microfilm must be washed after de-velopment and fixing to reduce the residual hemicals to an acceptable level. If the film s to be maintained as archival film, special rocessing procedures must be followed.

Diazo microfilm processing is simpler. The xposed microfilm must be passed through a heated ammonia gas chamber where the liazo dyes in the film react with the ammonia fumes to form a light area wher-ever the film has been exposed to light (producing a nonreversing or direct image). ome equipment is available that does not equire special venting for fumes, and the rocess is neither difficult nor expensive to naintain. Development is rapid, and the rocess often immediately follows exposure f the duplicating microfilm in an in-line peration.

Vesicular microfilm is also usually developed n-line. Immediately following exposure to ltraviolet light, the film is passed over a eat roller, allowed to cool briefly, and assed through a second exposure station hat floods the unexposed areas with ultra-iolet light. The reason for the second ex-osure to ultraviolet light is to stabilize the nexposed sensitized material on the film.

Reversal Processing. Silver halide film may be processed with special techniques to pro-duce a nonreversing image. This is com-monly used for silver halide duplicates of conventional camera master films where a negative duplicate is desired, and occasion-ally for positive COM film when a negative duplicating master film is required to make paper prints or negative diazo duplicates. Vesicular films, which normally reverse polarity, are usually used for large-volume COM duplication.

Archival Processing. Silver halide microfilm, either the camera microfilm or the dupli-cated copies, can be used for permanent rec-ord copies or archival storage if it is proc-essed to reduce the concentration of the re-sidual fixing agent ("hypo," which is typi-cally sodium thiosulfate) to less than 1 microgram per square centimeter but more than zero. An optimum concentration of 0.7 microgram per square centimeter in a clear area is recommended. This requirement may be met by performing the tests as specified in ANSI PH4.8 "Methylene Blue Method for Measuring Thiosulfate and the Silver Den-sitometric Method for Measuring Chemicals in Films, Plates, and Papers" or by submit-ting a test sample from a clear area of the film, measuring at least 2 square inches, to the Office of the Executive Director (NAT), National Archives Building, General Serv-ices Administration, Washington, DC 20408. There is a charge of $5.00 for each sample tested, although small numbers of samples may be tested by the National Ar-chives and Records Service without charge. Permanent microfilm records produced by COM must meet the same processing stand-ards. If the processing is the reversal type, it must be full photographic reversal and not the halide-type reversal.

IV. MICROFILM SYSTEMS

System Characteristics

A microfilm system typically consists of information on a microfilm media; equipment for recording, processing, reproducing, retrieving, and viewing the information; and, as needed, various indexing or retrieval aids. Microfilm systems are normally classified first by film width and format and then by the indexing and retrieval means. For example, there are 35mm roll systems and 35mm aperture cards and 16mm cartridge systems with odometer, bar code, or serial indexing. These variations in film width, image placement and size, and indexing aids usually prevent ready interchange of microforms between different types of equipment or basic systems.

Certain indexing and retrieval techniques can best be used with each type of microform. Because of the diverse handling and storage characteristics of each type of microform, certain indexing techniques are more suitable to one than to another. Such factors as basic film characteristics, microform arrangements, indexing aspects, retrieval equipment characteristics, and the needs of the user all influence the determination of which microform is best for a specific application. Microform selection is discussed further in chapter VII, Microfilm Systems Design.

16mm Microfilm Systems and Retrieval Techniques

Roll film in reels, cartridges, and cassettes are the three major types of 16mm systems. Reels are flanged spools, cartridges are self-threading enclosed spools, and cassettes enclose both the supply and takeup spools. Special retrieval techniques are needed for roll film systems, since many images are placed on a single roll. (Of course, the arrangement system of the microfilmed records can assist in reducing the area of the roll film to be searched.) Figure 16 illustrates some of the common indexing or retrieval methods for 16mm roll microfilm systems. These techniques are described below.

Flashcards. Retrieval of information can be aided if appropriate flashcards or targets are used to permit high-speed identification of significant file breaks in structured files such as files arranged in serial number order or alphabetically by name. The flashcards highlight the segments of a microfilmed file by indicating the beginning of a particular segment of the alphabetic or numeric arrangement of the file. These flashcards cannot be read while the film is moving at high speeds, but they are noticeable dividers that can aid in locating the many images on roll film.

Bar Code. A bar or line placed between the individual frames of microfilm will appear as a streak on the screen as the film moves through the reader. If these lines are properly positioned and calibrated, a bar code (also called code line) indexing scheme can be readily developed. These code lines can be made to represent numbers or letters in sequence as the bars appear on the screen. The bars are normally photographed with the original documents. In certain rotary cameras they can be placed automatically to correspond with the count of the number of images microfilmed. Up to three code lines can be photographed at the same time. Generally, not less than 20 frames should be used for the basic bar code indexing group because a lesser number of frames would not allow sufficient visibility on the screen.

Bar codes are extremely flexible for any kind of 16mm system because they can be read either forward or backward, are relatively simple to generate, and can be used for preparing indexes either before or after the exposure of the microfilm. Their disadvantages are that they lack precision as they normally pinpoint only within 20 frames of the image needed, and also they may cause some eyestrain with constant use.

RETRIEVAL METHODS USED ON 16 mm ROLL FILM

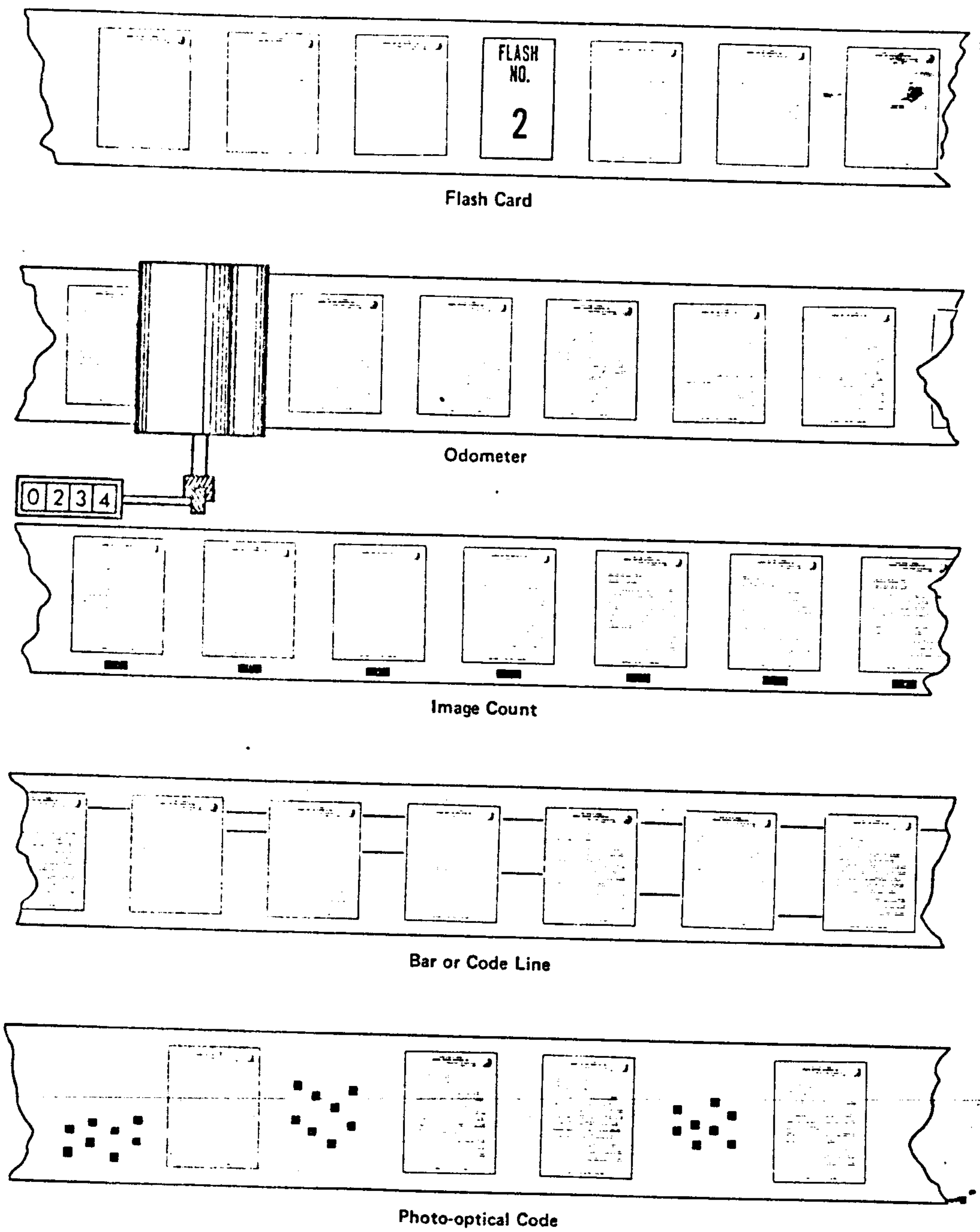


Figure 16

Odometer (Film Travel). An odometer can be used to measure the amount of film travel into a microfilm reader, generally using an arbitrary unit of length. When using a 24:1 reduction ratio and letter-size pages, many odometers give an approximate count for each image. Within a given manufacturer's microfilm reader line, microfilm cartridges or reels calibrated on one unit can be used on other units, but the same odometer setting will probably not be accurate on units from another manufacturer.

Odometer indexing done from finished microfilm can be very accurate, leading the searcher to within a few frames of his desired position. If the frames are sequentially numbered and the number noted with the odometer setting, accurate and precise retrieval can be accomplished quickly. This indexing is a locating scheme, and it can be combined with any subject or content indexing to form a complete system. Computer-generated odometer indexes can be produced on microfilm in conjunction with COM units. If film leaders are equal in length, duplicate films are as precisely measured as the master film. Odometer indexing is available for reels and cartridges but not for cassettes.

Document Mark (Image Count). Document count systems count the number of document marks, and, under keyboard control, stop the microfilm at the proper document count. These document marks are black areas (blips) placed below each image. The indexing used is similar to the serial number or odometer indexing to a single frame, but, in this case, a keyboard and an electronic control unit are required. These added components increase the price of the retrieval unit considerably. Various other automated features are also available with these systems.

Document count systems are particularly attractive if the document count itself can automatically correspond with the pages being microfilmed. They have the advantage of precise and automatic retrieval to the specific frame. They are often used in automated systems that couple a computer index searching unit with a cartridge microfilm retrieval device.

Photo-Optical Binary Code. This technique uses a binary code representation of numbers or other indexing references on the film adjacent to the appropriate image. Use of this type of code permits true random filing and searching of information. The coding aspects, however, greatly increase the input cost of microfilming and reduce the image capacity of the cartridge. Typically, photo-optical coding is best applied to microfilmed files that have a clear-cut files arrangement scheme. For example, photo-optical codes can be used to represent the symbols for the subject categories of a subjectively arranged file.

16mm Retrieval Equipment Cost. Systems based on simple numeric or alphabetic arrangements and bar code retrieval systems can be used on any 16mm reader, and hence offer the lowest equipment cost with the widest application. Odometer units are more costly, while mark counting systems add several magnitudes of cost to the equipment.

EXAMPLE OF A MICROFILM STRIP

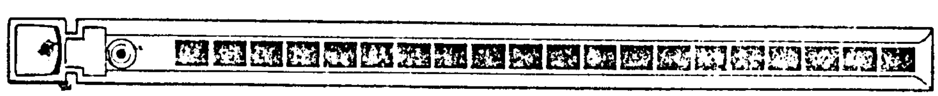


Figure 17

Photo-optical binary code units are several times again more costly than document mark units. Manually operated readers are, of course, less expensive than motorized readers, but the latter are normally used if the reference volume is high, regardless of the indexing and retrieval method used.

8mm Microfilm Systems

Eight-millimeter microfilm systems require a reduction ratio of about 34 to 38:1, and consequently are best used for systems that do not require maximum image quality. A two-step reduction process greatly improves the quality at 38:1, and this process has been used in micro-publishing. Some 8mm microfilms are created by filming two tracks on 16mm microfilm and splitting the film. These systems typically use film cassettes, and they allow use of smaller readers than 16mm systems.

Microfilm Strips

Microstrips are short sections of 16mm microfilm contained in a rigid plastic holder (See fig. 17.) Microfilm strip systems are noted for the ease of changing the strips, making them particularly attractive for rapidly changing indexes and files. The strip is designed for rapid retrieval using eye-readable indexes on the end of the strip, and, in some cases, a container is used that can hold 10 or more strips. A special reader is required for a microfilm strip system.

Advantages of microstrip systems include ready interchangeability of the microfilm for updating and ease of manipulation of the strips. Microstrip systems are frequently used for directory-type applications such as lists of ZIP codes.

Aperture Cards

Aperture cards unitize 16mm or 35mm microfilm, providing a convenient carrier for the microfilm chip that permits convenient indexing and retrieval of the chip. Aperture cards permit use of individual frames of microfilm as the unit of issue. If machine punches are placed in the cards, some machine sorting is possible, but it is not usually recommended because the film or card may be damaged.

Aperture cards may offer an ideal solution where a unitized record is required and where the additional expense of mounting and identifying the film in aperture cards is not prohibitive. Aperture cards can be misfiled, however, thereby losing a major advantage of roll microfilm systems.

Special readers for aperture cards are available with 18- by 24-inch screens for aperture card systems involving engineering drawings. When aperture cards are used for small letter-size case files (typically up to eight documents per card using a 24:1 reduction ratio), certain readers designed for microfiche can also be used to view aperture cards.

Microfiche

A microfiche is basically a unit record, containing a multiple of page images on a sheet of film. Conventional card-filing arrangements and techniques can be used for retrieving fiche. Typically, information identifying the documents contained in a fiche is included in a header or title area at the top of the fiche. Automated file retrieval devices are also available. Microfiche offers very convenient reproduction, and a great number of fiche readers and reader-printers are available on the market. Microfiche are normally more expensive to produce than the equivalent roll microfilm because of the additional steps and equipment required to produce the fiche. However, microfiche readers are much less expensive than motorized roll film readers and require less maintenance.

Microfiche are generated by three general methods. The "strip-up" process uses 16mm microfilm (or 35mm sprocketed microfilm) in strips to form a matrix for reproduction. The step-and-repeat camera accomplishes the same result but places exposures directly onto the microfiche itself. Microfiche are also generated directly by computer output microfilm techniques.

Microfiche can be produced at various reduction ratios and in various sizes and formats. A summary of some of the commonly used formats and reduction ratios is shown in figure 18. In the Government, most distribution microfiche meet the National Microfilm Association (NMA) standards. These require a 105 by 148.75mm filmsheet (nominally 4 by 6 inches), a reduction ratio of about 24:1, and 98 frames of images consisting of 7 rows of 14 images each.

lower right-hand corner. This index refers to rows and columns within the specific microfiche. In COM-produced microfiche the pagination sequence is usually arranged in vertical columns across the fiche from left to right, as opposed to the normal left to right sequence in rows from top to bottom, the arrangement used on standard document-type microfiche.

Two-Step Reduction Microfilm

Conventional microfilm can be further reduced by using a specialized two-step reduction process. This two-step reduction technique permits high reductions without significant loss of resolution quality. The first step is accomplished using conventional microfilming techniques, while the second reduction is made on a high-quality master microfilm by specialized equipment. Special techniques are also required to produce the reference or distribution copies.

Reduction ratios of 100:1 or more are commonly used. This greatly increases the packing factor to 1,000 or more pages per microfiche. The special techniques required greatly increase the cost of original micro-

COMMON MICROFICHE FORMATS

Common Name	Reduction Ratio	Original Page Size	Rows	Cols.	No. of Frames
* COSATI	20:1	8½x11"	5	12	60
NMA	24:1	8½x11"	7	14	98
COM	42:1	8½x11"	13	25	325
COM	42:1	14x11"	13	16	208
MINI-CATS	48:1	14x11"	15	18	270

*The former Committee on Scientific and Technical Information (COSATI) has now adopted the NMA format, but many fiche in this format are still in use.

Figure 18

High Reduction Microfiche

High reduction microfiche (or "superfiche") are produced at a 42:1 or 48:1 reduction ratio. These reduction ratios are not ordinarily used for document microfilm but are limited to microfiche produced by computer output microfilmers. See figure 18 for the number of images that can be placed on various types of high reduction fiche. An indexing frame(s) is commonly produced as the final frame(s) of the microfiche in the filming to several times that of conventional microfilming, but the cost per page for reproduction is greatly reduced. This makes the two-step reduction process particularly valuable in micropublishing applications.

Ultrafiche viewing equipment is generally tailored to the specific microform utilized, and reader-printers are not commonly available. Positive polarity is popular because negatives absorb too much heat from the concentrated light that is required to project them.

Super-imposed ultrafiche, utilizing two layers of positive images, permit stacking of two fiche images in the same optical path. Ultrafiche are sometimes laminated in clear, thick plastic, permitting selective focusing through one layer of images into a second. Dirt or scratches on the surface do not appear on the reader screen because they are out of focus.

Microfilm Jackets

A microfilm jacket is a multiple-image microform created by placing strips of 16mm or 35mm microfilm in sleeves of a clear plastic jacket. This jacket serves both as a carrier and as an identification means, in effect creating a special form of microfiche. If the jackets are contact printed to another sheet of microfilm, a microfiche is created. Readers designed for microfiche are also usable for jackets.

Jackets for microfilm are produced in many sizes and varieties. Most common are the 4- by 6-inch jacket with four or five horizontal sleeves or pockets for insertion of 16mm microfilm. Another format has both 16mm and 35mm pockets on a single jacket the size of a tabulating card. A special form of aperture card is created by inserting a frame of microfilm into a jacket-type aperture card.

Jacket microfilm creates a unit record that permits filing, storage, and retrieval by the identification placed on the jacket. To this extent it is similar to microfiche but more suitable for updating short documents because additional frames or strips can easily be added to the jacket if space remains.

Film duplicates made from jacket microfilm must be contact printed through the jacket, resulting in some loss of image sharpness. If only one generation is to be made, however, this loss is minor.

Compared to other microform systems, the microfilm jacket system is usually more expensive than reels or cartridges but often less expensive than an equivalent microfiche system. Its most popular use is for case-filed records that can require either updating of individual file records or adding new records as a case is continued.

Other Microforms

The variation in reduction ratios and the matrix placement of the images on a clear base is infinite and various formats of microforms are developed to meet specialized applications. Generally, these microforms require highly specialized equipment to produce them originally, to duplicate them, and to use or read them. Their use in any system should be based on careful systems analysis, cost/benefit analysis, and finally on performance, quality, and actual system throughout speed from original input to actual retrieval output on a reader screen or paper copy. These specialized systems are often justified on the basis of a unique capability not otherwise available in conventional microform systems.

Indexing Systems

Indexing systems permit us to find the information for which we are searching. They are based upon the content or information value of the microimages. The method for storing and retrieving the microimage, however, is based upon the particular microform. The indexing system and the retrieval method must be coordinated in a successful microfilm systems design.

Indexing Methods

There are various indexing methods available today for use with microform systems. Most methods assign a conceptual series of identifying tags to a specific document, and the tags are later searched for purposes of information retrieval. These tags may be author, title, subject, keywords, descriptors, serial numbers, or any term or code useful in later retrieval. When combined with microform storage the index, the index-search mechanism, and the information storage and retrieval device, an information retrieval system is formed. These systems are discussed in detail, along with the indexing aspects, in the GSA Records Management Handbooks "Information Retrieval" and "Microform Retrieval Equipment Guide."

Note that there are several aspects to indexing. We must initially index or otherwise assign tags to the information contained in the microimage. At some later date, in conjunction with retrieval of information these tags must be searched to identify the appropriate information. In microfilm systems this information is usually identified as a retrieval address. This locating address is then used to actually find or retrieve the filmed information. There follows a brief description of various types of indexing methods applied to microforms.

Subject Indexing. Subject-classification schemes classify information into various subjects pertinent to the information contained in the documents. Often code symbols are assigned to the subject categories. Then, the indexing code symbols, with their microfilm address numbers typically are the key to finding information in microfilmed subject files, and not the documents or microimages themselves. A subject-classification system is relatively easy to use and understand. A subject file, however, does not offer great precision in finding information because various users of the file can have differing interpretations of the kind of materials filed under the various subjects.

Coordinate Indexing. Coordinate indexing utilizes many terms or characteristics to describe the attributes of a document. As many of these terms or characteristics as desired can be assigned to a single document. For retrieval, a search is made for those documents that contain all the desired terms. Searches can be accomplished manually, using such devices as optical coincidence cards, columnar cards, or a computer-prepared dual dictionary. This is an alphabetic listing of indexing terms indicating after each term the numbers assigned to documents indexed under each term. Computer searches can also be made. Some of the more advanced information retrieval devices allow coordinate searching of characteristics coupled with actual retrieval of the desired microimage.

Special Listings. Special listings can be made of the contents of an information file using keywords, authors or originators, special subject headings, account numbers, and the like. Computer-prepared permuted indexes, such as keyword in-context or keyword out-of-context listings can provide access to a file by indicating the titles of documents and their assigned location tags. (See fig. 19 for an example.) As many different indexes (name, number, and source) as necessary can be produced, in all cases referring the user to the access address number of the microimage.

Name or Number Arrangements. The most common form of indexing used with microform systems is name or number indexing, where the basic numeric or alphabetic sequence of the documents on microfilm is used as the only indexing and access point. Examples are files arranged by social security numbers, part numbers, or names of persons or organizations. Sometimes with numerical files the serial number is not the locating number, and a cross-reference from one or more serial listings to a retrieval number is required. For example, if customer records are arranged by customer number, a cross-reference may be required between the customer number and the reel and frame number.

SAMPLES OF COMPUTER - PRODUCED INDEXES

WORD TITLE INDEX

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MICROELECTRONICS                                                                                              MINIMIZING

 SOLID LOGIC TECHNOLOGY, VERSATILE, HIGH-PERFORMANCE MICROELECTRONICS                                         IBMJ642 132
  A PROGRAM ENTAILING THE LARGE SCALE APPLICATION OF MICROELECTRONICS                       UNIQUE ASPECTS OF   R656-74
DESIGN OF COMPUTERS                      THE IMPACT OF MICROELECTRONICS AND AUTOMATION ON THE ENGINEERING     AUS 66  434
                                                      MICROFILM INFORMATION RETRIEVAL SYSTEM                  TCB8642  47
SYSTEM                                         500-MC MICROLOGIC CIRCUITS AND AN EXPERIMENTAL DIGITAL        IFIP652 501
                                                      MICROPROGRAM CONTROL FOR SYSTEM-360                     IBMS674 222
            THE LOGICAL ORGANIZATION OF THE PB 440 MICROPROGRAMMABLE COMPUTER                                R643-36
                                                      MICROPROGRAMMED CONTROL IN PROBLEM-ORIENTED LANGUAGES   IEEC675 652
SYSTEM-360 MODEL 30                                 A MICROPROGRAMMED IMPLEMENTATION OF EULER ON IBM          CACM679 549
                                    'INTERGRAPHIC, ' A MICROPROGRAMMED, GRAPHICAL-INTERFACE COMPUTER           IEEC676 773
                                                      MICROPROGRAMMING AND STORED LOGIC                       DTMN642  24
                                                      MICROPROGRAMMING EMULATORS AND PROGRAMMING LANGUAGES    CACM663 230
                                                      MICROPROGRAMMING FOR DATA ACQUISITION AND CONTROL       FJCC651  77
                                                      MICROPROGRAMMING REVISITED                              PACM67  457
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                      THE DESIGN OF A 4096 WORD, 1 MICROSECOND MAGNETIC FILM STORE                            R644-39
                           AUTOMATIC DERIVATION OF MICROSENTENCES                                             CACM666 443
                            CHARACTERISTICS OF MICROSTRIP TRANSMISSION LINES                                  IEEC672 185
                                          ARITHMETIC MICROSYSTEMS FOR THE SYNTHESIS OF FUNCTION GENERATORS    IEEP660 1910
                                             DIGITAL MICROTAPE RECORDER                                       OEIP64  581
                 AN EXPERIMENTAL NONDESTRUCTIVE MICROWAVE FERRITE CORE READOUT USING STRIPLINE               IEEC654 428
                                          CONTINUOUS MICROWAVE OSCILLATIONS OF CURRENT IN GALLIUM ARSENIDE    IBMJ645 545
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                    MIDAS III, A COMPILER VERSION OF MIDAS                                                    SIM6663 160
                                                      MIDAS - HOW IT WORKS AND HOW IT'S WORKED                FJCC641 313
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ONS (AN EXAMPLE FOR THE APPLICATIONS OF THE ENLARGED MIDAS PROGRAM)   /R USING GENERALIZED LAGUERRE FUNCTI   SIM4653 152
                                                      MIDAS, AN ANALOG APPROACH TO DIGITAL COMPUTATION        SIM3643  17
      COMPUTATION BY A HYBRID COMPUTER FOR THE APOLLO MIDCOURSE ABORT SIMULATION               TRAJECTORY     SIM9672  81
                                                  THE MIGHTY MAN-COMPUTER TEAM                                FJCC652   1
     A 375 NANOSECOND MAIN MEMORY SYSTEM UTILIZING 7 MIL CORES                                                FJCC651 985
                                            A RUGGED MILITARILY FIELDABLE MASS STORE (MEM-BRAIN FILE)         SJCC67  239
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                 ***THE UNITS DIGIT OF THE VOLUME NUMBER IS GIVEN BETWEEN 'TCB' AND THE YEAR DIGITS.***

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TCB8641  23  INTERCONNECTION OF COMPUTERS * D. L. A. BARBER
TCB8641  29  LAN-DEC COMPUTER * A. G. DE MESQUITA, G. A. H. THOMAS
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Figure 19

Serial Imprinting. A special form of serial arrangement is created when each page or frame is sequentially numbered as it is filmed. Some rotary cameras can automatically print a sequential number on each sheet as it is microfilmed, creating a serial number that can be used for both indexing and locating. This simple method of numbering for later retrieval is very effective for situations where the input is randomly arranged. To create an index, a special listing is made (from the sheets after filming) with reference to the reel and serial number. Computer listings of the documents and their serial numbers are often made and used as an index for retrieval purposes.

Index Searching

Of the various indexing methods noted above, only the coordinated indexing typically requires special devices. Indexes may be produced by using computer techniques, and the indexes can be printed and used in book style or produced on a separate computer output microfilm. Also note that in most cases the indexing is physically separated from the microimage collection to which it pertains. This allows manipulation of the index without affecting information content, and this is a key feature in computer-assisted searching.

Computer-Assisted Searching

By use of simple photographic methods, microfilm can record large masses of both textual and nontextual data. Input and storage of this information on microfilm costs only a fraction of the cost of the equivalent amount of data stored within a computer. Indexing data, on the other hand, usually

EXAMPLE OF A MICROFILM/COMPUTER TERMINAL FOR COMPUTER ACCESS MICROFILM

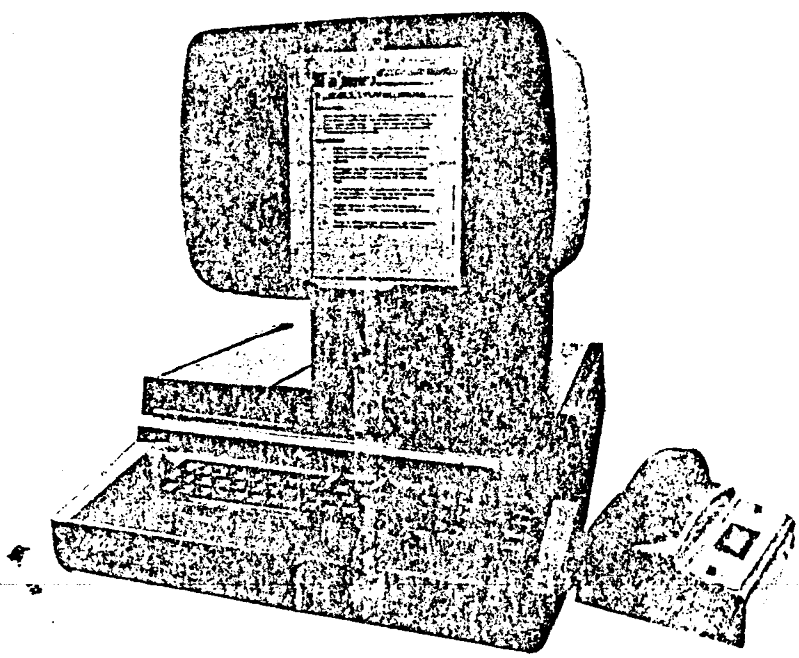

Figure 20

consists of relatively few terms or coded attributes and can be readily entered a character at a time into a computer for manipulation and search. This combination of microform storage of a large mass of information and computer storage and manipulation of the associated index is an attractive combination that uses the best of each medium. This type of system is sometimes referred to as a Computer Access Microfilm (CAM) system.

The index manipulation and search can be accomplished by two methods. In one method the index is manipulated, sorted, and formatted by the computer and then printed. In the second method the index file is formatted for retrieval searching, and the searching is done by a computer routine that identifies the addresses of pertinent documents which satisfy the requirements of the search inquiry. If a number of inquiries are grouped and run together against an index data base, a high degree of search efficiency can be obtained. In other cases the time delay of batch processing is not desirable, and computer programs and inquiry devices are provided to query the data base in an on-line fashion. This can be done with either a dedicated computer or a time-shared computer. (See figure 20 for an example of an on-line microfilm/computer terminal permitting computer searching coupled with microfilm image retrieval.)

If a well-defined access or retrieval number is available, virtually any kind of a computer index search system can be coupled with any kind of microform retrieval system. But to the extent that the computer retrieval system is very precise, precise indexing is also required. The cost of this indexing and the programs required to search the computer-stored index can be very expensive in relation to the cost of the microfilm storage and retrieval system. The cost of the computer time required to do the searching is usually a minor expense compared to the cost of developing and loading the system.

Deep index searching can be well justified for those systems that require it by the total performance of the system. The proper combination of mass information storage in microform coupled with the index data storage and manipulation search capability of the computer can offer sizeable savings over manual retrieval and search methods. A thorough system study and cost model estimate should be made to determine cost effectiveness.

V. COMPUTER OUTPUT MICROFILM (COM)

Recording of Computer Output Directly on Microfilm

In the early 1950's technologies were developed in the display and plotting fields that permitted special purpose devices to record computer output directly on microfilm. In one case a special cathode ray display tube was developed that shaped an electron beam into the form of letters and numbers, using a matrix containing these shapes through which the electronic beam was focused. The shaped beam could be positioned under computer control, permitting alpha-numeric information to be placed anywhere on the face of the display. This device is known as the Charactron® shaped-beam tube.

The shaped-beam tube required only addressing of the character within the matrix, so that simple X-Y instructions were sufficient to write information on the face of the tube. The method is inherently a high-speed process, and consequently the shaped-beam tube has been extensively used for high-speed alpha-numeric printout applications producing textual information, as opposed to graphic charts or special displays.

A second technology involved rapid plotting on the face of a cathode ray tube of curves and other mathematical functions produced by the computer's calculations and photographing the trace as it was produced. Positioning of the beam could be controlled by the computer not only to produce curves and straight-line axes, but also letters, numbers, and other shapes. This technology formed the basis of the scientific or graphic plotters for computer output microfilm.

Graphic displays and plotting require extensive control of the electronic beam to stroke-write even simple characters, and consequently the early graphic COM units were not fast when compared to the business or shaped-beam units. This is no longer true because special character generators are now used in conjunction with display tubes for rapid generation of either graphic or alphanumeric information.

In all cases, computer output microfilm recorders offer high-speed recording of computer output. They record about ten times faster than conventional line printers and many times faster than conventional pen-type plotters. It is this capability to unbottle close to the full output of the computer that makes computer output microfilm so attractive in many applications. In addition, the physical compacting of the information into microfilm format permits the output to be handled more easily by the users, whereas paper format would be bulky, regardless of the speed of output.

COM Recording. Several elements are generally found in computer output microfilm recorders. Some means of input for the computer-produced information must be provided, such as a tape drive or an on-line interface with an existing computer installation. This input is fed to a logic-control unit that converts the digital output from the input device to the character format or graphic display required, producing this information on the face of the display tube. The logic-control unit also controls the microfilm camera that photographs whatever is displayed on the face of the tube. When a complete page of information is generated, the film is exposed and advanced one frame. While the writing and graphic display of information on the face of the cathode ray tube can be done at electronic speeds, the mechanical advance and stopping of the film for each page of information is relatively slow and is a major factor in limiting the output of a computer output microfilm recorder. Figure 21 illustrates the basic components of a typical COM recorder.

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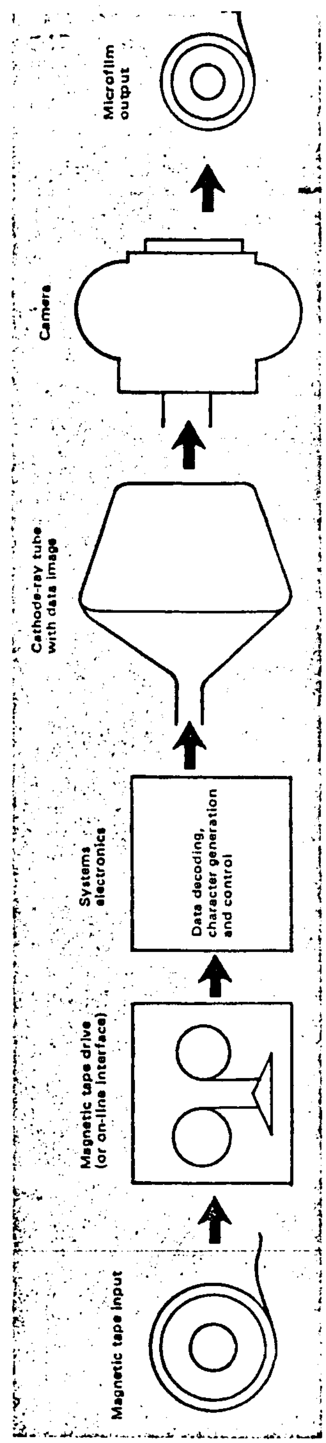
The characters, or other information generated on the face of the display tube, appear as bright figures on a dark background. The microfilm sees this as a negative image (i.e., clear figures on a dark background), and in development the image becomes positive with dark figures on a clear background. The original camera microfilm as produced by computer output microfilm recorders is, therefore, normally positive microfilm. If negative microfilm is desired, a duplicate copy must be made on a reversing microfilm (such as vesicular film), or the original camera film must be reversal processed to produce a negative camera microfilm.

Computer Compatibility. The information recorded on magnetic tape used to drive a COM recorder must be compatible with the coding and formatting requirements of the specific recorder being used. The number of tracks, the recording method, the character coding, and the block and record formatting, among other factors, must be acceptable to the COM unit. If this compatibility does not exist, software and conversion programs for the host computer are generally available to make the required conversions.

Existing computer tapes formatted for a line printer also can be used in computer output microfilmers by programing the host computer to make the recorder perform in a manner similar to a line printer. But when the COM recorder is used in this way, its full potential is not realized. For example, it cannot produce such indexing and retrieval aids as code lines, document marks, photo-optical binary codes, or microfiche headers. Also, it cannot produce formats of forms to be used as an overlay for alphanumeric information being generated.

COM Outputs. Most COM recorders have a universal camera capable of output to 16mm, 35mm, or 105mm formats. Some COM cameras have additional capabilities to handle 70mm and the 82.5mm (tabulating card size) microfiche. This capability to produce a multitude of formats is not always available in the older or specialized COM recorders.

COMPONENTS OF A COMPUTER OUTPUT MICROFILM RECORDER



Digital information from the magnetic tape unit (or a computer) is converted to characters and lines for display and recording.

Figure 21

In addition, most of the newer COM units have a choice of reduction ratios that can be utilized in producing all formats. These reduction ratios typically are 24:1 and 42:1, although other reduction ratios are used. The Department of Defense supply catalog system (MINI-CATS) uses 48:1. COM-produced microfiche with reduction ratios higher than 40:1 are sometimes called superfiche, and these typically contain over 200 pages of computer output on a single 105mm by 148.75mm sheet of microfilm. See figure 22 for an illustration of a COM-produced microfiche and typical configurations available.

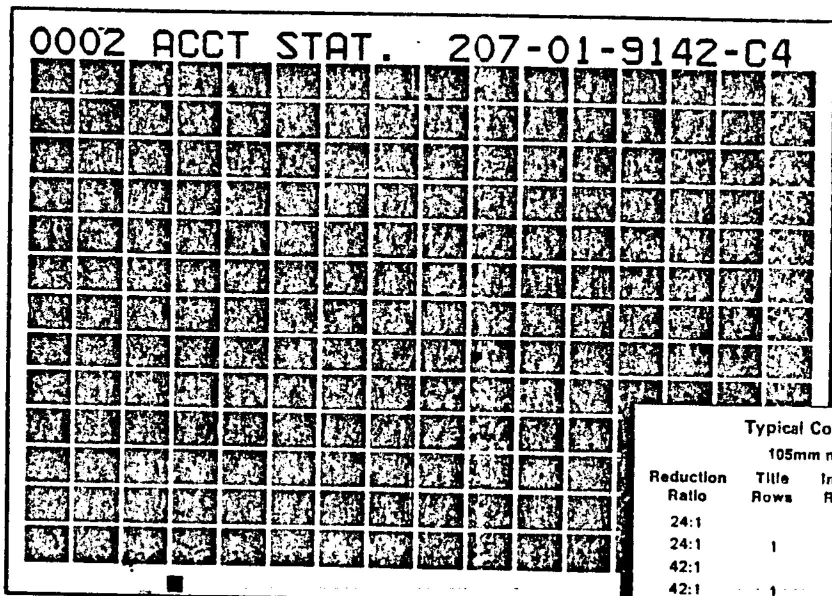
The larger scientific-graphic plotting computer output microfilm units contain their own minicomputer that permits sophisticated software to be used to produce special displays and graphics. This software covers the generation of special figures and characters, straight lines and circles, automatic dimensioning and flow charting, and other functions similar to those available for sophisticated plotters.

Graphic units have the capability of plotting complex functions one against the other or in combination with an axis. This feature can be applied in business applications as charts of sales or deviations from budgets in addition to many other forms of management information. It is often easier to comprehend masses of statistical information when such facts are presented graphically. Figure 23 illustrates an output of a COM recorder with graphic capability.

Types of COM Recorders

In addition to the two kinds of cathode ray tube recording methods previously mentioned—the shaped-beam tube and stroke

TYPICAL COM FORMATS FOR MICROFICHE



Typical Configurations
105mm microfiche

Reduction Ratio	Title Rows	Image Rows	Images per Row	Total Images
24:1		8	9	72
24:1	1	7	9	63
42:1		14	16	224
42:1	1	13	16	208
42:1	2	12	16	192
48:1	1	15	18	270

Figure 22

A COM PRODUCED THREE-DIMENSIONAL PLOT

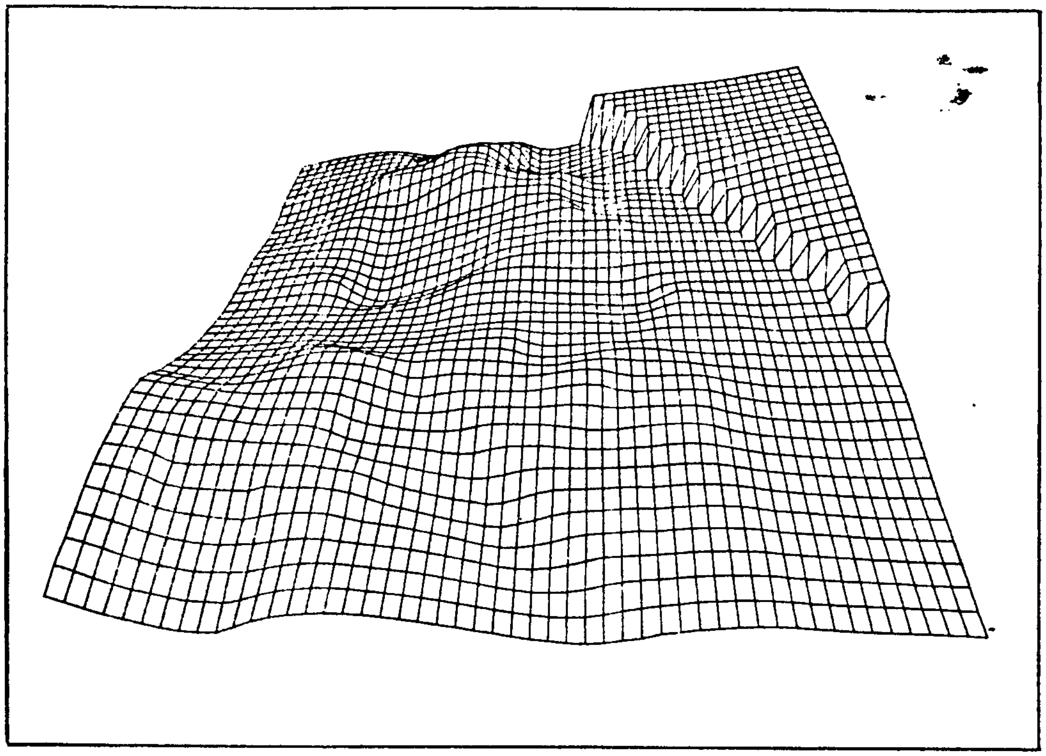


Figure 23

character writing—several other methods of character generation are commonly used in COM recorders. A third method of cathode ray tube recording known as dot matrix is used to form characters and letters of any desired shape in various sizes on the face of the display. A fourth method, electron beam recording, brings the microfilm itself inside the envelope of the recording electron tube. In this method, the image is recorded directly on a special dry silver microfilm that can be developed in-line through a heat development process.

A matrix of light-emitting diodes is coupled with fiber optics to produce a single, printline type display in yet another method of recording computer output microfilm. When energized by a pattern of signals, the diodes emit a light pattern forming a character. A single line at a time is formed, and fiber optics are used to position the matrix display so that it can be photographed as a printline. Unlike most other recording methods for COM, a single line at a time is printed closely simulating the operation of a conventional line printer. This method of recording is therefore commonly used in COM units that serve as a direct plug-in type replacement for a line printer.

The light energy available in a CRT tube is relatively low, but lasers are now being used in COM units to produce high-energy recording on microfilm. This energy is sufficient to expose relatively insensitive film, such as vesicular microfilms that also permit in-line heat development of the film.

In addition, a laser has extremely high resolution and can be used to record a digital-type pattern for later reading back to a computer.

COM Advantages

Computer output microfilm is best used when the full advantages of rapid output and the use of microfilm medium can be exploited. These advantages include:

- *Reduction of Bulk.* COM miniaturizes the output of a computer and reduces the problems inherent in handling bulk paper computer printouts.

- *High-Speed Computer Output.* Computer listings are not always economical to produce because their size requires too much time on the line printer. Since COM is generally at least 10 times faster than the line printer, it is economically feasible to produce greater amounts of information.

- *Ease of Reproduction of COM Microforms.* It is faster to reproduce rolls or other formats of microfilmed information than to copy individual pages of data on paper. A microfiche containing 98 pages, for instance, can be duplicated in 2 to 10 seconds. In the same amount of time, an office copier can duplicate less than 10 pages.

- *Reduction in Cost.* Page for page, COM output is less expensive than the equivalent paper copy. Per page costs are usually under 2 cents each.

COM is particularly effective in applications designed specifically to capitalize on COM capabilities not found in normal computer printers. Typical examples are:

- *Multi-Type Styles.* Not only are upper and lower cases common but also italic and boldface type. Some COM units can be programed to generate any desired type face. Other units have full typeset graphic quality competitive with lead composition.

- *Retrieval Coding.* Bar codes and document marks for 16mm output are commonly available, and some units can generate photo-optical binary coded microfilm. Software programs can set these codes from the information content of the image.

- *Automatic Indexing of Microfiche.* A row and frame index is produced by a computer program and placed as the last frame(s) on each fiche. Titling indicating the contents of a microfiche can also be done automatically.

- *Forms Overlay:* A form overlay can be exposed along with the computer information to provide columns and logotypes. These overlays greatly increase the user's comprehension of tabular data arrangements.

- *Graphic Plots and Charts.* The COM unit provides a great potential in its capability to plot lines, curves, and graphics. Given proper software, COM units can change virtually incomprehensible data tables into visuals capable of displaying a massive amount of interrelated information. Even three-dimensional plots can be COM-produced. (See fig. 23.) By producing a series of displays in sequence, complex data arrays can be animated.

COM Applications

Typical COM applications often use COM's massive printout capability or its capability for graphic plotting. In the first case, a large changing collection of data is routinely produced on computer output microfilm. The MINI-CATS system of the Department of Defense, produced at a 48:1 reduction on

EXAMPLE OF COM OUTPUT PHOTOCOMPOSITION

airframe frequencies of those modes which could produce ground or air resonance. Because of the numerous elastic, inertial, and aerodynamic coupling possibilities between the blade modes of a hingeless rotor, the dynamic analysis and the dynamic design are particularly demanding. A hingeless rotorcraft becomes highly unstable in forward flight and has a strong pitch-up tendency. Suitable feedback elements must be used to overcome this tendency. The feedback elements interfere with the dynamic rotor stability and add to the numerous parameters, whose effects must be studied in a hingeless rotor stability analysis.

5-3 DRIVE SYSTEM TORSIONAL DYNAMICS

LIST OF SYMBOLS

- I = lumped mass polar moment of inertia, slug-in.^{2}
- k = lumped stiffness, in.-lb/rad
- T/ q = partial derivative of the kinetic energy function with respect to the coordinate velocity $\dot{q}$
- V/ q = partial derivative of the potential energy function with respect to the coordinate q
- q = generalized coordinate
- Q_R/ω_R = damping factor for main rotor
- Q_M/ω_M = damping factor for turbine, transmission, and fan (lumped)
- Q_T/ω_T = damping factor for tail rotor
- Q = torque
- ω = circular frequency, rad/sec
- ω_i = circular natural frequency of the i^{th} mode rad/sec
- f_i = natural frequency, Hz
- J = impedance or mass polar moment of inertia
- θ = torsional amplitude
- k_n = stiffness of the n^{th} stiffness element
- p = operator signifying the time derivative

Subscripts

- E = pertaining to the engine or engine shaft
- F = pertaining to the cooling fan or fan drive shaft
- G = pertaining to the transmission
- M = pertaining to turbine, fan, and transmission lumped
- R = pertaining to the main rotor or main rotor shaft
- T = pertaining to the tail rotor or tail rotor drive
- mn = occurring between the m^{th} and n^{th} stiffness elements
- Ln = occurring at the left end of the n^{th} stiffness element
- On = occurring at the right end of the n^{th} stiffness element

Superscripts

- ′ = indicates that impedances have been accumulated from the right
- * = indicates that impedances have been accumulated from the left

5-3.1 SCOPE

This paragraph presents a design philosophy and design criteria for attaining the freedom from critical speeds or flywheel resonances required by par. 3.6.4 of MIL-S-8698. Methods are shown for predicting the natural frequencies of the drive system as well as methods for optimizing the system in the early stages of design. It is not the purpose of this paragraph to provide a means of structural substantiation for any part of the drive system since this substantiation shall be accomplished by analysis of the effects of the loads developed during the flight test program. However, calculations based on the methods shown here will provide an excellent basis for interpreting the test results.

5-3.2 DESIGN PHILOSOPHY AND DESIGN CRITERIA

The ideal design would require complete freedom from vibration. The necessary deviations from the ideal shall assure that the residual vibration is not structurally damaging and does not interfere with the operation or control of the aircraft. Flight safety and the comfort of the passengers and crew shall be assured. The criteria which follow are considered necessary for the accomplishment of these objectives:

1. Resonance, in any branch of the drive system with any multiple of the product of the rotor speed and the number of rotor blades for any of the system's rotors, shall be avoided by a 25% margin.

2. Natural frequencies of torsional vibration shall not be less than 3 Hz unless means are provided to assure that there can be no inadvertent cycling of the blade pitch controls by the pilot. This is particularly

Figure 24

microfiche, is such an example. The use of COM not only reduces the physical size of the supply catalogs to a drawer full of microfiche versus a 20-foot shelf of paper catalogs but also permits the catalog to be completely republished four times a year rather than annually with supplemental updates as was done in the paper catalog. Any large computer-produced data base that is rapidly changing and requires updating is generally a good COM application, especially if many copies are needed.

Graphic COM units have been used to produce a series of changing plots. For example, changes in the price and volumes of stocks listed on the major stock exchanges are plotted weekly using COM techniques to visually portray trends. These trends are vitally important in the buy-sell decisions. The plots are made after the close of the market on Friday, reproduced on printing plates, and printed and distributed to arrive throughout the country on Monday morning. In this case, no amount of manual plotting could produce the charts in sufficient time to meet the Monday morning deadline. (See fig. 3, chapter I.)

A third application rapidly evolving in the COM area is that of computer photocomposition or computer typesetting. In these uses, the capability of the COM unit to modify type styles and sizes is being used to produce special publications that require a variety of styles rather than the single font available in a computer printer. Using special computer programs, telephone directories, stock directories, inventory listings, and other specialized publications are currently produced by this method. (See fig. 24.)

Additional Information About COM

The National Archives and Records Service, General Services Administration, will issue "Computer Output Microfilm," a handbook in this "Managing Information Retrieval" series of its Records Management Handbooks.

The National Microfilm Association (8728 Colesville Road, Silver Spring, MD 20910) has publications related to COM, including COM standards. A list of their publications is available upon request.

Several organizations have been formed to encourage interchange of information. These user organizations are valuable sources of information concerning applications and special COM software.

The National Technical Information Service, U.S. Department of Commerce (Springfield, VA 22151) collects, indexes, and distributes unclassified Government research reports. Various reports on COM (and other technical areas) are available. An up-to-date bibliography with abstracts can be produced on demand for a $25 fee.

VI. WHEN TO MICROFILM

Designing a Microfilm System

The designer of a microfilm system must understand the nature of the material to be filmed, its flow through successive operations, and the use to be made of the information. The shape, size, and condition of the material will often determine the microfilm production methods and formats, while the use of the information will set the requirements for indexing and retrieval. This chapter considers these aspects in determining whether to microfilm; the following chapter considers how to design a microfilm system and how to evaluate and select alternative systems (including the present paperwork system).

When To Consider Microfilm

The prime reason to use microfilm is to achieve better physical management of the material concerned. The reduction in size, the improved handling and reproduction, and a bound order improves usage by several magnitudes. Preservation of historical or otherwise valuable records is another reason often given as a basis for microfilming.

There follows a discussion of some of the problems often encountered with conventional files as well as examples of how microforms have overcome some of them. In considering the feasibility of a microfilm system, a systems designer must evaluate not only the severity of these paper copy systems problems but also the cost/benefits of a proposed microform solution, as well as its capabilities, if any, to solve the problems encountered.

Possible Problems of Paper Copy Storage

The problems of storing information in its original paper copy format must be understood in evaluating when and why to microfilm records. Factors of size, access, preservation, and identification are present as potential problems in every paper copy system.

The physical size of paper copies is relevant both in terms of the space required to store a particular collection and in terms of the variation in size of individual records. Back collections of newspapers, for example, are extremely difficult to store on other than open shelving. Access is clumsy, and piles of newspapers are usually heavy. Business records can be stuffed in file cabinets, and the file cabinets can reduce office space to narrow aisles unless a systematic records retention and disposal plan is actively followed. The physical bulk of computer-produced paper records often reduces their usability. Engineering drawings are filed by size rather than by their content to facilitate storage more than reference needs. Handling large roll-type engineering drawings often requires the equivalent of an octopus rather than a small feminine file clerk. In all instances, the physical size of the collection itself often reduces the usability of the information. Access can be limited, and misfiled or charged-out records are common.

The ready availability of rapid copy machines has compounded conventional filing problems. Multiple copies of all types of documents are now reproduced and filed in multiple files. Centralized filing, once the backbone of business files operations, is often considered less necessary because everyone has his own copy. Many partial files tend to exist rather than one well organized complete collection of information. The lack of controls over the location of an agency's records in turn generates the need for more individual copies of every record created.

Unless physically bound into a book, paper copies received daily for filing are usually unit records with one or a few pages representing a single filing unit. This characteristic results in multiple possibilities for filing and indexing any set of documents according to office practice, or a user creating his own file system and arranging his documents accordingly. Even within a standard subject file system, many variations are possible when indexing and filing recorded information.

Paper copy systems exist to store information for some period of time. While most systems are suitable for their intended need, if historical or permanent reference value does develop, some types of paper may not be a suitable medium for more than a few years' storage. This is particularly true in environments having severe air contamination or in storage facilities having high humidity and dirt.

Microfilm System Solutions

Reducing Bulk in Files. The reduction of file space realized with the use of microfilm is probably its most obvious advantage. Only about 2 percent of the space required for paper files is required for microfilm.

Storage and Retrieval of Information. Large collections of information can not only be stored but often can be retrieved faster by using microform indexing and retrieval techniques. For example, retrieval of material from large technical catalog files is greatly improved by using microfilm instead of paper copy, and many such catalog files are being converted to microform systems.

Reproducing Information. Old historical records are usually unique copies and are often too fragile to use or even photocopy. Access to these records, which would otherwise be completely unavailable, is gained through conversion to microfilm. For example, the Schomburg Collection of Negro Literature and History, representing many unique and rare literary items, is widely available in microfilm. The National Archives and Records Service micropublishing program is designed specifically to make available to as many users as feasible many collections of older records in its custody for which a reasonably high reference rate has been established.

Distributing Information. It is much easier and cheaper to distribute microfilmed copies of a document to many scattered locations than to send multiple copies of a paper document in the mail to each location. Both Government agencies and private organizations base their micropublishing programs on the ease of distributing miniaturized information and the ease of storing, retrieving, and updating it at the many locations receiving the microforms.

Rapid Accessibility. Miniaturization of large records collections using microforms makes it possible to keep the entire collection in one location. With paper records, older records that a user requires may be in a storage facility some distance away from the office. With miniaturization, it is also easier to manipulate the information or mechanize its retrieval when reference needs justify it. Much less time is required for micropublishing large data bases than that needed for conventional publishing, so that access is also improved by shorter turnaround periods.

Preservation of Records. Microfilm can easily record and conveniently preserve decaying and fragile records. Reduction in size and lower reproduction costs may also permit storage of the original film offsite for security.

Microfilming Versus Federal Records Center Storage

Federal records centers provide an economical means for storing inactive records that are covered by disposition schedules and that normally are stored for at least 3 years. Microfilm storage and retrieval systems are most efficient for records with a high reference activity and for which the user has a need for immediate access to the entire records collection.

Because of the cost/benefits offered by center storage, as compared to microfilming, it is seldom, that an analyst can justify microfilming solely in lieu of storing a collection of inactive records in a Federal records center. While it is difficult to show precisely comparable costs, consider the following comparison based on presently available costs covering the operations of the center system as compared to charges made for reimbursable microfilming by Federal records centers. These computed costs for maintaining a cubic foot of records in a regional Federal records center include costs of accessioning, disposal, reference services, and shelving, and also maintenance charges for space occupied. At the time of this writing one cubic foot of records can be fully maintained and referenced for about 70 years before this computed cost equals the center microfilm charges for producing a master negative and a diazo working copy of a typical roll of microfilm containing these records. These microfilm charges do not include charges for extensive document preparation prior to microfilming, or costs of viewing equipment at users' offices.

Records Activity Factors

Microfilm systems can be designed for either highly active records or for relatively inactive records. Whether active or inactive, each microfilm system designer must consider the record activity at the time of microfilming and the retrieval requirements after microfilming. Some records, such as engineering drawings, are microfilmed as soon as they are released from the draftsman. In other cases, microfilming may be delayed until the record becomes relatively stable and unlikely to change.

Microfilm designed for use in an active information system is usually produced at a point when the record becomes relatively formal, and it is recognized as a complete record. Documents in the process of being prepared are seldom microfilmed because incomplete fragmentary information on office transactions is of little value.

To the extent that microfilming active records may introduce a delay in the flow of information from several hours to even a week or more, alternate paper systems may be needed to permit usage in the paper format while the microfilms are being produced.

Determining the Potential for a Microfilm System

To summarize the points mentioned previously, there are certain commonsense considerations a systems designer must take into account when determining the validity of a proposed microfilm system. These include:

(1) The recorded information will be in continuous use for a long period.

(2) The information is needed at a single location where there is a high reference rate, or at numerous locations having a moderate to low reference rate.

(These two conditions should be met to compensate for the initial expense involved in producing the microfilm and providing needed viewing equipment.)

(3) The microfilm system will have a proven capability to meet known user requirements.

(4) The existing system cannot meet user requirements for information as effectively as the proposed microfilm system, even if the existing system is improved to operate at top efficiency.

In addition to these commonsense considerations, three other factors listed below can guide a systems designer in determining when to apply microfilm in lieu of a conventional paper system.

(If a microfilm system is proposed in lieu of an existing computer system, the systems designer will base his decision on the capabilities, if any, of the microfilm system to meet proven information requirements of users more economically than the computer system, rather than the factors for comparing microfilm with conventional paper systems listed below.)

Factor 1. Obtain as many as possible of the various advantages of microfilm as compared to paper records, as follows:

a. Space and filing equipment savings.

b. Records of a uniform size for filing and searching.

c. Immediate access to an entire file of information retained in office space on microfilm, instead of breaking the file periodically and transferring segments to storage space at another location.

d. Ease of obtaining relatively inexpensive duplicate copies of recorded information for multiple users of records, including copies for vital records storage facilities.

e. Ease of sending copies of miniaturized records to multiple users at many locations.

f. Ease of manipulating miniaturized records for reference and the possibility of mechanizing searches of microforms.

g. The acceptability of microforms as permanent storage media, if properly produced and maintained.

h. The ability to maintain file integrity by using roll film formats or by making inexpensive duplicates of needed information from a master microfilm set of unit records.

(Note: Few, if any, microfilming programs can be justified solely on the basis of saving space and filing equipment, because of the availability of controlled storage space for inactive records in Federal records centers.)

Factor 2. Consider the following limitations of most microforms in designing a system:

a. Relatively high costs of producing good quality microforms including: personnel, materials, and equipment costs for physically arranging and preparing paper documents for filming, camera operation, film processing, film inspection, film duplication, packaging, maintaining the master set and microfilm copies, and preparing finding aids as required.

b. The need to obtain viewing equipment at each user location and, as required, equipment to convert microfilm images back to paper copies.

c. The need for personnel with special skills to produce quality microforms.

d. The need for a promotional effort to sell first-time users of microforms on accepting miniaturized records instead of paper records.

e. Except for library-type applications, the need for making certain, often based on the advice of legal counsel, of the legal acceptability of microfilm as applied to the specific records under consideration.

f. The expenses of merging updated information into the microfilm system.

Factor 3. The cost/benefit justification required. Because of the relatively large capital costs involved in a proposed microfilm system. agency management should expect a systems designer to provide a complete cost/benefit comparison of the existing system and the proposed microfilm system. Unless the designer can demonstrate the cost effectiveness of the microfilm system, it probably should not be installed. See chapter VII, page 53, for details on how to present cost/benefit justifications to agency management.

VII. MICROFILM SYSTEMS DESIGN

System Design Principles

A good microfilm system is designed by following the basic principles of systems analysis that would be used in analyzing any information storage and retrieval system. The first step is recognition of the problems associated with the present system or realization of the need for a new system. After the need for a new system or system improvement is established, the analyst must gather, organize, and analyze all of the facts related to the problem. These facts will include the current methods of record creation, the need for the record in carrying out the mission of the agency, the content and format of the record, and the current flow of the recorded information from creation or receipt through storage and maintenance to final disposition. The facts must be analyzed with a view to designing a system which meets the functional needs of the users including any special agency requirements. The system requirements are translated into equipment and technical processes, and finally into specific procedures and instructions to develop the operating system. Figure 25 illustrates these concepts of microfilm systems design.

MICROFILM SYSTEMS DESIGN CONCEPTS

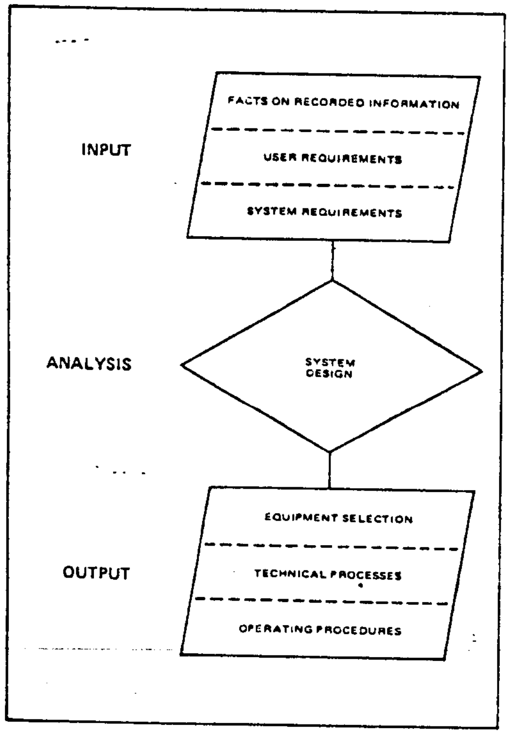


Figure 25

Surveying the Present Paperwork System

A good system cannot be designed in a vacuum, and a thorough understanding of the existing paperwork system is imperative. The preparation of a detailed flow chart of information as it moves through the existing paperwork processes facilitates obtaining an understanding of the system. The physical flow of information must be traced, and required actions must be noted to determine who does what and when. All information transfers must be documented. Delays in handling information should also be noted. To obtain adequate information, the systems designer should make first-hand observations of the system and interview the personnel involved.

Standard flow charting methods can be used in defining the problem and determining the solution. The National Microfilm Association has developed flow chart symbols and a template specifically designed for micrographic systems. In addition, the National Archives and Records Service has a handbook "Simplified Flowcharting," which outlines uniform flow charting techniques and symbols usable for flow charting any type of paperwork system.

Collecting the Data

Defining the Scope and Coverage. The overall paperwork system may be very complex and broad. A clear definition of which segments of the overall system will be included is needed early in the analysis. The designer must have a clear picture of the overall system and how the parts interrelate to be able to decide which information can be advantageously recorded and used on microforms.

The analyst must set limits within the overall system processes for study and concentrate on the processes which have the best potential for conversion to microfilm. Sometimes only 10 percent of a collection of recorded information will generate 90 percent or more of the actual usage. In such cases, a logical system design would separate the high-activity portion from the low-activity records. The same is true if the active and inactive segments of a records collection are separated and identified. The analyst may determine that microfilming is practical only for the relatively inactive segment of a file. leaving the active segment that requires constant interfiling as paper copy.

Describing the Record. Each collection or type of record in the system should be fully described and identified. The purpose of this identification is to determine the complete range of physical variations in the records, such as physical size, age, and the like. In particular, the analyst should note conditions such as the following that will affect the photographic process:

- *Background color.* Red and pink backgrounds are difficult to photograph satisfactorily as are yellow on white or blue on blue and other low-contrast combinations. Other colors will cause some variation in overall background density as compared to black on white. Color-keyed material may have to be marked as the colors will appear as shades of gray on black and white film.

- *Type size and quality.* The size and quality (clarity) of the smallest type size should be noted, and the reduction ratio to be used must be capable of handling this minimum size and quality type face. Lightly penciled annotations or smudged rubberstamped imprints may not be legible on microfilm.

- *Photographs.* Microfilming and reproduction of continuous tone photographs requires a special microfilm in cases where the continuous tone of the photograph is vital to the information content. Printed photographs, such as halftones from magazines or newspapers, will generally microfilm with sufficient quality to satisfy the average situation.

The analyst should obtain information on how the material is physically arranged, how it is bound together (paper clips, staples, hard bindings, and folders), the sequential arrangement applied to the file, and the methods by which it is actually indexed and located within the physical collection. Most files will require some cleanup prior to microfilming, and often removal of duplicated or unnecessary information may be needed in addition to removal of staples, clips, or other incidental materials. The papers may have a high percentage of pages with folds or tears that will require special treatment. In addition. resequencing the papers to insure the proper arrangement of the file may be needed prior to microfilming. The analyst should also obtain information on the rate of activity and types of uses made of the records. The use of indexes, the interfiling practices, and the identity of the users should be noted. The requirements for updating the file must also be carefully determined and noted, particularly for active file use.

Some files will require special treatment because of the sensitive nature of the information they contain. Classified materials must be handled following approved security control procedures including those covering the maintenance of microfilm duplicates. The security officer responsible for such holdings should be consulted prior to any decision to microfilm. In addition, appropriate procedures and safeguards should be built into the microfilm system to insure that no records are lost and that minimum delay is encountered during the microfilming processes.

User Requirements

Identifying Users and Needs. A systems designer must be able to identify who needs what, where, and when. Typically, users will be in one of three general classes: major users, the average or typical users, and minor or incidental users of information. Users should be grouped into these or other typical classes as necessary to best describe the use of the recorded information. Other classes might be those who analyze and further process the information received and those who merely retrieve the data needed for transcription and deliver it to the ultimate user.

For each class of user, the frequency of his use of the files, the methods by which he requests and locates information, and the responses required should be determined. The amount of delay tolerable in locating information is a helpful additional item.

Users are seldom located together, and the geographic or physical distribution of all users of the system should be determined. This geographic distribution is usually different from the location of the present files, since the present files are usually in one location only, while the potential and actual users of a microform may be geographically dispersed.

Usage of Information. Each set of users will typically have different requirements for actual use of information. In some cases, retrieval is necessary only to make a quick reference check of a specific fact, number, or other item of data. Within a personnel file, for example, one may desire to confirm the initial date of employment of an employee. Similarly, inventory control and stock level systems seldom require a complete page of information but rather only a specific line or fact. In other cases, however, the complete paper copy is required, and typically the user presently makes a photocopy of the existing paper records. In yet other instances, the user may require the complete text or a multiple number of pages of information, such as in a library situation. Another variation is possible where the user needs bits of information from several points within a single record, and he currently abstracts the information he desires. These variations in usage have great impact on the system design and should be carefully established and noted for all users.

Quality and Standardization Requirements. Requirements for further reproduction of the microfilm to both film and paper copy should be noted and related to the overall quality of the original material. System requirements to interface with existing microfilm formats should also be noted as this factor may limit the choices available to the system designer. Finally, consideration must be given to future growth and expansion of the system. A 5-year projection of data volume and reference activity is often helpful in determining the importance of the growth factor.

Data Analysis

The information collected must be organized into user requirements for information and finally into system requirements for the proposed methods, equipment, materials, and procedures that will be used.

User Requirements. Information collected should be arranged in such a manner that user requirements for information at each location involved can be readily presented. These requirements should be noted in terms of the quantity and quality of the needed information, the indexing and/or search tools required, the frequency of use for each type of recorded information, and the acceptability of or requirements for microfilm equipment at each location. It is helpful to note any special preferences of users, in addition to requirements for training or attitude development prior to introduction of the microform system. High rates of reference among particular groups may warrant special consideration to meet their needs. Those expected to use microfilm equipment more than a few minutes a day in the ordinary course of their work should receive special attention and participate fully in the definition of their requirements and eventually in the selection of their microfilm equipment.

System Requirements. System requirements can be expressed in terms of input processing and output of information, and should take into account compatibility with existing systems, costs involved, and possible growth of the system.

Input considerations for the microfilm system concern how material will be microfilmed and the characteristics of the original documents. Input can generally be divided into two operations: establishing the initial microfilm file and later maintaining or updating the file. The system designer must establish where, when, and how to microfilm the initial file. In some instances, if it is necessary to keep to a minimum the time records being microfilmed are restricted from use, the analyst must make certain his microfilm input processing meets these needs.

The indexing of microfilm information systems is often done during this input process. Depending upon the selected indexing method, this step may be necessary prior to or immediately following the microfilming of the records.

The analyst must also plan for an updating procedure if other than a closed file is involved. Overall system requirements for updating the microfilm and its index must be specified. These functions are usually performed at a central point, but sometimes it may be necessary for the user or file-holder to interfile updated microfilm information with previous information, such as in a decentralized engineering drawing file on microfilm aperture cards.

Finally, *output requirements* for the system must be defined. How must the system provide information to the user? How many different places are required for output? What variations will be made in the use of the information at these points? The users' requirements developed previously must be defined in terms of system requirements for actual delivery of information. This analysis tells the designer what information is required where, how often it is needed, and the acceptable formats of this information.

An additional set of requirements exists for the overall system. As previously noted, it may be desirable to use available microfilm equipment. In addition, other information bases may be available in a specific format that would be more accessible to users if placed on microfilm. At the same time some consideration of the future needs and growth for the file is essential to provide an open end of the system. Future growth should not be stifled by some inherent shortcoming of the overall system design. Finally, requirements for economy of operation and total system costs must be kept in mind. No Government office has unlimited funds at its disposal. Regardless of the advantages claimed for a proposed microfilm system, both the initial installation costs and the continuing operating costs of a microfilm system must be held to reasonable limits.

Microfilm Alternatives

A systems designer may sometimes find that there are several different types of systems and microforms that might satisfy the system requirements as he has identified them. In other cases, careful consideration of the user and system requirements will reduce the number of feasible alternatives and show one type of system and microform superior to the others. One factor that may affect the choice of the microform is its overall compatibility with other microfilm systems in the agency or office. For example, microfiche may be the logical choice, but use of this microform may not be feasible if it will not permit use of available equipment and would require the acquisition of much new equipment. Other factors that may affect the type of microform selected are the following:

Document Size and Shape. Document size, shape, and quality may limit the types of microfilm systems that are feasible. Using conventional methods, documents larger than 12 by 18 inches cannot be satisfactorily microfilmed in 16mm roll formats nor conventional microfiche formats. Large-size documents, such as newspapers, maps, or engineering drawings require 35mm film. If a microfiche format is desired for large documents, the master is typically made by stripping 35mm film or using 35mm jackets rather than by using a step-and-repeat camera.

To use a rotary camera for microfilming, for example, documents must be single pages and may not be ragged or fragile. Large bound volumes require a planetary camera and a special cradle to keep pages on a plane at the proper focus position.

Document Quality. If the original documents are of poor quality for photographing with wide variations in color, contrast, or extremely fine typeface, planetary microfilming is desirable to attain the highest possible quality film output. These same factors may also make it desirable to use less than the maximum reduction ratio in order to improve microfilm quality. If a great number of film generations are needed, a very high initial film quality must be obtained, often by using low reduction ratios. A resolution loss of 10 percent in each generation is not uncommon. Sometimes the system designer cannot control the original document quality because the documents are from many sources, such as income tax forms. In some microfilm systems, a great deal of preliminary time may be needed to enhance the contrast on the original document in order to obtain usable microfilms. In one engineering drawing system, it was necessary to employ several draftsmen to improve the quality of drawings before microfilming them.

Selecting the Microform

If high image quality requirements or the size of original documents dictates, 35mm film may be selected, and the choice then usually becomes one of a 35mm reel or cartridge system, or of cutting and mounting frames into aperture cards or jackets.

If document size and quality permit using 16mm formats, the choice then becomes a selection of various 16mm reel, cartridge, or cassette microforms versus a microfiche or jacket format. The choice between the roll system and the microfiche system is largely dictated by the nature of the original documents or the need for compatibility with other existing microform equipment. For example, conventional microfiche systems are adaptable where the basic documents microfilmed consist of 20 or more pages of information, such as technical reports. In addition, the microfiche format is typically used in situations in which a copy of the document is sent to many different users. With the advent of computer output microfilm, the microfiche format has found wide popularity even for serial-type files of stock numbers and inventory control systems because microfiche readers are relatively inexpensive and easily maintained and because of the ease of physically filing and retrieving individual microfiche. Microfiche should be considered, therefore, for systems requiring many low-cost viewers and rapid retrieval.

Roll systems are particularly adaptable to large collections of single or several-page records, particularly where a separate indexing system is maintained and a retrieval locating number is utilized. Roll systems, however, are difficult to update.

These physical attributes of various

microforms are only one factor the systems designer considers in selecting a specific microform. Features such as file integrity, rapid and easy handling, equipment costs and availability, and user needs are important and must be considered before the microform is selected. The specific advantages and disadvantages of each of these microforms are discussed in more detail in chapter IV.

Meeting Storage and Retrieval Needs

A systems designer should consider the needs of users in storing, retrieving, and filing the microforms they will receive in addition to the reference needs of these recipients. The designer should consider such matters affecting users as:

- Work involved in the initial installation and operation of the equipment.
- Planning for the initial establishment of the microfilm file and the appropriate indexes.
- Training of users in both the operation of equipment and use of the microfilm.
- Instructions on interfiling and maintaining both the microform and any index system on a current basis.
- Adjustment, cleaning, and minor maintenance of microfilm equipment.
- Microfilm storage equipment and supply needs at all user locations.

Unless these types of needs of users are satisfied, they may reject a microfilm system they feel is too difficult to operate and maintain and which they believe causes them difficulties in obtaining needed information.

Determining Costs

Any microfilm system, with its requirements for document preparation prior to filming, camera operation and film processing, film inspection, and use of readers or reader-printers to view and retrieve the information will involve substantial costs. With the wide variety of microforms, indexing methods, and retrieval systems available, some of the alternatives are inherently more expensive than others.

For example, basic roll microfilm systems, consisting of document filming on a rotary or planetary camera combined with simple manual readers and simple indexing systems, are the least expensive to establish. These systems, however, may require the user to spend more time to find the information he is seeking than more sophisticated systems. The more advanced systems, requiring a complex index, are more costly to establish because of the indexing labor required, and usually demand more sophisticated readers and reader-printers. The more complex automated retrieval systems, combining computer index search with automatic retrieval of the microfilm image involve such high installation costs that they usually must be justified on some other basis than cost, such as speed of retrieval, file integrity, ease of operation, or improved service to the public.

Cost/Benefit Presentations

Regardless of the complexity of the microfilm system to be installed, any microfilm system normally involves such extensive costs that agency managers should expect a systems designer to provide them with some form of cost/benefit justification to assist them in deciding whether or not to accept a proposed system.

While there are several ways the designer can format his justification, two that have been used are as follows:

Comparison of the cost effectiveness of the present paper system and proposed microfilm system. This method of determining cost effectiveness attempts to quantify and compare the costs attributable to the present system with the tangible and intangible costs and benefits of the proposed alternative microfilm system.

Before any analysis can be made, however, a common basis for comparison of the systems must be defined. Volumes of recorded information, rates of input and search time, and coverage of the present system should be compared against similar volumes, rates, and coverages of proposed alternative systems.

Adjustments to the data may be necessary to obtain a valid comparison if the present system and the proposed system do not appear to be basically similar in all these areas.

Comparing tangible costs is the easiest method of presenting such a cost/benefit analysis. By assigning dollar values to represent the costs of both systems and the benefits to be obtained from a proposed microfilm system, it is possible to derive comparable costs, net savings, or cost avoidance figures. Figure 26 illustrates a format for a side-by-side comparison of costs and possible benefits. A separate form could be prepared if more than one alternative microfilm system is proposed.

Separate attachments should be included for itemizing the components comprising the various cost/benefit categories included on the summary form.

Direct labor costs are calculated on the basis of total hours required to operate the present information facilities and those estimated to operate a proposed microfilm system. The total hours are converted to dollars using appropriate average hourly wage rates paid to various types of employees involved. Supervisory and other personnel costs are expressed as a percentage of the direct labor costs; for example, 10 percent represents supervisory costs and 7½ percent represents health and retirement benefits Government employees receive.

Equipment costs include purchases (amortized), rentals, depreciation, and maintenance expressed in dollars and converted to annual, monthly, or hourly rates as appropriate to match other cost categories.

Supply and other costs include the costs of all film, film processing, reader-printer paper and chemicals, cartridges, projection lamps, labels, and file folders.

While not fitting the format of figure 26, figure 30 on page 75 provides information that can assist the systems designer in estimating proposed microfilm systems costs. This figure presents the present charges for reimbursable microfilm services by the Federal records centers of GSA and is periodically revised and updated (primarily when salaries of Government employees are revised). If an agency is not planning to establish its own microfilming operations, these costs for microfilming, film processing, and film duplicating can be used in estimating proposed microfilming costs. Note that they do not include any costs for searching, such as costs of readers, reader-printers and similar equipment. Before using the fees in this figure, the designer should check with NARS to obtain the most recent fee schedule.

If deemed appropriate, additional costs expressed as a percentage of the totals shown as item 5 of figure 26 can be added to represent other overhead costs, such as space, management services, and heat and light. This overhead figure can represent part of the intangible costs of the present and proposed systems.

It is more difficult to compute dollar benefits derivable from the installation of a microfilm system. These are often intangible, such as faster retrieval of information, greater use of the data base, and better service to the public. There could even be some intangible costs of the present system that might not have been included in the overhead percentage (item 6 of figure 26); for example, estimated costs of "can't finds" or other costs associated with lack of retrieval

SUMMARY COMPARISON OF ANNUAL COSTS – PRESENT AND PROPOSED SYSTEM

ATTACHMENTS:

A. Direct Labor Schedule
B. Basis for Supervisory and Other Personnel Costs and Other Overhead
C. Equipment Schedule and Calculation of Annual Cost (include maintenance)
D. Schedule of Supply and Other Costs
E. Intangible Costs/Benefits

(Enter N/A for any item not applicable.)

		Present	Proposed	
Direct Labor Costs per year (hours x average rate/hr) (See Attachment A)	TOTAL	$______	$______	(1)
Supervisory and Other Personnel Costs (____ % of Direct Labor Costs) (See Attachment B)	TOTAL	$______	$______	(2)
Equipment Annual Cost (See Attachment C)	TOTAL	$______	$______	(3)
Supply and Other Costs per year (See Attachment D)	TOTAL	$______	$______	(4)
TOTAL Costs (Items 1 to 4)		$______	$______	(5)
Other Overhead (___% Item 5) (See Attachment B)		$______	$______	(6)
TOTAL Cost Per Year		$______	$______	(7)
Intangible Costs or Benefits per year (See Attachment E)		$______	$______	(8)
Derived Cost		$______	$______	(9)

Figure 26

SAMPLE FORM FOR OFFSETTING PRESENT SYSTEMS COSTS

CURRENT ANNUAL INFORMATION COST (Complete this part to summarize total current information retrieval resources and costs, which need to be taken into consideration, when developing the proposed system. Enter N/A for any item not applicable.

1. PERSONNEL COSTS	a. SUPERVISION AND OPERATION OF INFORMATION FACILITIES	
	b. OTHER PERSONNEL COST INVOLVED IN STORING AND RETRIEVING THIS DATA	
	TOTAL ANNUAL PERSONNEL COSTS	
2. EQUIPMENT COSTS AND SERVICE CHARGES	a. RENTAL COSTS, IF ANY	
	b. DEPRECIATION	
	c. MAINTENANCE	
	d. OTHER EQUIPMENT COSTS	
	TOTAL ANNUAL EQUIPMENT COSTS	
3. SUPPLY COSTS	a.	
	b.	
	c.	
	TOTAL ANNUAL SUPPLY COSTS	
4. SPACE AND MISCELLANEOUS COSTS	a. SPACE	
	b. MISCELLANEOUS COSTS	
	TOTAL ANNUAL SPACE AND MISC. COSTS	
5.a TOTAL GROSS CURRENT ANNUAL COSTS to be taken into consideration in development of the proposed system (items 1 through 4)		
5.b LESS ANNUAL RESIDUAL COSTS, IF ANY FOR SERVICING EXISTING INFORMATION FACILITIES, WHICH MUST STILL BE REFERRED TO AFTER NEW SYSTEM IS INSTALLED		
6. ADJUSTED GROSS CURRENT ANNUAL EXPENDITURES FOR STORAGE AND RETRIEVAL OF INFORMATION, WHICH ARE AVAILABLE FOR APPLICATION TOWARD COST OF NEW SYSTEM		
7. ESTIMATED COSTS attributed to NOT being able to RETRIEVE and/or manipulate information WHEN NEEDED. (describe)		
8. VALUE OF USER MANHOURS, which could be saved, if modern information retrieval system was installed		
9. TOTAL Estimated net annual expenditures, which are available for application to cost of proposed information retrieval system (add items 6 through 8)		

Figure 27

of needed information because of system deficiencies. Such intangible benefits and costs can be estimated, quantified, and thoroughly documented on attachment E.

If intangible costs are included, they should be entered in item 8 and added to the total costs of the present system (item 7) to compute item 9. Intangible dollar benefits derivable from a proposed microfilm system can be entered as item 8 and subtracted from total costs entered as item 7, to prode the derived cost for the proposed system (item 9).

In effect, this method provides a cost justification for a proposed microfilm system, which can be manipulated to show either a positive or negative relationship depending on what factors are considered. The systems designer must clearly establish in his presentation to agency managers the difference between the tangible and intangible costs and benefits. The more intangible the costs or benefits are, the less valid management should hold the dollar figures estimated to represent them. Often, the systems designer will attempt to convince agency managers that the intangible benefits obtained from a proposed microfilm system will outweigh the estimated greater tangible costs as compared to the present paper system.

Estimating the amount of microfilm systems costs that can be offset by the present system. Another method that has been used in presenting proposed microfilm systems costs is to ascertain how much of the costs of the proposed microfilm system can be offset by costs associated with the present system. Figure 27 presents a format that can be used to estimate proposed microfilming systems costs in this manner.

When applying this method, the systems designer must consider all appropriate tangible and intangible costs of the present method. Such costs as those involving personnel, equipment, service charges, supplies, and space can be used as an offset to costs associated with the proposed microfilm system. Note that item 7 of figure 27 allows for quantifying intangible costs of the present system resulting from its inability to retrieve information when needed, and item 8 for estimating intangible benefits from faster and easier retrieval of information by the proposed microfilm system.

Whatever method is used, the key is for the systems designer to have valid facts that can convince his agency managers that the costs attributable to a proposed microfilm system can be justified in terms of the benefits that will be derived from the system.

Planning for Implementation and User Training

The systems designer should develop a detailed plan for implementing the proposed microfilm system. Microfilm is often a new medium for most users, and unless the proposed system is properly presented and introduced, user acceptance may be marginal. Onsite training of the users is highly desirable, as is appropriate followup and refresher training. Most microfilm systems exceed paper systems in their capabilities, and these advantages must be stressed. The supervisory personnel of user groups must be aware of potential problems and how to solve them. One major potential problem that should be avoided is the overuse of reader-printers by those who insist on reading hard copy only. If properly designed readers have been provided, most information requests can be answered by viewing the information on the reader screens.

The implementation phase is also important. In large systems, parallel operation of a test group of users is often desirable in discovering simple ways to improve the system. Proper internal publicity can shape attitudes in user acceptance of microfilm.

The implementation plan, prepared as part of the system design, can include:

- Overall time scheduling.
- Selection of the test material and user evaluation groups.
- Test and evaluation plan.
- Equipment and supply procurement schedules.
- Facilities and services schedule.
- Microfilming schedule and logistics of moving and controlling film and paper.

- Initial, intermediate, and final distribution plans.
- User training and acceptance.
- Equipment maintenance and repair plans.
- File updating and control plans.