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# **MICROMATION**

# **FILM MANUAL**

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***Datagraphix***

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## FILM MANUAL

### FOREWORD

Microfilm is the name given to photographic film which bears a greatly reduced image, usually of a printed document.

This manual is concerned primarily with microfilm but it does, however, give general information on different kinds of film; its structure, its uses, its handling, its possibilities and limitations.

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## SECTION I

### HISTORY OF MICROFILM

The first important date in the history of microfilm is 1839. In that year John Benjamin Danzer of Manchester, England, installed a microscope lens in a camera and succeeded in making a microphotograph of a document. Rene Dagron, however, is generally considered the father of microphotography because the first patent ever granted in microphotography was issued to Dagron in France in 1859.

Probably the first use of a microform was during the siege of Paris by Prussian armies in 1870-71 when microfiche was used by the French postal authorities to communicate with the outside world. The tiny microfiche were transported by carrier pigeons in a "Pigeon V-Mail" service. Information was microfilmed on collodion plates, stripped, and cut to approximately 36 x 60 mm. Each strip could contain up to 80,000 words and one carrier pigeon could fly as many as 21 of these stripped-collodion films. When the pigeon arrived in Paris, the films were sandwiched between glass and projected on a wall. By the end of the war, some 2½ million copied messages had been successfully carried across the German lines.

Not until after World War I was microfilm used to solve important business problems. The innovation that opened the way was the development of the rotary microfilm camera by George McCarthy, a New York city bank clerk and amateur inventor.

McCarthy frequently encountered problems on his job when customers claimed that their account had been debited for checks never drawn. Since the bank returned cancelled checks to its customers, it frequently was not possible to determine whether the customer was telling the truth. So, McCarthy set out to invent a machine that would make a photographic record at high speed of all checks deposited. With the aid of Raymond Hessert, an engineer partner, he worked out a machine in which a check conveyor belt was synchronized with a motion picture camera. They applied for a patent in 1925. Unfortunately, checks on some colored papers did not photograph clearly and neither did signatures in light blue ink. While bankers showed interest in the check photographing machine, they were not interested enough to purchase it. The engineer partner grew discouraged and McCarthy bought him out.

Shortly afterward, McCarthy's tenacity paid off in storybook fashion. The management of Eastman Kodak Company had learned about the machine, and they showed more than just interest. Kodak signed a handsome contract with McCarthy involving a lump sum payment, future salary, and royalties. Then Kodak put its engineers to work ironing out the kinks in the check recording machine. On May 26, 1931, the U. S. Patent Office issued Patent No. 1,806,763 to Mr. George Lewis

McCarthy for a "Photographic Apparatus" which was, in reality, the first microfilm camera.

By 1933, there were 700 machines operating in American banks. The machine had, by then, been given the name Recordak.

Active commercial use of the microfilm in the control of business records outside the banking field was also promoted by the new Recordak Corporation in the 1930's. Rotary cameras went into use for such purposes as making records of retail receipts in department stores. Stores adopted systems whereby they mailed sales receipts to customers as proof of purchase after making a microfilm record, thus saving considerable extra paper work.

For many years microfilm continued to be used solely for protection and in limited use by banks and department stores. A new and large scale use for microfilm came in 1936 when the Social Security Act was passed and millions of applications were processed and a year later it was decided to put these records on microfilm for protection.

Then in 1940 a real milestone was reached when the U. S. Government legalized the destruction of documents after they had been micro-filmed.

During World War II, microfilm was used extensively by industry to safeguard engineering drawings, V-mail was introduced during this period and it is estimated that some one and one-half-billion letters were filmed and delivered to the Armed Forces overseas. In addition to this, aperture cards were used in intelligence work to a limited degree.

In 1947, the Social Security Administration converted 90 million ledger sheets to a film system that had provisions for quarterly updating. This was done by means of punch card tabulation. This system was so successful that many other government agencies and industrial operations made large scale film conversions. Most of this conversion was done on 16mm or 35mm roll film. The files created were largely manual with retrieval speed dependent on the simplicity of the subject matter and the quality of the indexing.

As the microfilm industry continued to grow, the use of roll film and aperture cards became more automated with more sophisticated hardware. At this point cartridge and magazine systems were brought into use by 3M, Bell & Howell and Recordak. Paralleling these systems other microforms evolved. These included such film forms as microfiche, microjackets, microstrips and non-film forms such as micro-opaques.

The advent of the computer brought about the most significant development for microfilm: tying in Micromation recording, storage and retrieval capabilities with computer output to create a complete practical and economical information dissemination system.

## SECTION II

### INTRODUCTION TO MICROPHOTOGRAPHY

#### 2-1. STANDARD MICROFILM SIZES

Microfilm stock is usually supplied in roll form and is perfed (perforated) or unperfed (unperforated). Perfed film has sprocket holes accurately located along one or both edges to aid in transporting and positioning the film for successive exposures in a camera or for accurate projection of images (movies).

The standard sizes of roll film are:

- \* 16mm - the standard for most administrative or business applications.
- \* 35mm - principally used for scientific and technical applications.
- \* 70mm - used for large technical graphics and limited aperture card applications.
- \* 105mm - used for the production of microfiche.

Large sheet film in various sizes is also used in microfilming for special applications.

#### 2-2. RECORDING METHODS

Microfilm is recorded by the following types of cameras.

1. Planetary Camera - a microfilm camera in which the film and the document being recorded remain in a stationary position during exposure.
2. Rotary Camera - a microfilm camera in which the film moves during exposure in synchronization with a moving document so there is no relative movement between film and document.
3. Step and Repeat Camera - (Microfiche Camera) a microfilm camera that exposes a series of images on an area of film according to a predetermined format, usually in orderly rows and columns.

4. COM Camera - a COM (Computer Output Microfilm) camera that records a frame of data produced by a computer and displayed directly on a CRT (Cathode Ray Tube). The camera advances by signal from an input device or an internal command.
5. Universal Camera - a special type of COM microfilm camera capable of producing a variety of image location formats on different sizes of roll film, for roll microfilm, microfiche and aperture cards.
6. COM Movie Camera - (16 and/or 35mm) a specially designed microfilm camera that will produce images on roll film capable of being projected in a standard motion picture projector.

### 2-3. RATIOS OF REDUCTION AND BLOW-BACK

Ratios currently in use vary from 10 to 150 times.

1. Reduction ratio refers to the amount of optical reduction used to record a page of data onto microfilm, i.e., 25 to 1 means a reduction to 1/25th of normal size.
2. Blow-back ratio refers to the amount of magnification used to view a micro form, i.e., 25X means magnification of 25 times.

### 2-4. IMAGE FORMATS ON FILM

Images can be recorded onto film in any of the following formats.

1. Simplex - a single frame of data across the width of the film.
2. Duplex - the front of a document on  $\frac{1}{2}$  frame and the back of the document on the other  $\frac{1}{2}$  frame. This is done simultaneously by a system of mirrors or prisms.
3. Four Plex - four pages of data per frame of 35mm film.
4. Duo - recording of data by masking  $\frac{1}{2}$  the width of the film and photographing on the exposed half. When the full length of film is exposed the mask is shifted to cover the previously exposed portion and data is then photographed on the unmasked portion.

5. Two Up - two frames recorded across the width of the film by moving either film or lens.

## 2-5. RECORDING MODES

The image can be positioned on the film in either of two modes.

- \* Comic Mode - pages of data recorded in comic strip fashion along the length of film, i.e., the top of the recorded page being parallel to the length of the film.
- \* Cine Mode - pages of data recorded in cinema fashion across the width of film, i.e., the top of the recorded page being perpendicular to the length of the film.

## 2-6. FILM IMAGE

The exposure of film to light results in a latent image upon the film which must be developed in order to be viewed.

The sign, negative or positive, of the image is called polarity. A negative image is one in which the values of light and dark of the original subject are inverted. A positive image is one in which the values of light and dark of the original subject are represented in their natural order.

Another way to reference film image polarity is by description of the line to the background, i.e., black lines on a clear background can be referenced as black line, and clear lines on a black background can be referenced as white line.

Polarity is used when referring to processes and equipment. For example, a process which produces black line copy from a black line original is termed non-reversal or direct image. A process which produces a black line copy from a white line original is termed a reversal process. This generally refers to copying other than film, i.e., electrophotography.

Note 1: Special explanation is needed for this terminology as it relates to the processing of silver film images. "Normal" processing of silver film produces an image which is reversed in polarity from the object of the photograph. (White character on the face of the tube will yield a black line image on

the film "normally" processed in the Datagraphix 156.) The opposite of this, where an image is produced on the silver film with the same polarity as the object of the photograph, is called "reversal" processing. To produce a white character on the film as is on the face of the tube the film would have to be "reversal" processed.

Note 2: Micromation Printer Polarity - All film produced on micromation printers, if normally processed, will yield a black line on a clear background.

## 2-7. FILM STRUCTURE

All films have a similar structure whether silver, diazo, Kalvar or dry silver. The general structure is shown in figure 2-1.

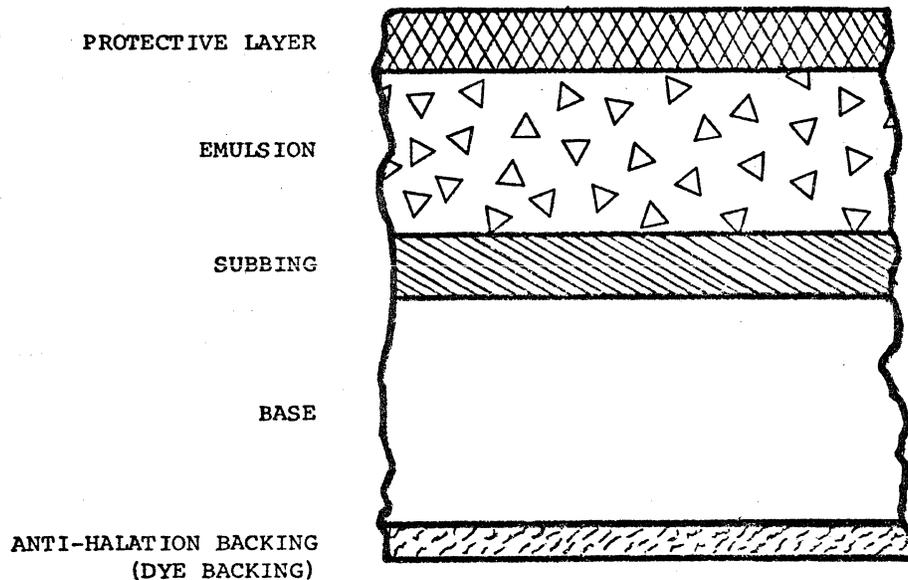


Figure 2-1. Typical Silver Halide Film Structure.

## A. Emulsion

1. Photosensitizer - the light sensitive material. This is normally, in microfilming, silver halides and salts that produce silver images and diazonium compounds which are formed into either light scattering centers or coupled to form a dye image.
2. Vehicle - a substance which holds the photosensitizer.  
Silver film: a gelatin, usually of animal origin.  
Diazo film: a coating frequently inbibed into the base.  
Kalvar film: a saran type plastic.

## B. Subbing

A clear adhesive which holds the emulsion to the base.

## C. Base

A material used to support the emulsion and backing. The most common base stocks are cellulose acetate propionate, cellulose acetate butyrate and polyester (mylar).

## D. Backing

A material to reduce reflected light (anti-halation) or to reduce static electricity (anti-static). Both may be part of the film. Our new Datagraphix film has a dye back that is removed during development.

## 2-8. FILM DENSITY

Diffuse density is a measure of the absorption of light by an image.

The density of an image is expressed by numbers ranging from .010, almost perfectly clear to 4.0 or more, almost completely opaque. A densitometer is an instrument used to check the image density. Two popular densitometers are the Welsh Densicron and the Macbeth Quantalog. The nature of Vesicular film is different from normal silver halide film. Therefore, Vesicular film that has a diffuse density of .03 to .04 may appear quite opaque when viewed on a projection screen, whereas silver of this density would be rather clear. The difference in density between the clear area of the film and an image area is called contrast. In microfilm work, contrast should be high.

A graph indicating how density changes with the amount of exposure is called D Log E, or H and D Curve, this curve is generally S

shaped. The relative slope of the main or straight line portion is called the Gamma. A Gamma of 1 would be a straight line, 45° from the vertical. A lower Gamma would indicate a lot of intermediate densities, which are not desirable on microfilm, and a Gamma higher than 1 indicates a high resolution film as used for microfilm.

## 2-9. H & D CURVES - (Hurter and Driffield Curve)

Using vesicular film as an example.

There are three types of density which are related to specific methods of measurement:

1. Visual Diffuse Density - that density measured when the incident light is parallel, and all of the transmitted light is collected.
2. Diffuse Printing Density - that density measured when the incident light is the light to be used in contact printing on the material.
3. Projection Density - that density measured when the incident light is parallel and only that portion of the transmitted light which enters a given aperture is collected.

The ratio of projection density to visual diffuse density is much greater in vesicular films than in silver films. Moreover, the projection density of a given sample of vesicular film, unlike silver, changes appreciably with the relative apertures of collection and illumination.

The visual diffuse densities of vesicular Microfilm are quite low. The characteristic curve (H & D Curve) of vesicular film, based on the measurement of diffuse densities, has an average gamma of 0.30 and a density range of about 0.50 density units. The exposure range is about 1.3. This characteristic curve indicates a low contrast material with a very limited density range.

When printing density characteristics (those which would be used in contact printing a vesicular image on vesicular film with a mercury arc source) are referred to, the density range increases to about 0.70 and the gamma to about 0.70. Average characteristic curves for visual diffuse density and for printing density are shown in Figure 2-2.

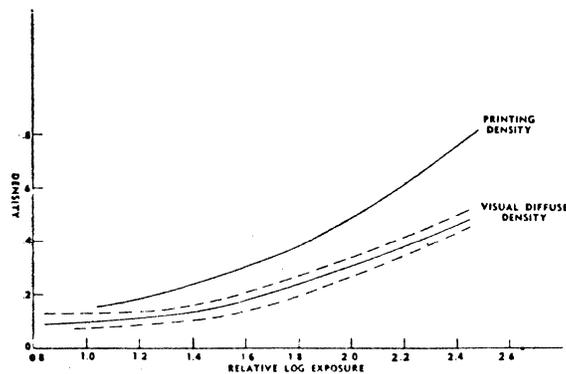


Figure 2-2. Average Characteristic (H & D) Curve.

The characteristic curves of a vesicular film (Figure 2-3) show the projection density as a function of Log E for various apertures of illumination and collection. From the table which explains these curves, it can be seen that a reciprocity exists between the illumination and collection apertures; that is, a given characteristic curve is associated with a particular relative aperture of either the illumination or the collection cone, whichever has the smaller numerical value. For example, curve 2 refers to either a collection relative aperture of f/2.0 together with all illumination relative apertures of from f/2.0 to f/∞, or else an illumination relative aperture of f/2.0 together with all collection apertures of from f/2.0 to f/∞. It follows that the maximum projection density of a vesicular image is limited by both the collection and the illumination relative apertures in exactly the same way.

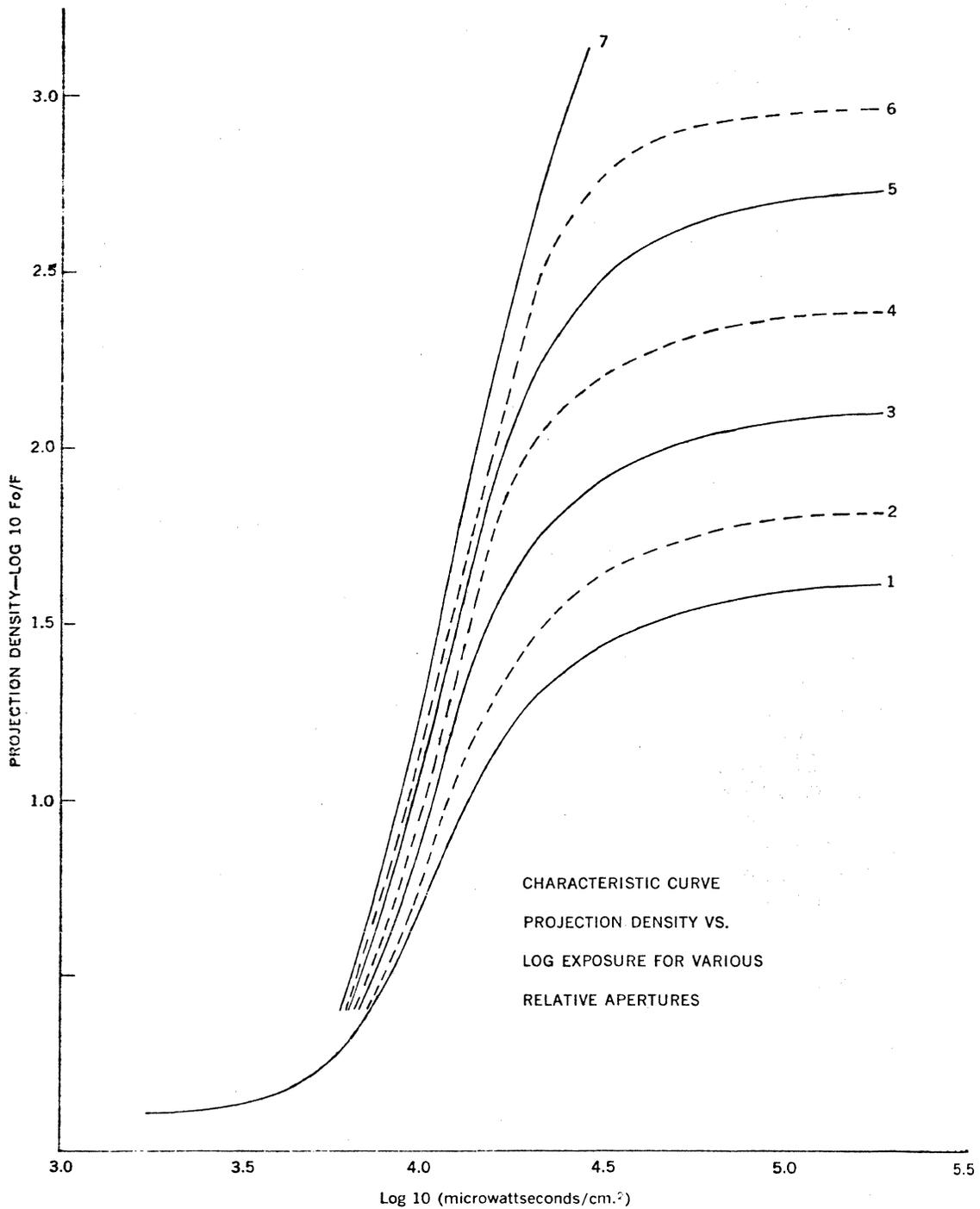
Vesicular films with high diffuse density for contact printing or direct viewing are also available. In these films use is made of the multiple internal scattering effect that occurs with increasing vesicular density and a controlled, special absorption characteristic built into the film.

## 2-10. RESOLUTION

Resolution, often called definition, is the ability to display a pair of parallel lines as distinctly separate lines.

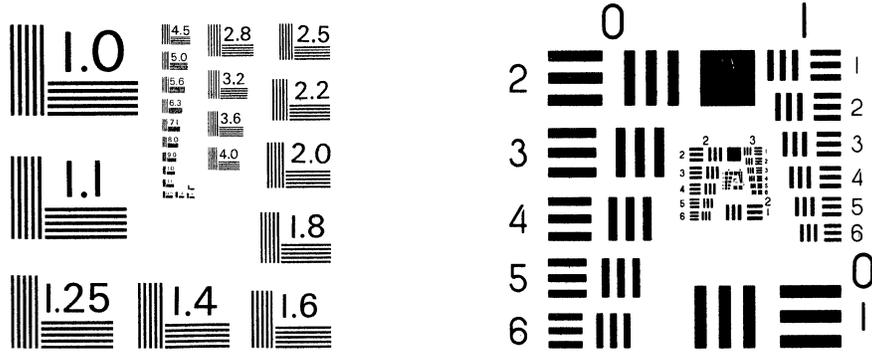
Resolution is checked by photographing a test target which has varying sizes of lines with different spacings (see figure 2-4). The results are viewed through a microscope, and a judgement is made regarding the smallest set of lines which appear as definite lines and spaces. A resolution table converts the number of the smallest readable group into a resolution figure.

Usually microfilm runs in excess of 100 line pairs per millimeter. This means that lines and spaces which have a width of only 1/200th



Curve Number	1		2		3		4		5		6		7	
Relative aperture of Collection Nc	∞	1.5	∞	2.0	∞	2.8	∞	4.0	∞	5.6	∞	8.0	∞	16.0
Relative Aperture of Illumination Ni	1.5	∞	2.0	∞	2.8	∞	4.0	∞	5.6	∞	8.0	∞	16.0	∞

Figure 2-3. Relative Log Exposure.



FIVE BAR

THREE BAR

National Bureau  
of Standards

Figure 2-4. Resolution Test Targets.

of a millimeter can be distinguished. It is photographically possible to get resolutions in excess of 300 line pairs per millimeter.

For every generation of duplication of microfilm, resolution is lost. The amount of loss depends on the duplicating equipment, the type and quality of film used and the quality of the master being duplicated.

## 2-11. SPECTRUM AND SPECTRUM ANALYSIS

In 1666, Isaac Newton sent a beam of white light through a prism which broke the light into seven bands which he called the spectrum. Newton showed that light we think of as white light is actually made up of different colors. These seven separate colors are red, orange, yellow, green, blue, indigo, and violet. More than one hundred colors can be seen if the light is carefully separated. A Dutch physicist, Huggins, at the same time as Newton, believed that light behaved as waves in the water and gave rise to the wave theory. In 1801, Thomas Young presented proof that light is transmitted in waves. Light waves are of different lengths and the wave length determined the color. Red has the longest wave and violet has the shortest wave in the spectrum. Light does not separate through air because all of the waves travel at the same speed, but when it strikes something they travel at their own speed (longer -- slower, shorter -- faster). In 1900, Planck stated that light consisted of definite packages of energy and each "quantum" depends on the length of the wave or the vibrations per second. He combined Newton's and Huggin's theories and brought about the development of the quantum theory.

## 2-12. ULTRAVIOLET RAYS

The band of electromagnetic waves just beyond the violet end of the visible light spectrum are the ultraviolet rays (UV). These are broken up into three categories being the near UV region, the middle UV region and the far UV region.

The sun is the most common natural source of UV. The UV is absorbed by the gases around the sun and by the smoke and air that we breathe. Short UV waves (the far region) are most harmful to the body and can cause skin cancer.

Mercury vapor lamps are the most common sources of artificially generated UV. They are made of quartz or fluorite because of their transparency for ultraviolet since ordinary glass absorbs ultraviolet.

Ultraviolet can be an important part in medicine as a tonic and disinfectant to speed the healing of wounds. Treatment of milk with ultraviolet produces vitamin D, and eggs become more nourishing when treated with ultraviolet.

## 2-13. LIGHT SOURCES FOR PHOTOGRAPHY

### A. Daylight

A mixture of direct sunlight and reflected light from the sky and from nearby objects; the relative proportions of the two kinds of light depend on the location of the subject, the altitude of the sun and particularly on the atmospheric conditions. With no clouds, the sky light is 20%. Thin clouds reduce this light by 1/3. Maximum illumination available from the sun at 42° latitude is about 10,000 foot-candles.

### B. Artificial Light

1. Incandescent Tungsten Lamps - consist of a drawn filament of tungsten in a glass globe containing argon and nitrogen. Life from 200-1000 hours.
2. Photoflood Lamp - a tungsten filament lamp in which the filament is operated at voltage much higher than normal. Life from 2-10 hours.
3. Flash Lamps - may be divided into two types. The first, and more common, type consists of a glass bulb containing:
  - (a) Aluminum or aluminum-magnesium in the form of
    - (1) wire
    - (2) shredded foil
    - (3) leaf foil
  - (b) Oxygen at a pressure equivalent to about 300 mm of mercury.
  - (c) A small filament covered with a primer and connected to the terminals of the lamp.

When current is applied, the filament is heated, primer ignited and, in the atmosphere of oxygen, the aluminum is consumed within a fraction of a second producing a light of high intensity.

The second type, known as the Speed Midget (SM) lamp, contains neither foil nor wire filling. A heavy coating of primer carried on the filament and lead-in wires burns in oxygen to produce the light. There is more rapid combustion in this lamp (5 milliseconds) as compared with 20 milliseconds for the foil and wire lamps.

4. Carbon Arc Lamp - the simplest arc lamp consists of two carbon electrodes so arranged that they can be made to touch and, when sufficiently heated by a current of electricity, separated so as to leave a small air gap. The resistance to the passage of an electric current across the gap between the two electrodes raises the temperature to the vaporization point producing an intense light. The carbon arc lamp is useful in photo-mechanical processes, in blue printing (Diazo) and other processes.
5. Gaseous Conductor Lamps - lamps of this type consist of a tubular bulb with an electrode in each end, the tube being filled with sodium, neon, mercury or another suitable element. When a current of suitable voltage is applied, the flow of current produces an arc, and light is produced as a result of electronic displacements within the atomic structure of the gas. The spectrum is confined to four bright lines in the violet, blue, green and yellow, the visual appearance being strongly bluish. Lamps of this type, therefore, are not suitable for use with color sensitive materials in photography. They are useful for projection printing, blue printing, photomechanical reproduction processes.

Advantages include low current consumption, high degree of diffusion and low operating temperature. The disadvantage is the required time to start the lamps. This makes them undesirable when the light must be switched on and off such as in a contact printer.

6. Fluorescent Lamps - these lamps are a development of the mercury vapor lamp. The vapor pressure and voltage are adjusted so that the discharge produces little visible light, but has a high emission of energy in the ultra-violet. The inside of the bulb is then coated with certain phosphors which are capable of absorbing energy of short wavelength and re-radiating this energy in a longer wavelength range. The nature of the energy finally emitted can be controlled by an appropriate choice of coatings, e.g., Calcium Tungstate 3100A<sup>o</sup> Peaks @ 4400A<sup>o</sup> to 7000A<sup>o</sup>; Cadmium Borate 3200A<sup>o</sup> Peaks @ 6000A<sup>o</sup> to 7500A<sup>o</sup>.

## 2-14. LENSES

Two Standard Series of lens markings indicate relative apertures:

*	European f Nos.	-	1.5	2.5	3.5	4.5	6.3	9	12.5	18	
*	American f Nos.	-	1.4	2.0	2.8	4.0	5.6	8	11	16	22
			32	etc.							

The square of the f number shows the relative light gathering power, i.e., 1 f stop change is a factor of 2 in light gathering:

\* f No. - 1.4 2.0 2.8 4.0 5.6 8 11 16

\* f No.<sup>2</sup> - 2.0 4.0 8.0 16.0 32 64 128 256

The apertures are numbered inversely to the size of the opening. The smallest f number indicates the largest opening; the largest f number indicates the smallest opening.

The sharpness of the image is greatest when only the center of the lens is used. As the aperture is increased and the area closer to the edge of the lens is used, the sharpness of the image decreases. As the aperture is made smaller, a longer exposure is needed to admit enough light to expose the film properly. A balance must be found between the amount of light available, the time available and the aperture opening chosen.

In Micromation, the f stop range normally used is from f 2.8 to f 5.6.

## 2-15. PHOTOGRAPHIC COMPOUNDS

Photography is concerned with the light sensitive compounds of silver, iron, chromium, and the diazo compounds in the solid state. These are usually suspended in viscous or jelled colloidal media, such as gelatin, albumen, glue, casein, agar, cellulose esters, or plastics.

Of the many light sensitive systems, only a few have found commercial applications in photography. We can list the following:

- \* Silver halides and salts that produce silver images.
- \* Iron complexes which produce ferrous salts.
- \* Alkaline dichromates that produce chromium oxides which are capable of tanning gelatin or other colloids.
- \* Diazo compounds that lose nitrogen and are decomposed into products which may be formed into scattering centers or the undecomposed diazo coupled to form a dye image.
- \* Sensitive dyes that are bleached by light.
- \* Photoconductors.

- \* Free Radicals.
- \* Photopolymers.
- \* Dye formers other than diazo.

## 2-16. DRY SILVER

The relatively new 3M dry silver materials have created considerable interest in the area of hard copy printout from cathode ray tubes and appear to come the closest to the ideal medium. Dry silver is developed by application of heat in the range from 200° F to 270° F depending on the film type. Its sensitivity is high enough so that with fiber optic tubes, practical writing speeds of over 80,000 inches/second have been demonstrated with the most sensitive types. The transparency material in this mode exhibits a writing speed of approximately 10,000 inches/second. It is reported that even faster film is being developed.

The spectral sensitivity peak of most of the dry silver materials lies in the middle of the visible spectrum where some fairly high efficiency phosphors, such as P20 and P31 can be used. For the most sensitive types, contrast is better than direct print oscillographic papers, but not as good as the electrophotographic processes. Dry silver materials are available in opaque (Types 777 and 774) or transparency (Type 784) forms. Type 777 is presently the most sensitive of the family.

The development of dry silver appears to be a little more critical than that for vesicular films and should be closely controlled for best results.

## SECTION III

### SILVER FILM

#### 3-1. RESEARCH

Conventional silver film is fast enough to record data being placed on the face of a CRT, has excellent quality and is recognized worldwide as a recording medium. However, it has some disadvantages; sensitivity to room light, relatively long development times, the use of development chemicals considered toxic, the care required in handling and the procedures required for archival permanence.

Much research is being carried out to develop film that can be handled easily in room environment, is fast enough to record CRT data and is easily developed. Dry silver is one method actually in use today that records CRT output and is developed by heat. Some work has been done by Boeing using Kalvar to record CRT data. A film still in development uses a thermoplastic that accepts CRT data and can be erased and used over again. Excellent recording has been done using photographic paper, but this requires wet processing.

Ultraviolet imaging film has been developed which has a higher sensitivity than Kalvar, but it is not fast enough as yet for single shot camera exposure from a CRT. Work is being done on Photopolymer film and Photoplastics but, with the exception of dry silver, no other method has yet achieved the speed of conventional silver. We will discuss here only the recording materials in use in COM systems.

#### 3-2. SILVER HALIDE IMAGING

Silver Halide photographic materials are based on the phenomenon of light absorption. Silver photographic films consist of a dispersion of silver halide granules in a media such as gelatin (emulsion) coated on a transparent backing material such as glass or cellulose acetate butyrate. The emulsion coating thickness is approximately 0.0004". Light sensitive compounds of silver halides and salts that produce silver images are uniformly dispersed in the emulsion coating. Upon exposure to light, radiant energy is absorbed which creates a latent image which can not be detected until chemically developed. When the exposed film is placed in

a developer solution, the developer attacks the exposed grains which contain the latent image material and free the silver from its compound, depositing it as tiny, irregular grains of metallic silver. These grains of metallic silver absorb light incident upon them to form the image.

### 3-3. EMULSION

The photographic emulsion is not, strictly speaking, a true emulsion but a dispersion of crystalline silver halide in a colloid. The term emulsion has been in use so long, however, and is so generally understood, that the distinction is largely academic. The silver halides employed are the chloride, bromide and iodide. The silver halide is produced by adding silver nitrate to a solution of the halide, i.e., potassium bromide in a solution of gelatin.

In the absence of gelatin, the crystals of silver halide are precipitated and settle to the bottom, but in gelatin they remain uniformly distributed in the solution. The photographic emulsion is thus a suspension of crystalline silver halide in gelatin. The gelatin functions, also, as a protective colloid. Without the protective action of a colloid, all possibility of developing the image is eliminated as the silver halide, whether exposed or not, is immediately reduced to silver on contact with the developer.

#### A. Gelatin

The superiority of gelatin over the other colloids is due to its physical properties and to its influence on the sensitivity of the silver halide.

Indirectly, gelatin contributes importantly to the light sensitivity of the silver halide. The sensitivity of crystals of pure silver halide is comparatively low regardless of the halide or the size of the crystal. The sensitivity of photographic emulsions is due to the formation of sensitivity centers on the silver halide crystals from the decomposition of substances found in gelatin.

Gelatin has the disadvantage that it is of animal origin and, therefore, subject to unordered variations. Moreover, it is costly to produce in a highly refined condition and is subject to attacks by animal and vegetable organisms, insects and bacteria. However, no better material has yet been found.

#### B. Silver Halide Grain

The usefulness of present day photographic materials is a result of the tiny individual particles of silver halide which are suspended in the gelatin. These particles are extremely sensitive to

light and store up the effect of an exceedingly small amount of light. This effect can, in turn, be multiplied by the action of the developer. This stored-up effect of light is known as the latent image and it is so small that it cannot be detected by any means other than by development itself. Therefore, the nature of the latent image and the nature of development processes are closely related. An understanding of these processes requires a knowledge of the structure of the silver halide grains themselves.

#### C. Structure of the Silver Halide Grain

The silver halide grains are minute crystals completely insulated from each other by gelatin. All emulsions contain a range of grain sizes but the average within a given emulsion ranges from exceedingly small (0.1 micron) in slow emulsions to several microns in the fast emulsions. The grains are thin platelets with triangular, hexagonal and a variety of other shapes. In addition to their normal crystal structure, the grains contain certain specks of foreign material called sensitivity specks.

#### D. Reaction of Silver Halides with Light

Light is a form of electromagnetic wave energy which occurs in small units called quanta. When a quantum of light strikes an object, the light may be reflected, transmitted or absorbed. When a quantum of light strikes an object, the light may be reflected, transmitted or absorbed. When the light is absorbed, it is converted to some other type of energy; it may change into heat or may cause some reaction to take place. In such photo reactions, it is only the light that is absorbed which can be effective and not that which is transmitted or reflected.

#### E. Sensitivity Specks

Sensitivity specks are specks of silver sulfide on the silver halide grains of the emulsion. The concentration speck theory of the latent image assumes that the function of the sensitivity centers is to "concentrate the silver atoms reduced by the light absorbed by silver bromide." The specific mechanism by which the specks concentrate in the silver has not been established. It was assumed that the silver atoms which were formed by light would collide with the specks and remain there so that the specks would grow in size during exposure and would reach a critical size which would make a grain developable.

### 3-4. FILM BASE AND BACKING REQUIREMENTS

#### A. Film Base

The requirements of a satisfactory film base are exacting as indicated by the following:

1. Optical Requirements
  - . Transparent
  - . Free from haze and visible imperfections
  - . Colorless
2. Chemical Requirements
  - . Chemically Stable
  - . Inert to highly sensitive emulsions
  - . Good adherence of the emulsion layer
  - . Unaffected by photographic chemicals
  - . Moisture resistant
3. Physical Requirements
  - . Strong, tough and hard but not brittle
  - . Stiff but flexible
  - . Elastic and plastic properties
  - . Tear resistant
  - . Free from curl, buckle, etc.
  - . Dimensionally stable
4. Thermal Requirements
  - . High softening temperature
  - . Slow burning

Cellulose nitrate (celluloid) was used as a film base for a great many years but it suffered from inferior chemical stability and was a great fire hazard. For these reasons, it has been replaced by "safety base" made from slow burning cellulose organic acid esters.

Cellulose acetate, containing 38% to 40% acetyl, is slow-burning and is used in the manufacturing of some safety films. There are two major disadvantages:

- \* Less resistant to moisture than nitrate, therefore, less dimensionally stable.
- \* Inferior tensile strength and flexibility.

Mixed organic acid cellulose esters such as cellulose acetate propionate and cellulose acetate butyrate give products with improved physical properties compared with regular cellulose acetate. These have become the favorite of film makers since 1937.

### B. Antihalation Backing

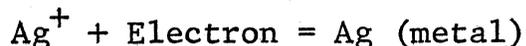
(Dye) for nonhalation must meet the following requirements.

1. High light absorption particularly in the region of maximum emulsion sensitivity.
2. No effect on emulsion or film base under ordinary storage conditions.
3. No effect on the process of development.
4. Completely bleached or removed either in the developer or fixing bath, preferably the former.
5. No undesirable residual products left on the film after ordinary fixing, washing, and drying.

## 3-5. DEVELOPING

### A. Theory of Development

The development of the photographic latent image is essentially the reduction of grains of exposed silver halide to metallic silver.



During normal development, only exposed grains containing a latent image are reduced. If development is extended for a longer period of time, all grains are developed. Thus, the development of the latent image is a rate phenomenon with the development of the exposed grains taking place at a faster rate than the development of the unexposed grains. In order for a reducing agent to be a developer it must fall within the proper range of reducing power.

If it is too weak a reducing agent, it cannot reduce silver halide at all, and if it is too strong, it will immediately reduce the unexposed grains as well as the exposed grains.

In addition to the ability to differentiate between exposed and unexposed silver halide, a developing agent, to be practical must:

1. Have sufficient energy to develop the latent image adequately.
2. Be free from tendency to fog.
3. Be reasonably stable in solution.
4. Be soluble in water or in the presence of sulfide or an alkali.
5. Not soften the gelatin layer.
6. Have characteristics that will not vary greatly with changes in temperature, dilution or composition.
7. Be non-toxic.

#### B. Developing Action

When the exposed film is placed in a developer solution, the developer attacks the exposed grains which contain the latent image material, freeing the silver from its compound and depositing it as tiny, irregular grains of metallic silver. The developer will also attack the unexposed areas so that a relatively small amount of fog is formed under normal development conditions.

Quality of the development process principally depends on four factors that must be rigidly controlled if a high degree of quality is to be achieved.

- . Temperature of fluids
- . Agitation of chemical solutions
- . Time of development
- . Degree of chemical freshness or exhaustion

The relation between the development of fog, as measured by the relationship to the respective densities, is termed the selectivity of the developing agent. This characteristic, depends upon the conditions under which the developer is used, the formula, and the degree of development.

1. Temperature of the Developer Solution - The rate of development is affected by temperature. As temperature increases the rate of development increases.

Low Temperature          normal time          underdevelopment

High Temperature        normal time          overdevelopment

At high temperature, the gelatin of the emulsion becomes swollen and tender and is easily damaged and may loosen from the support. This is called reticulation and causes fine line wrinkles in the silver.

2. Agitation of the Developer - If the exposed film is allowed to develop without agitation of the developer solution, the developing power of the solution in contact with the emulsion becomes exhausted. When agitated, fresh portions of solution are constantly brought to the emulsion surface so that the rate of development remains constant and will not allow mottle or density streaks to form.
3. Time of Development - When the exposed material is placed in the developer, the solution penetrates the emulsion reducing the exposed Ag crystals to metallic silver. The longer the development, the more Ag is formed and the blacker the image. The maximum density and minimum density increase to their highest points. If carried on too long, the developer may begin to act on unexposed silver crystals and cause "developer fog."
4. Dilution on Development - Slight dilution of the developer affects principally the time of development. The variation in time of development is more marked with those developers which oxidize readily. Fog tends to increase due to increased oxidation. The developer solution becomes slower in action as a result of:
  - . Depletion of the developing agent.
  - . The restraining effect of by-products of the process of development (sodium bromide, -iodide).

### C. Developing Solutions

A typical developing solution contains a solvent, developing agent, preservation, an alkali and a restrainer.

1. Solvent - The solvent used in film development is water. Normally, hard water causes no photographic effect and can be used without special consideration. However, metallic or sulphur content or the presence of granular

content would indicate a necessity to filter the water in order to maintain good developmental quality.

2. Developing Agents - The developing agent, normally meta-quinone or hydroquinone, is a mild reducing agent.  $\text{Ag}^{\text{O}}$  acts as a catalyst causing reaction with other atones. The developer is oxidized and the silver reduced to metallic silver.
3. The Preservative - All organic developing agents have a strong affinity for oxygen and require additive agents for stability.

The addition of sulfide:

- \* Protects organic developing agents against aerial oxidation.
- \* Prevents the formation of staining developer products.
- \* Acts as a silver halide solvent by the formation of complexes.
- \* Is a weak alkali and under certain conditions increases the rate of development and the maximum density obtainable.

Insufficient amounts of the preservative result in rapid oxidation of the developer causing:

- \* A loss in developing power.
- \* Formation of colored oxidation products which stain the gelatin.
- \* Oxidation fog.

Large amounts of the preservative improve the keeping properties of the developer but increase the time of development and reduce the effective emulsion speed throughout the solvent action on silver bromide.

4. The Alkali - The function of the alkali is to increase the ionization of the developing agent and to absorb the bromide liberated in development. The alkalies in general use include the alkaline carbonates, caustic alkalies, borates, etc.
5. The Restrainer - The addition of potassium bromide is ordinarily for the purpose of preventing fog. Whenever maximum contrast is required, a relatively high concentration of bromide is usually necessary. The effect of adding restrainer varies with the developing agent and is greatest with those of low potential.

## D. Care of Developer Solutions

1. Replenishment of Development Solutions - The loss in density and contrast due to partial exhaustion of the developing solution may be overcome to a certain extent by adding a replenishing solution. This may be either a solution of the same composition as the original formula or a more concentrated solution. This replenishment is to compensate for the developer used during the developing process. Developers cannot be replenished indefinitely because of the accumulation of silver sludge, dirt and gelatin.
2. Testing Developing Solutions - Testing is of value for:
  - . Maintaining uniformity of processing through the use of standardized solutions.
  - . Determining the source of unusual behavior, i.e., fog, etc. For most purposes, comparative photographic tests are adequate.

The step wedge is easily used for comparisons and are more easily and accurately made. Comparisons should be made visually of the following:

- . Fog.
  - . Threshold value (the first exposure producing visible density).
  - . Density scale and progression.
3. Developer Fog - Developer fog may be produced by the following:
    - . Solution improperly compounded -- dilution.
    - . Excessive solution temperature.
    - . Excessive developing time.
    - . Solution contaminated with metallic salts.
    - . Solution contains sodium sulfide as a result of the reduction of the sulfite to sulfide by bacterial or fungus growths.
    - . Exposure of film to air during development (oxidation fog).
  4. Developer Stain - Stains usually have a metallic appearance in reflected light and a reddish or purplish color

in transmitted light. Stain is frequently termed dichroic fog. Stain from developers may arise with:

- . Excessive oxidation.
- . Excessive temperature.
- . Excessive exposure to air during development.
- . Use of old developer.

### 3-6. FIXING

#### A. Theory of Fixing

After the development process, the undeveloped silver halide must be removed to keep it from obscuring the image. The emulsion is now treated in the fixing process which reduces the unexposed silver halide to neutral salts which are removed from the film. The function of a fixing agent is rather limited and the requirements are as follows:

1. It should dissolve silver halides without affecting the silver image.
2. It should be readily soluble in water yet stable.
3. It should not cause excessive swelling or softening of gelatin.

The most important fixing agents are the thiosulfates -- Sodium thiosulfate, ammonium thiosulfate, lithium thiosulfate and guanidine thiosulfate. If fixing is incomplete, no amount of washing can render the image permanent and the compounds of silver sodium thiosulfate remaining will discolor with the passage of time.

#### B. Acid Fixing and Hardening Bath

The acid fixing and hardening bath usually contains:

1. A solvent of silver halide -- Hypo.
2. Anti-Staining Agent -- Organic Acid (acetic).
3. Preservative -- Sodium Sulfide.
4. Hardening Agent -- Alum.

### C. Effect of Use on the Acid Fixing and Hardening Bath

The principle changes taking place with use in the fixing bath are:

1. The concentration of hypo is reduced and silver accumulates in the solution. In time, these accumulates decompose to form a yellow-colored stain that consists chiefly of silver sulfide.
2. Alkaline halides accumulate in the bath. Sodium bromide and silver iodide forms and retards the rate of fixing.
3. The pH of the bath is reduced by the developer brought in by the wet film. A sludge of aluminum sulfate forms and the bath no longer hardens the gelatin satisfactorily.

A fixing bath used near to the point of exhaustion will form complexes that are absorbed by the silver grains and the gelatin and cannot be removed by washing. They will eventually discolor and stain and are not easily removed.

For practical purposes, a fixing bath may be regarded as exhausted when a few drops (3-4) of a 10% solution of potassium iodide added to 25cc of the fixing bath causes a yellow precipitate to form.

### D. Rate of Fixing

The time required for the fixing process varies for the following reasons.

1. Nature and thickness of the emulsion. Large grain emulsions fix more slowly than fine grain emulsions. Emulsion containing silver iodide fix more slowly than those of silver bromide and these, in turn, more slowly than emulsions of silver chloride.
2. The composition of the fixing bath. As the fixing bath becomes less concentrated, the fixing time increases.
3. The temperature. As the temperature increases, the fixing time decreases.
4. Agitation. Agitation of the solution reduces the fixing time.

## 3-7. REVERSAL PROCESSING

Reversal processing is a more lengthy method due to the additional steps taken in the processing cycle. The steps in reversal processing using a Datagraphix F-89 as a processor are:

1. A development bath - Which develops the exposed Silver Halide.
2. Wash - Which washes away the loosened exposed Silver Halide.
3. A bleaching bath to make the developed silver soluble.
4. A wash to remove the bleach.
5. A clearing bath to remove the now soluble silver.
6. Re-exposure of the emulsion - Which exposes the previously unexposed silver halide by means of a small lamp.
7. Development of the newly exposed silver halide.
8. Hypo fix bath to fix the image.
9. A wash.
10. Additional clearing bath if deemed necessary.

### 3-8. WASHING

#### A. Reasons for Washing

The fixing process converts the insoluble silver halides into soluble compounds which are removable in washing. Washing also removes the fixing agent and its oxidation products from the emulsion. These, if left, would slowly combine with the silver image to produce a brown-yellow stain of silver sulfide, usually with some loss in density.

#### B. Time Required for Washing

The time required for washing depends on:

1. The efficiency of washing - The more rapid the change of water in contact with the gelatin layer, the less time required for washing.
2. The composition of the fixing bath - The washing time varies with the effectiveness of the fixing bath.
3. Temperature of the wash water - Washing efficiency increases rapidly with an increase in the temperature of the water.

4. The pH of the wash water - Increasing the pH value from 7 to 11 increases the rate of washing.
5. Extent to which the hypo must be removed - Archival quality washing is more thorough and takes longer. It varies the safe concentration of residual hypo or thio-sulfate on the film from 0.005 to 0.10 mg. per square inch. This is for film storage of 50 to 100 years.

### C. Tests for Residual Hypo

The presence of hypo on the film may be detected from the discoloration of an alkaline solution of potassium permanganate, or an iodine starch solution. The latter is more sensitive, but both procedures only indicate the presence of hypo in the water draining from the surface of the film.

The Crabtree test is currently the best test for the presence of residual hypo on the film and is extremely sensitive. An actual sample of the film is used, not just the water in the test. A new test is being developed called the "Methylene Blue" test which will be even more accurate.

### 3-9. DRYING

The drying process simply removes the moisture absorbed by the gelatin during processing. Normal drying temperature is  $125^{\circ}\text{F} \pm 5^{\circ}\text{F}$  at a Relative Humidity below 80%.

### 3-10. MIXING THE SOLUTIONS

The mixing agitation should not introduce excessive air into the solution because developers oxidize readily. Any violent agitation can weaken the developer solution and form staining compounds. Care should be taken to be thorough when mixing water with the developer because the developer is heavier than water. If not thoroughly mixed, the developer tends to remain at the bottom of the vessel.

### 3-11. SILVER RECOVERY

There are several methods by which the silver in a used fixing bath may be recovered; usually, however, the financial return is

hardly sufficient to justify the time and labor required. Precipitation of the silver as silver sulfide with sodium sulfide is the cheapest, but has the disadvantage of forming obnoxious odors.

The use of zinc dust has the advantage that no fumes are formed, but the amount of silver recovered is less.

Metallic units of zinc, copper and iron on which the silver precipitates are available commercially.

There is also some very elaborate equipment available to recover silver by electrolytic means, but is beyond the resources of most firms.

### 3-12. SHELF LIFE

Some photographic chemicals have a shelf life of 2-3 months @ 65° - 70° F, but only a few days @ 90° - 95° F. Chemicals applied by Datagraphix for the 156 are stable from 20° F to 110° F.

Silver film has a normal shelf life of two years in a controlled temperature-humidity environment.

Silver film has been certified in order to set standards for vehicles, sensitizers and emulsions. Depending upon the components of a given silver film, it is certified from the standards for a certain period of archival life, usually from 20 to 40 years.

### 3-13. GENERAL INFORMATION

- \* Contrast - The contrast of silver halide materials is extremely high in all instances.
- \* Resolving Power - High resolution is available in silver halide materials, however, because of grain, it is not as high as diazo materials.
- \* Exposure Latitude - A wide latitude of exposure is available with silver halides as compared to any other type photo-recording material.
- \* Speed - Silver halide films can be found in any speed range, but is at least 10<sup>5</sup> faster than the fastest diazo type materials.

- \* Color Sensitivity - Silver halide films can be sensitive to any color in the spectrum.
- \* Keeping Qualities - In controlled environment unexposed silver halide film can be kept for at least two years.
- \* Permanence - Archival permanence can be achieved with silver halide film with proper development, washing and a controlled environment.
- \* Suitability - Silver halide film is suitable for any type photo-recording and duplicating.

## SECTION IV

### ASA SPECIFICATIONS FOR SILVER FILM

#### 4-1. BURNING QUALITIES

ASA defines a photographic film as being no more hazardous than common newsprint paper. The present standard states that the nitrate nitrogen analysis is to be made on the complete film, instead of on the support, after removal of any gelatin or gelatin substitute layers. The allowable limit of nitrate nitrogen is 0.40 percent.

In order to be classified as photographic film it must be:

- \* Difficult to ignite
- \* Slow burning.
- \* Evolve a limited amount of toxic oxides of nitrogen during decomposition.

Three toxic gases are evolved when photographic films of cellulose nitrate are decomposed by heat. These gases are:

- \* Nitrogen
- \* Carbon monoxide
- \* Hydrocyanic acid

Hydrocyanic acid is not evolved in sufficient quantities to be a hazard.

#### 4-2. STORAGE

##### A. Permanence

In storing microfilm, there are two degrees of permanence.

- \* Commercial permanence - Does not need to extend beyond a period sufficient for general business purposes.
- \* Archival permanence - Preservation which is to be carried to the maximum period obtainable.

## B. Effects of Storage

### \* Commercial permanence:

- . Temperature - not to exceed 100° F.
- . Relative Humidity - 25% to 60%.

### \* Archival permanence:

- . Temperature - 60° to 80° F.
- . Relative humidity - 40% to 50%.

Storing film at temperatures above 100° F will reduce the pliability of the film. If stored below the temperature of the handling room, the film must be brought to room temperature before it is removed from the container.

Prolonged exposure to relative humidity above 60% will damage or destroy the gelatin because of the growth of mold, and will eventually cause the base to stick and buckle. Exposure to a relative humidity below 25% will cause brittleness and electric charges which attract dust.

Sulphur dioxide is the most common gaseous impurity in industrial atmospheres and a few parts per million is likely to cause some detrimental effects. Hydrogen sulfide is not a common impurity, but is very active in low concentrations and occurs in air washers containing decomposed biological slime.

## 4-3. FIRE PROTECTION STANDARDS

Representative samples stored for 6 hours at 50% relative humidity showed the following effects.

### A. Dry Heat

1. 250° - no effect.
2. 300° - some warping but still printable.
3. 350° - reproduction impossible.

### B. Steam

200-225° F - severe distortion, reproduction impossible.

Film reels of noncorrosive plastic or nonferrous metals can stand a 350° F temperature for 4 hours.

#### 4-4. PERIODIC INSPECTION

Select film at random every two years for inspection. If conditions are not as recommended, film should be inspected every six months. If no deterioration is detected under these reduced conditions, the interval can be gradually increased to a period not to exceed one year.

#### 4-5. CARE DURING USE

The temperature of the film when used in 16mm or 35mm viewers, should not exceed 167° F.

SECTION V  
PHOTOGRAPHIC CHEMICALS

5-1. CHEMICAL HAZARDS

Store all chemicals in cool, dry, dark spaces. Chemicals that react violently with each other should be separated to prevent danger of fire or explosion. For example, never store potassium permanganate near glycerine.

Label all chemical bottles and containers correctly and completely, and take special care to be certain that poisons are so labeled. If a label is accidentally destroyed and there is any doubt as to the contents of the container, the material should be discarded. Never taste chemicals to determine their identities. If the identity of a chemical is doubtful it should be discarded.

Shelves for corrosive chemical storage must be sturdy and provided with copings to prevent containers from extending over or slipping off the edge.

Do not begin siphoning operations by sucking chemicals through a tube.

Avoid inhaling dust or fumes. Many chemicals, especially those for color work, are toxic.

5-2. MIXING CHEMICALS

Acid to water. Always add acid to water; never add water to acid. The acid should be added slowly and with constant mixing.

Acid and cyanide. Never mix an acid and a cyanide, as a lethal gas will be released.

Dissolving alkalies. When dissolving strong alkalies such as sodium hydroxide or potassium hydroxide, use cool water.

Pyrex containers. Use Pyrex glass containers when working with acids. Thick walled glass containers should never be used in mixing chemicals as such glass is subject to breaking due to temperature changes.

5-3. HAZARDOUS CHEMICALS USED IN FILM PROCESSING

<u>CHEMICAL</u>	<u>DANGER</u>	<u>EMERGENCY TREATMENT</u>
Acetic Acid, Glacial	Causes bad burns on contact with skin.	Wash affected areas in floods of water.
Acetone (film cement)	Fumes are toxic and highly explosive.	Remove patient to fresh air.
Acids (See specific acid on this list.)	Burns	Wash acid off with large quantities of cold water.
Acids: Mineral (as Sulfuric, Hydrochloric)	Poison	Do NOT induce vomiting.
Alcohol (Ethyl, Methyl and Isopropyl)	Flammable Poison	
Ammonium Hydroxide	Extremely irritating to eyes and mucous membranes.	Wash with floods of water.
Carbon Tetrachloride	Extremely toxic fumes.	Remove patient to fresh air and keep warm, not hot.
Chrome Alum Potassium	Irritating to nose and skin.	Wash affected areas with abundant quantities of warm soap and water.
Color Developers (Aromatic Amine)	Toxic	Wash affected areas liberally with water.
Cyanides	Deadly poison	SPEED IS ESSENTIAL. Artificial respiration, if patient is unconscious or breathing with difficulty.
Dispotassium Monosodium	Deadly poison	See Cyanide above.

<u>CHEMICAL</u>	<u>DANGER</u>	<u>EMERGENCY TREATMENT</u>
Formaldehyde	Poison - Suffocating odor. Intense irritant to mucous membranes.	Artificial respiration if necessary.
Hydroquinone	Toxic	Remove to fresh air.
Dydroxylamine	Toxic	Wash affected areas in abundant amounts of soap and water.
Hydrochloride	Can be absorbed by the skin.	
Mercuric Chloride	Extremely poisonous. Extremely dangerous to handle and use.	
Mono Methyl Para Aminophenol Sulfate (Metol, Elon)	Toxic to skin of some people.	
Nitric Acid	Causes painful burns. Poison	Wash affected areas with large quantities of soap and water.
Paraformaldehyde	Poison, toxic fumes	See Trioxymethylene
*Potassium Bichromate	Poison	
Potassium Ferrocyanide and Ferricyanide	Poison	See Cyanides
*Potassium Hydroxide	Poison Causes painful burns.	Wash affected areas with water.
Potassium Permanganate	Poison Combines with glycerine, alcohol, etc. to cause explosive spontaneous combustion.	
Pyrogalllic Acid	Skin irritant	
Silver Nitrate	Causes bad burns	Wash affected parts with water.

<u>CHEMICAL</u>	<u>DANGER</u>	<u>EMERGENCY TREATMENT</u>
Sodium Carbonate	Irritating to eyes and respiratory tract.	Wash in large amounts of warm water. Irrigate eyes for 15 minutes.
Sodium Cyanide	Poison	See Cyanides.
*Sodium Hydroxide	Causes burns. Poison	Wash affected areas with floods of water.
Sodium Sulfide	Dangerous to eyes. Fire Hazard. In presence of heat or acids gives off hydrogen sulfide which is highly toxic.	Wash eyes with large amounts of warm water.
Sodium Sulfocyanate	Poison	See Cyanides.
*Sulfuric Acid	Corrosive liquid Poison	See Acids, Mineral.

\*These chemicals are used in reversal processing, as in the Datagraphix 89.

## SECTION VI

### DIAZOFILMS

#### 6-1. HISTORY

Diazonium salts were first synthesized over a century ago. In the 1920's the diazotype reproduction process came out of Germany and the Netherlands as a direct competitor to the blueprint, or ferro-prussiate, process in the field of technical reproduction. The early diazotype materials and processing machines were crude, but the essential simplicity of the process, its versatility, its ability to process cut sheets as well as rolls, and the speed with which prints could be produced, gave the process rapid acceptance. The vast increase in communications during and after World War II caused a tremendous growth of the process. Through licensing arrangements, and as a result of the expiration of basic patents, many manufacturers entered the field. Today, there are over 40 manufacturers of diazotype reproduction materials in the United States.

The diazotype process began as a method for making prints of technical drawings and is usually associated with this application, but its versatility, low cost and aesthetic capabilities have opened up many other areas where it is now used extensively. Diazotype formulas are coated on a variety of papers, cloths and films. Diazo films are available in several thicknesses, either clear, or with matte surfaces for pencil and ink additions. Cellulose-acetate films are used for routing applications. Polyester films are available for situations requiring unusual physical strength, durability and dimensional stability.

#### 6-2. THE DIAZO PROCESS

The diazo process is based on the behavior of a class of compounds known as diazonium salts. The name indicates that the compounds in this family possess a pair (di-) of nitrogen (azo, from "azote", the French word for nitrogen) atoms in their structure. These compounds are capable of combining chemically, through the action of other substances known as couplers, with phenols or amines to produce substances which are strongly colored. What makes diazonium salts suitable for use in a reproduction

process is that in addition to the foregoing characteristics, they also possess a particular kind of photosensitivity.

In the diazo process, the action of light destroys the ability of the diazonium compounds to react with a coupler to form a visible dye image. Therefore, the processed image is clear where light has struck and colored where light did not reach it.

If a sheet of diazo-coated material is processed without exposure to light, the sheet will be dark with dyestuffs over its entire surface. If, however, a sheet of diazo-coated material is placed in contact with a document sufficiently translucent for light to pass through it, the lines of the image will prevent light from reaching the photosensitive diazo coating. The diazonium salts in the image areas which were unaffected by the action of light react with the coupler to form a visible image. The process thus forms a direct-positive image rather than a negative one.

### 6-3. DIAZO DEVELOPING

There are three major variants of the diazo developing process and several minor ones. The difference between the major variants is largely in the way the latent image is developed. They are referred to as vapor, moist, or thermal.

The vapor diazo process. In this process, both the diazonium salts and the coupler are incorporated in the coating, together with an organic acid to prevent a premature reaction. An exposed sheet of this material is processed by passing it through a device having an enclosure containing ammonia vapor. The strongly alkaline ammonia neutralizes the acid present in the coating, allowing the coupler and the diazonium salts in the unexposed image areas to combine to form a visible image. A variation on this method is the use of anhydrous ammonia instead of liquid ammonia. The introduction of a small quantity of water in the developing chamber provides the moisture needed.

The moist diazo process. In this process, the coating contains only the diazonium salts. An exposed sheet of this material is processed by passing it through a device which moistens the coating with an alkaline solution which contains the coupler.

The thermal diazo process. In an effort to eliminate both the use of a solution in the moist process and the ammonia fumes which accompany dry processing, processes which apply only heat to make the latent image

visible have been recently introduced. In the thermal diazo process, all of the components required to form the final image are contained in the coating.

Other variations. The principal variant from the processes described above is a diazo reversal material. The coating is such that, unlike any other diazo material, a positive image is produced from a translucent negative. Reversal material can be processed in conventional diazo machines. After development, reversal materials must be washed to preserve the image.

Other variants employ the light-sensitivity of diazo materials to aid in forming a latent image which is not a dye image. These include the Kalvar process (described separately) in which bubbles are formed which refract light, rather than a dye which reflects light, a metal diazonium process which ultimately yields a silver image, and a method for the production of lithographic plates.

#### 6-4. DIAZOFILM PROPERTIES

The physical and chemical natures of film diazotypes and silver-halide photography differ greatly.

##### A. Resolution

A diazo image is formed by an organic dye, whereas a silver image is composed of inorganic particles.

Differences in resolution are determined by the difference in the size of a silver particle in a fine-grain emulsion, such as a Lippman emulsion, and the size of the dye molecule. The silver particle averages approximately 0.3 microns or 3,000 angstroms as compared to approximately 15 angstroms for a diazo molecule.

Resolution capabilities of diazofilms have been determined to be in excess of 1,000 lines per millimeter.

##### B. Sensitometry

Because the silver image is a particle system, its printing characteristics can be directly related to its measured visual densities. This is true,

because, within limits, a silver-particle system is blind to the spectral characteristics of light. Therefore, the particles in the silver image will have essentially the same relative absorption characteristics, whether the light source is ultraviolet, visible or infrared.

Such is not the case with the diazo image. Because this image is a transparent-dye system, it is selective in its absorption of light-radiation. Consequently, the visual density of a diazo image does not necessarily correspond to its printing density.

One advantage resulting from the selection absorption of the diazo image is its greater transmission of infrared which causes silver negative-transparencies to buckle and warp.

## 6-5. FILM SUPPORT AND SURFACE CHARACTERISTICS

Other differences between the silver and diazo processes are in the processing requirements. The silver process requires a hydrophillic, or water-accepting, layer on the surface of the film-support. The processing solutions must penetrate this layer so they can react with the silver-halide. Therefore, the surface of silver-process film is susceptible to scratching, finger-printing, and soiling. The diazo components do not require wet processing, they are dissolved within the surface of the film carrier. Consequently, diazo films are not nearly so susceptible to scratching, finger-printing, and soiling.

Base supports for positive-working diazofilms are as varied as that of silver-halide films. The most commonly used base is cellulose acetate. Polyester films for special needs are also available.

Film supports have been made in nominal thicknesses ranging from 1 to 20 mils.

## 6-6. GENERAL CHARACTERISTICS

### A. Quality Control

Diazo images are always developed to completion, and their sensitometric characteristics are therefore built-in by formulation. Silver-halide sensitometric characteristics are dependent on many factors, including

time and temperature of development, chemical constitution of the developer, etc.

#### B. Simplicity

The diazo-process is dry-developing and requires no dark room.

#### C. Versatility

There are many bridges between diazo and other methods of graphic reproduction. Diazo masters can be used to make, among others, silver-halide, xerographic, offset-lithographic, and electrostatic prints.

#### D. Image Life

Diazofilms are capable of long print life. Estimates of their print life have ranged from 50 to over 100 years. The oldest diazofilms of the current type in this country are approximately 18 years old and are said to be in a good state of preservation.

#### E. Radioactivity

Diazo-materials, before and after processing, are essentially insensitive to radioactivity.

#### F. Light Sources

The sensitivity of diazofilms fall between 3,000-4,500 angstroms. Peak sensitivity of positive-working diazofilms depends on the type of product and formulation and, in general, ranges from 3,800-4,100 angstroms.

The most commonly used light source for exposure of diazo products is the mercury-vapor lamp because of its relatively high actinic radiation. Fluorescent lamps, sun lamps, and photoflood lamps have been used in a variety of small devices to expose diazo materials, but all lack the efficiency, consistency and life expectancy of the mercury light source.

#### G. Contrast

The contrast of diazo materials ranges from moderate to high, depending on the type of coating and the purpose for which it is intended.

## H. Resolving Power

Unlike silver halide coatings which have a granular structure, each grain being made up of a number of molecules, the structure of diazo coatings is molecular. The size of a silver grain in a high resolution silver halide coating measures about 3,000 angstroms (one angstrom equals one-millionth of a millimeter) whereas the size of a typical diazo dye molecule is about 15 angstroms, or about 1/200th the size of the silver grain. The inherent resolving power of diazo coatings is thus extremely high.

## I. Exposure Latitude

Exposure in diazo copying machines is controlled by the rate at which the original and the sensitized material pass a high-intensity tubular light source. Slowing the rate of advance results in overexposure which yields a copy which will be faint and bleached in appearance. Increasing the rate of advance results in underexposed copies which will have a background tone. In general, exposure latitude is affected more by the characteristics of the process itself. In copying originals which are on a highly transparent support such as film, exposure latitude is fairly broad, but; if the support is low in translucency, exposure settings become critical. While copies of originals of the latter type may cause a certain amount of waste, the waste is more in the form of time rather than materials since the materials cost of ordinary diazo coatings are quite low.

## J. Speed

The speed of diazo materials is very low. The slow speed limits the process largely to reproduction by contact printing.

In general, the larger and more costly diazo machines designed for large-volume production have much stronger-intensity light sources than smaller machines and can thus operate at much higher speeds in terms of feet per minute.

## K. Color Sensitivity

Diazo compounds are sensitive only to light in the blue end of the visible spectrum and to ultraviolet in the nonvisible spectrum. Diazo coatings are consequently limited in their ability to reproduce blue lines.

## L. Keeping Qualities

Most manufacturers of diazo materials offer a shelf life guarantee of from 3 to 6 months, but, under good storage conditions in which the relative humidity does not vary much from 50 percent and the temperature from 70° F, acceptable copies can be produced on materials which have been stored for considerably longer periods.

## M. Permanence

No firm statement can be made about the permanence of diazo copies. In general, dyes are susceptible to fading from the action of light. For diazo copies stored where they are protected from light, and under conditions which do not vary greatly from a temperature of 70° F, and a relative humidity of 50 percent, the useful life expectancy has been variously estimated as being between 50 and 100 years.

## N. Duplication

The use of diazo materials for reproducing micro-transparencies has become increasingly widespread. Continuous printers for roll-to-roll film duplication are available and, with the growing use of microfiche, sheet-to-sheet printers for both low-volume and high-volume work are being marketed. Diazo films do not have the archival permanence possible with silver halide emulsions. However, the high resolution of diazo materials and the simplicity of the duplicating step, as compared with silver halide materials, make it useful for the production of distribution copies from a silver master negative. Individual microfiches, for example, can be duplicated under ordinary room-light conditions by means of small and relatively inexpensive equipment in approximately one minute and at a materials cost of a few cents.

## O. Suitability

For microforms:

- \* Camera recording - unsuitable. Because of the slow speed of diazo materials, neither equipment nor materials are available for camera recording.
- \* Microform duplicating - suitable. Diazo coatings on film are capable of producing excellent duplicates of micro-transparencies in roll or sheet form from either positives or negatives.
- \* Eye-legible copies from microforms - limited.

## SECTION VII

### VESICULAR FILM

#### 7-1. THE VESICULAR PROCESS

The vesicular process is based on the use of diazonium compounds, but it is quite unlike other diazo processes and is also markedly different from all other copying processes. A very thin diazonium emulsion layer (approximately 0.0005 inches) is coated on a polyester film base. When a sheet of this material is placed in contact with a translucent original and exposed to ultraviolet light in a range of from 3400 A° (Angstrom units) to 4400 A°, the diazonium compound decomposes and liberates nitrogen in the form of gas. The image is developed as the film passes over heated rollers. The heat causes the gaseous nitrogen to expand and form tiny vesicles (bubbles) in the plastic coating. These vesicles, which range in size from 0.5 to 2 microns in diameter, act as light-scattering centers causing a light pattern that is different from that of the unexposed areas. Since light-sensitive compounds are still present in unexposed areas, development must be followed by a "fixing" step. This is accomplished by exposing the entire film to ultraviolet light for approximately four times as long as required for the initial exposure. This completely decomposes the residual light-sensitive compounds. When viewed by reflected light, the exposed areas made up of these light-scattering centers are whitish in appearance, and the unexposed areas appear dark. When viewed by transmitted light (e.g., in a microfilm reader), light is transmitted by the unexposed areas but is dispersed by the light-scattering centers in the exposed areas so that these areas appear dark. The high light intensity required to expose vesicular material limits the process largely to contact copying from translucent originals. But its high resolution, 150 line pairs/mm, along with other characteristics make it a very useful process for duplicating micro-transparencies.

#### 7-2. FORMATION OF THE IMAGE

Vesicular film undergoes three processing stages: exposure, developing and fixing. Each of these processing steps will be discussed at length in the following paragraphs.

Vesicular materials are sensitive to light in the near ultraviolet region. The photosensitivity curve shows the response extends from below 3400 A° with maximum photosensitivity at 3850 A°. Vesicular film is not photographically sensitive to ordinary levels of visible light for short periods of time. The time required for exposure depends on the intensity of the light source, that is, the time required to get 200 milliwatt/seconds/cm<sup>2</sup> of actinic energy on the film.

In use, the vesicular film and the original are held closely together (contact printing process) so that the light shines through the original onto the vesicular. Wherever the original is black, the vesicular film is shielded from the light and the diazonium compound remains intact. Where the original film is clear, the ultraviolet light destroys the diazonium compound and releases nitrogen, water and carbon dioxide and the number of molecules is increased. The free molecules which are released increase internal pressure by a factor of approximately three.

Exposures longer than 60 seconds are useful, but the density obtained is no longer directly proportional to the exposure time. For long exposure times, there is a slight loss in maximum density because some of the gas generated diffuses during the prolonged exposure. Temperature of the film over 110° F during exposure will also cause a high diffusion rate of the latent-image-forming gas with a subsequent reduction of the maximum density.

In summary, it can be said that upon exposure to ultraviolet light, the diazonium compound suspended in the vehicle is photo decomposed to produce nitrogen gas. Space formerly occupied by the diazonium compound becomes a pocket of high pressure. At this point the latent image has been formed.

### 7-3. DEVELOPMENT

The film is developed by applying sufficient heat momentarily to soften the emulsion vehicle to form a bubble, or vesicle.

When the heat is removed, the softened emulsion vehicle crystallizes again, but this time the arrangement of crystallites in a thin shell around each individual vesicle produces a scattering center. These sub-micron-sized bubbles, .5 to 2.0 microns in diameter, become the permanent vesicular image.

## A. Methods of Development

Heat is all that is really necessary to develop a vesicular image. Any method of heating the film sufficiently will produce a permanent, high quality image. Three methods are used.

- \* Conduction - The heat necessary for development may be conducted into the film by a heated drum, roller, platen or a liquid heat-transfer medium such as glycerin.
- \* Convection - The heat may be a stream of hot air or the convection currents from either a heated oven or a heated platen in close proximity to the film.
- \* Radiation - Development by infrared radiation is possible because of the absorption spectrum of the film. This method, however, is not recommended except where the environment may be controlled precisely so that a combination of convection and radiation, detrimental to the formation of the image, does not occur.

## B. Energy of Development

The calculated energy required to develop a vesicular image is approximately  $0.13 \text{ cal/cm}^2/\text{mil}$  (total thickness which includes the base material plus emulsion thickness). The only basic requirement is that the emulsion layer be raised to a temperature of  $240^\circ \text{ F}$ . The temperature of the heat source to achieve this requirement will depend upon the dwell time and rate of heat transfer. Much higher temperatures of development can be used with the proper decrease in development (dwell) time.

NOTE: The shorter the development time, the more efficient is the use of nitrogen gas in forming the image.

## C. Latent Image Fade

The latent image in vesicular films will decay at an exponential rate depending upon the temperature. At normal room temperature, the gas which forms the latent image will diffuse from the film leaving an underdeveloped latent image over a period of several hours. At higher temperatures, the process takes place at a more rapid rate. Noticeable density loss may occur if excessive time elapses between exposure and development.

In development, the vehicle temperature is brought very rapidly through this diffusion range to a temperature above the softening point of the plastic, so that the predominant reaction is nucleation of the dissolved nitrogen and vesicle formation. Development should always follow as soon as practicable after exposure for normal processing.

#### D. Background Density

As the temperature increases, the background or density decreases until 220° F is reached. Therefore, 220° F, the starting point for development, must be reached for the background density to be at a minimum and cause the greatest possible contrast.

#### E. Projection Densities

At lower temperatures, from approximately 130° F to 160° F, a "sepia" image may occur. At this low development temperature, the bubbles or vesicles formed are of such small diameter that they change from Mees scattering to Raleigh scattering, the violet to blue component of white light is selectively attenuated, and the result is a sepia or pink tone to the image. At about 150° F, the maximum scattering density is obtained and the density increases only slightly with increasing temperature.

#### F. Thermal Resistance

The higher the development temperature (up to 265° F) the greater the thermal resistance. Above 265° F for two seconds some image degradation occurs. This degradation has little effect in making line copies but causes serious degradation in continuous tone copies.

One theory to explain the dependence of thermal resistance upon development temperature is that if the polymer chains forming the scattering centers are not pressed closely together to realize the full force of the Van Der Waal attraction, this outer shell will collapse upon heating, and the scattering centers will consequently decrease in size or completely disappear.

#### G. Permanence

Vesicular Film is stable under all normal conditions.

#### 7-4. FIXING

After exposure and development, the unexposed or clear sections of vesicular film still retain light-sensitive diazonium. The fixing technique consists of exposing the film overall to ultraviolet light, applying about four times the amount required for a maximum exposure, to completely decompose the sensitizer.

About ten minutes after the fixing exposure, the gas which was formed as a result of the decomposition of the diazonium compound starts to diffuse out through the plastic, and after a few hours there is nothing left to form bubbles. The film, during its diffusion period, should be kept below 110° F (about 3 hours).

Fixing is not necessary if the film can be protected either from exposure to ultraviolet or from exposure to high temperatures. In general, the higher the temperature of development, the higher the temperature the unfixed film can withstand without fogging, for example, in a projector.

The film must be fixed if a permanent image is desired. If the film is not fixed, it is very likely that when placed in any ordinary microfilm reader it will darken after just a few minutes. There is, in most microfilm readers, a sufficient amount of ultraviolet light and enough heat generated by the bulb to cause fogging due to simultaneous exposure and development. This darkening would not obliterate the image, but it might impair legibility.

In summary, as a precaution against subsequent and simultaneous exposure to light and heat which could fog the background, vesicular film is fixed with an overall exposure to an ultraviolet light source. When fixed, the residual sensitizer is decomposed and its nitrogen gases diffused from the film without being developed.

#### 7-5. GENERAL INFORMATION

##### A. Resolving Power

The resolving power of vesicular films used to duplicate microtransparencies is greater than 200 line pairs/millimeter. The highest resolving power is attained if a point light source is used within a range of 3600 to 4000Å°. Resolution is also affected by the time and temperature of development. In general, short exposure and development times produce greater sharpness.

## B. Exposure Latitude

The latitude of vesicular film is great enough to cover the normal contrast and resolution of any microfilm or other photographic product to be duplicated.

## C. Speed

Vesicular film can be processed at 200 feet per minute on some equipment now available; research has shown that the film itself can be used at 300 feet per minute, though the necessary equipment is not commercially available at this time.

## D. Shelf Life

The shelf life of unexposed vesicular film if stored under proper conditions is virtually unlimited.

## E. Permanence

Vesicular film is one of the most permanent of photo imagery yet devised. It is not affected by acids, bases, salts, detergents, or most solvents. The emulsion and base permit easy removal of fingerprints, oils, and grease and resist scratching, tearing, curl and embrittlement. Having no residual silver or hypo compounds, the image does not fade, discolor, or stain during storage, and there are no gelatin layers to support bacteria or fungus attacks.

## F. Suitability

The principal use for vesicular film is making contact duplicates from film negatives, or positives from microtransparencies.

The vesicular process is eminently suitable for the duplication of microtransparencies in both roll and sheet form. The high resolution of the material, its contrast characteristics, the fact that the process is completely dry and the speed with which duplicating can be done under conditions of ordinary room light are all advantageous.

## SECTION VIII

### MICROFORMS

#### 8-1. INTRODUCTION

Microfilm is available in many forms, ranging from roll film to film chips with either positive or negative images.

The form in which microfilm is prepared is called a microform. The National Microfilm Association defines microform as "a generic term for any form, either film or paper, which contains microimages."

The term "unitized" as used here will refer to microforms that hold one complete unit or subdivision of information without any unrelated or extraneous material. Examples of unitized microforms include microfiche and microfilm jackets. Roll microfilm, on the other hand, usually contains a variety of unrelated information units on the same roll and is therefore referred to as a "nonunitized" microform.

The following systems are used to unitize a particular group of microfilm records.

- \* Microtapes
- \* Acetate film jackets
- \* Microfiche
- \* Micro-opaque cards (more commonly known by the trade-name "Micro-cards")
- \* Microfilm aperture cards

Microtape and acetate film jackets have add-on capabilities and are therefore ideally suited for applications in which unitized files must be updated. Microfiche and micro-opaque cards, however, have no add-on capabilities. They are best suited for applications in which a unit of information is complete at the time of filming, and no further updating is required after the unit record is made.

Microtapes are prepared as a continuous printing operation. Negative roll microfilm is used to prepare a positive microfilm image of 16mm or 35mm photographic paper tape with pressure-sensitive adhesive backing. After processing, the microtape is cut to the proper length and pressure-applied to ordinary index cards.

Microtapes possess excellent add-on capabilities, since any particular microtape card may be updated without refilming an entire group of documents. However, additional copies cannot be prepared for microtapes, therefore a person wishing to refer to a particular document at his work stations must borrow the entire card. Consequently, there is the possibility that the borrowed card may be lost or damaged while out of file, or that requests for it may come in while it is away on loan. These are the principal disadvantages of microtape.

Acetate film jackets should be considered if a microform possessing add-on and reproduction capabilities is required. These jackets are made in standard index card sizes (3" x 5", 4" x 6", 5" x 8", etc.) of clear acetate. Each is separated into pockets (called chambers) by paper dividers glued between two sheets of acetate. Into these chambers can be inserted short strips of microfilm. The transparency of the jackets permits reproduction of enlarged copies of the microimages on a suitable reader-printer without removing the film from the jacket. "Micro-Thin" and "Micro-Folio" jackets allow for contact duplication.

Microfiche is a French word meaning Index card and a Datafilm Microfiche is a photographic index card with several page images on a card. There are several standards, but usually Microfiche has an eye visible title across the top so that it may be easily identified.

An aperture card is a machine sortable and/or selectable card with an aperture in it into which a piece of film is affixed. One to eight images can be contained in the aperture depending on the card format and the system employed.

There are three general categories of microfilm: Roll, Microfiche and Aperture Card. Roll datafilm is, at present, the most commonly used. For business applications, 16mm is almost universal. 35mm is normally used in scientific and technical application.

## 8-2. ROLL FILM

Roll film is the most common microform. Documents are filmed in 100 or 200 foot lengths and, after processing, are filed away on reels.

Roll film may be either Blackline or Whiteline. Blackline film is ideally suited for the rapid, inexpensive reproduction of white line copies of the microfilm roll. White line roll film is usually preferred for direct viewing, since the images are easier on the eyes.

Roll microfilm is useful in providing a safety record for important documents whose reconstruction must be insured in case of loss or damage. In this category are all the applications for banking purposes, insurance companies, legal applications, and even the microfilming of engineering drawings during the war years and several years thereafter.

Roll microfilm is used for reference to information which is continuous in form, such as newspapers, periodicals, books, etc. Today every major newspaper is microfilmed regularly, and positive rolls are distributed to libraries throughout the world for reference.

Roll microfilm has the one disadvantage: updating files already microfilmed. Additional related documents must be spliced into the original roll or the file must be completely recreated.

Roll film formats. With a standard DatagraphiX 16mm camera the modes used for recording are either cine or comic, although frame butting (continuous recording) can be accomplished on the DatagraphiX 4020 and 4060. With the Universal Camera System on the 4440 or 4360, recording can be accomplished using either 64 line frames or 76 line frames. There are also two reduction ratios available with the Universal Camera, 25X and 42X. Using 25X reduction, one page of information is recorded; with 42X reduction, two pages per frame are accommodated. Figures 8-1, 8-2, and 8-3, at the end of this section, show the formats used on DatagraphiX equipment.

In photographing documents using planetary or rotary cameras, formats similar to those discussed above are used but with different reduction ratios and variations. Orientation of images on a roll can be controlled by turning the document or the camera head and adjusting the reduction ratios accordingly. In 35mm recording, depending on the recording and viewing systems employed, cine or comic modes are used with reduction ratios between 10X and 25X. In 16mm recording, either cine or comic mode is used, depending on the recording and viewing systems with reduction ratios between 20X and 25X.

### 8-3. THE APERTURE CARD

The first breakthrough in mechanical handling and coding of single microfilm images was the invention of the aperture card in 1945. This was invented by John Langan while he was employed in the Office of Strategic Services in Washington, D.C. He and his associates successfully modified the tabulating card to hold a microfilm image. This permitted automatic sorting of a series of cards for any particular item or topic, giving at the same time all the pertinent correspondence, photographs, drawings, charts, etc., related to the particular information.

The major importance of attaching a microfilm image to a tabulating card was not specifically the ability of the tabulating card to be mechanically sorted, but more the fact that a single image was handled as a self-contained document which could be sorted and found the same as any card in a file.

As many as fifteen images can be inserted into a single card. In many instances one image is not enough to identify a specific set of circumstances, since more than one piece of information may be necessary to describe it fully.

The aperture card has ushered in an active use of microfilm for engineering drawings and selected business records.

### 8-4. MICROFICHE

Microfiche is a newly popular form of microfilm in which a related group of images are arranged on a card-shaped transparent sheet of film.

The great value of the microfiche is that all the pages of a report or handbook can be contained in a convenient unit easy to handle in a microfilm reader or printer and easy to duplicate for distribution. It represents a very simple information handling concept that can be readily understood.

Characteristics and uses. The microfiche has been used abroad since the beginning of the century, but it found little acceptance in the United States until recently. The most extensive early use was in the libraries of a few European countries, principally France. However, the growing need for a "unitized microform", a medium for recording and reproducing related groups of images in one convenient unit, led to another look at

microfiche by American technical libraries and information specialists charged with difficult projects.

Such government agencies as the Department of Defense, the Atomic Energy Commission and the National Aeronautics and Space Administration turned to microfiche to solve their growing problems in indexing and distributing the vast amount of technical information required by research laboratories and government contractors. The microfiche satisfies a need that cannot usually be filled by devices such as the aperture card in the distribution of technical information. While the aperture card provides an excellent medium for storing, sorting, indexing, and retrieving engineering drawings, there are limits to the amount of information that can be placed on one card.

Sometimes, a number of aperture cards have to be used to hold the microfilm image of one large engineering drawing. When parts of the same information unit will be separated in handling, it reduces efficiency and convenience. This happens only infrequently in the case of drawings, but with technical reports and manuals, the situation is usually different. Making fifty or more aperture cards to hold the pages of a detailed report would be a clumsy operation, and the results would be more difficult to mail and distribute than a microfiche.

Records managers at companies with active aperture card programs find that the aperture card can substitute for the microfiche in holding technical reports - provided these reports are fairly brief. It is possible to get about eight average-size pages of text on a microfilm image suited for mounting in an aperture card. If the facilities are already there, this may be the most simple and economical systems approach - until length and volume of reports increase.

In some handbook and specification sheet operations, microfilm cartridges containing short strips of roll microfilm have been used to hold government specifications to contractors. This system predates the current interest in microfiche among defense agencies and contractors, but it does not offer the same advantages in handling, distribution, and duplication of information as microfiche does.

Also, even though the microfiche has received little publicity in the United States until recently, a variation of the standard microfiche known as a micro-opaque card or "Microcard" (trade mark of the Microcard Corporation) has been employed in this country for many years to reduce magazines and scholarly publications to a simple paper card varying in size from 3" x 5" to 6" x 9".

Many jobs for microfiche are now being found in a number of business areas outside the government-agency-contractor network where the paper-work explosion has also been getting out of control. Companies, particularly large organizations with scattered branches, are finding microfiche a handy medium for distributing reports, procedures manuals, and other information that is bulky and expensive to duplicate and mail. A procedures manual that is mailed on microfiche to a remote branch can be duplicated there and easily stored for ready reference.

One of the first commercial uses of microfiche in the United States was begun a few years ago by the publishers of the Thomas' Register. Instead of a shelf of thick directories, the company is now able to offer customers a compact 4" x 6" card file containing the same information. Also, this is an application where use of microfiche makes it easier to update the complete file of information by substituting new units. Where previously it would have been necessary to wait for a new edition to incorporate new information into a directory, additional microfiche cards containing the latest information can be easily added.

Acetate film jackets are a type of microform where roll microfilm is cut and stored in transparent jackets. These jackets are often approximately the same size as a microfiche card, but their application is different. Here, strips and chips of microfilm containing one or more documents can be added and subtracted manually to update the information in the jacket - something that cannot be done with microfiche. Such an arrangement is well adapted to many applications where copies of deeds, wills, school or hospital records, and many other documents need to be stored in flexible units that can be altered as necessary. There would rarely be a requirement to distribute or reproduce all the information in a jacket in this type of file.

Specifications. Microfiche systems reduce a document to anywhere from 1/18th to 1/42nd its original size.

Three types of microfilm cameras can be used to make microfiche. The rotary camera that photographs documents as they move along a conveyor belt and the planetary camera which photographs the document while stationary on a bed, produce roll microfilm that can be cut into appropriate lengths and stripped into a transparent microfiche jacket. The result is a microfiche negative. However, in many government and service company facilities, microfiche are prepared by special planetary cameras with step-and-repeat film units. These cameras are so constructed that they can register the film images in a gridiron pattern on a rectangular sheet of film. When this sheet of film is developed, it is a microfiche negative and the stripping process is bypassed.

Computer output can be directly recorded in most microfiche formats with DatagraphiX's Universal Camera.

Microfiche cards may be prepared in any size. However, most current users employ one of the following: 3" x 5", 4" x 6", 5" x 8", and tabulating card size. The application will generally determine the card size selected.

For ease of retrieval, it is necessary to provide a means of identifying one microfiche unit from another. There are two ways of making such identification possible with the naked eye:

1. Provide for the filming of a descriptive title on the first page of each document. This original title page should be at least 8½" x 11" in size with the words of the title each two inches high. The filmed result will be an index title that can be read with the naked eye.
2. Provide for the addition of a title block along the top of the microfiche card. With hardcopy cameras, this is a separate operation and usually involves setting the title by one of the cold-type processes and subsequent processing and stripping. With the DatagraphiX Universal Camera, it is a singular process performed while recording data.

The majority of microfilm readers and reader-printers will accept microfiche for viewing and reproduction. It is, in fact, the overall ease with which reproduction can be made from microfiche that makes it such a convenient information storage medium.

Summing up, the advantages of microfiche over other types of microfilm can be stated as follows:

- \* Microfiche provides a quick and economical means of preparing and distributing multipaged reports.
- \* Because microfiche are unitized records of multipaged documents, they make possible the filing and easy retrieval of otherwise bulky material with a great reduction in filing space. The reduction of all documents to a standard size eliminates the need for special filing equipment.

Microfiche (filmcards) are used as a standard publishing tool by NASA, AEC, DOD, DDC, and OTS, and by industry and libraries. Because of the widespread use and increasing popularity of microfiche, sizes, formats, and classifications of filmcards have been standardized by

responsible federal, military, and commercial committees. The two standards controlling most of the microfiche today are the COSATI and NMA standards.

One of the most heavily used formats of microfiche is the U. S. Government's COSATI (Committee on Standardization for Administrative and Technical Information) format. It is being used not only by most government departments but also by practically all research and technical organizations, many educational institutions and contractors to the government.

The government COSATI standard is 3.250 inches by 7.375 inches or 105mm by 148mm. It contains 12 columns by 6 rows of microimages. The top row is used for titling the fiche so that it can be read with the unaided eye. The reduction rate is from 18X to 20X.

There are a number of other "standards", most of which are produced on 105mm film.

Microform formatting with the Universal Camera. The Universal Camera records page images on 16mm, 35mm or 105mm film in a near-infinite variety of film formats. It produces datafilm in either "comic" or "cine" mode and at reduction ratios of 25:1 or 42:1.

Standard or special formats can be generated for roll datafilm, aperture card and microfiche application.

Most 16mm film is printed "one-up" at a reduction rate of 24X, and a single film frame occupies most of the film width. With the Universal Camera, it becomes possible to print images "two-up" in comic mode at a 42X reduction rate. This special format results in:

- \* Cost savings in that less than half as much film is required as compared to the "one-up" 24X reduction rate method.
- \* Approximately 11,500 pages can be contained within a DatagraphiX 1700 datafilm cartridge.
- \* New data retrieval strategies may be employed in order to optimize record retrieval. For example, the production of a file in two sequences with one sequence in the top row and another sequence in the bottom row would permit the inquiry station operator to reference either sequence without changing cartridges, thereby reducing data retrieval time. Another example is the production of a file in one row and multi-copies of its index in the other row, so that the index is

readily available wherever in the file the datafilm is positioned. A number of other practical format schemes are possible.

Until DatagraphiX announced the Universal Camera, the jackets and "step and repeat" film were the only methods for producing microfiche. The jackets can utilize COM film but the step and repeat method is a source document recorder. With the Universal Camera, microfiche can be produced directly from a COM device eliminating jackets which require stripping and is a slower process.

Standard formats for aperture cards can be readily produced on the Universal Camera on 16mm film with the possibility for special formatting. However, special formats will be restricted by the equipment used to view or project the aperture card images.

Microfiche recording is on roll 105mm film with cutmarks for the automatic microfiche cutters.

Innumerable microfiche formats can be produced with the Universal Camera. All of the present formats, titled or untitled at 24X or 42X reduction, can be designed within the confines of the 105mm film width. Most of the standard formats of microfiche use a film unit 105mm high and 148mm wide which is approximately 4 by 6 inches. On this size piece of film it is possible to record as many as 72 page images in 24X reduction and 224 page images in a 42X reduction ratio.

Figures 8-4 through 8-14 show many microfiche formats.

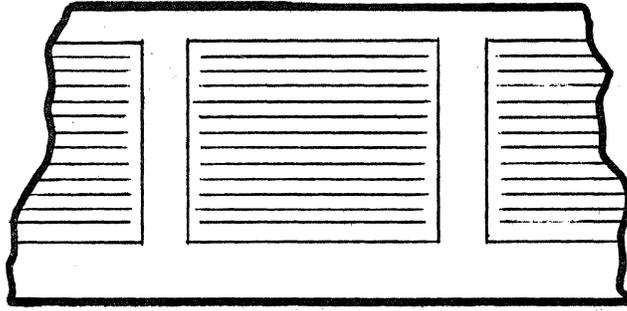


Figure 8-1. 16mm Microfilm, Comic or  $0^{\circ}$  Rotation, 25X Reduction.

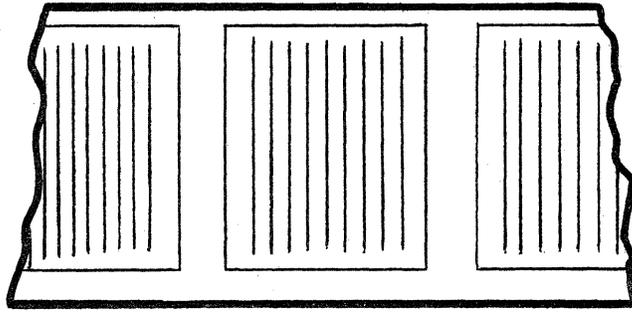
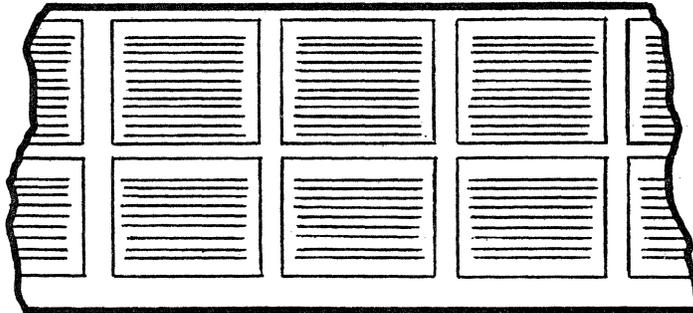


Figure 8-2. 16mm Microfilm, Cine or  $-90^{\circ}$  Rotation, 25X Reduction.



Figurs 8-3. 16mm Microfilm, Two-Up, Comic, 42X Reduction.

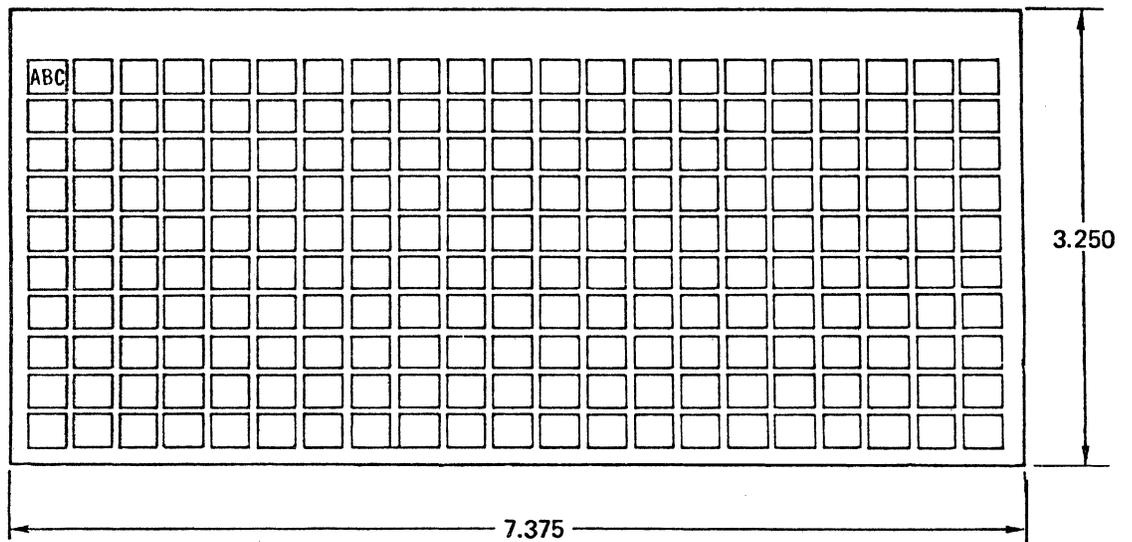


Figure 8-4. Microfiche, 3-1/4 X 7-3/8 inches, 210 Frames, 42X Reduction.

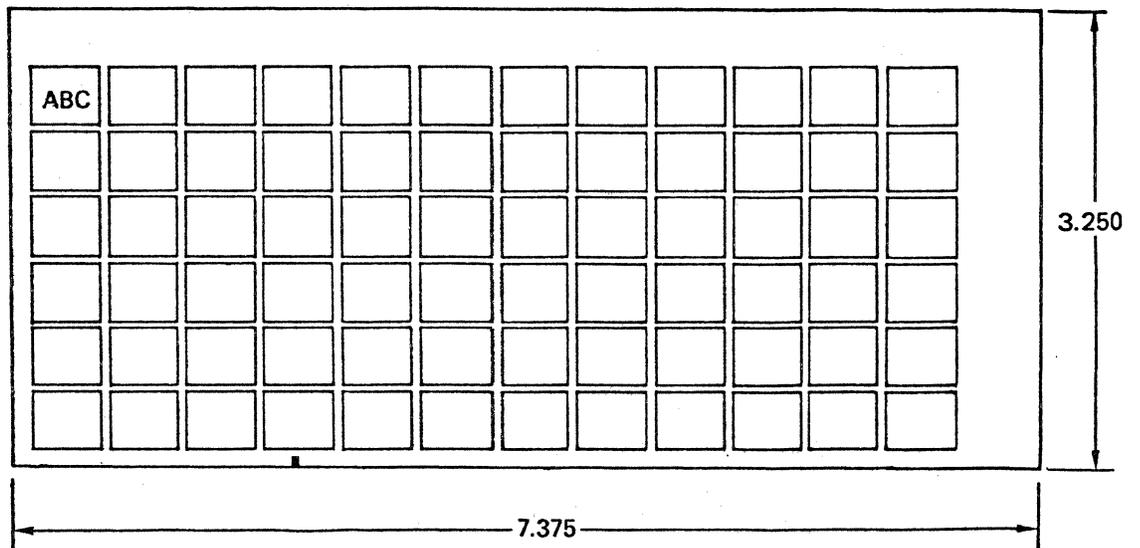


Figure 8-5. Microfiche, 3-1/4 X 7-3/8 inches, 72 Frames, 25X Reduction.

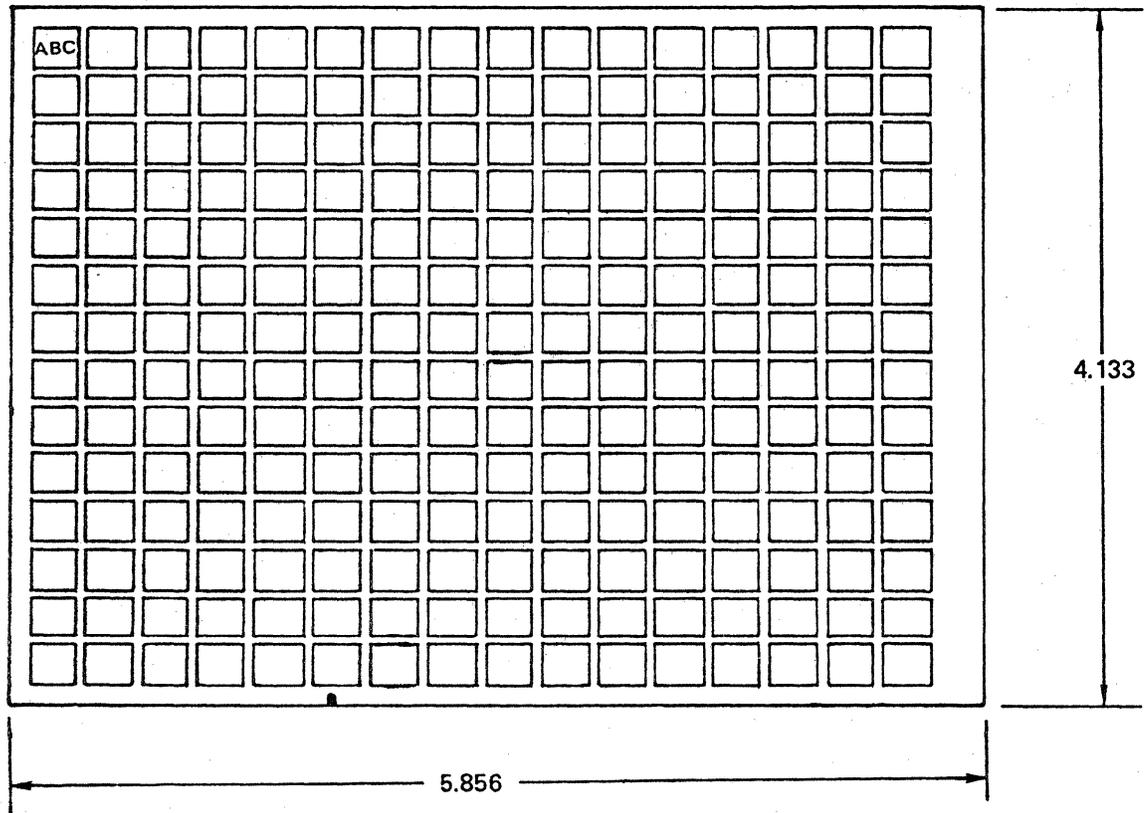


Figure 8-6. Microfiche, 4x6 inches (105x148.75mm), 224 Frames, 42X Reduction.

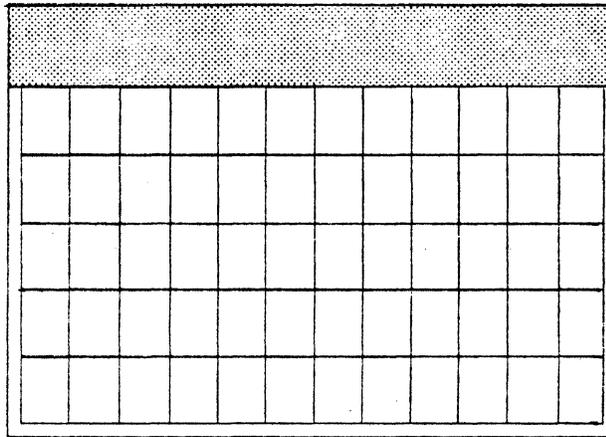


Figure 8-7. COSATI Microfiche Format, 105x148mm, 60 Frames.

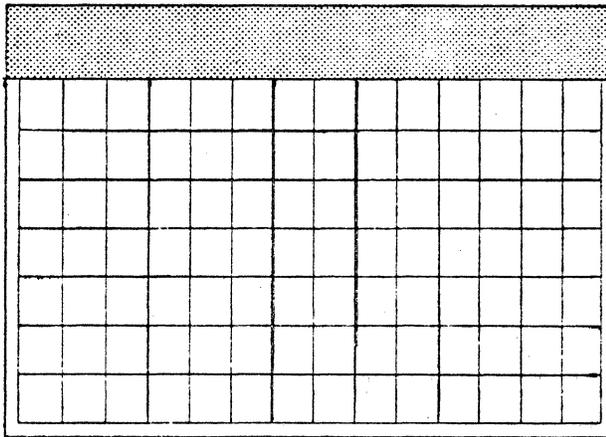


Figure 8-8. NMA Microfiche Format, 105x148mm, 98 Frames.

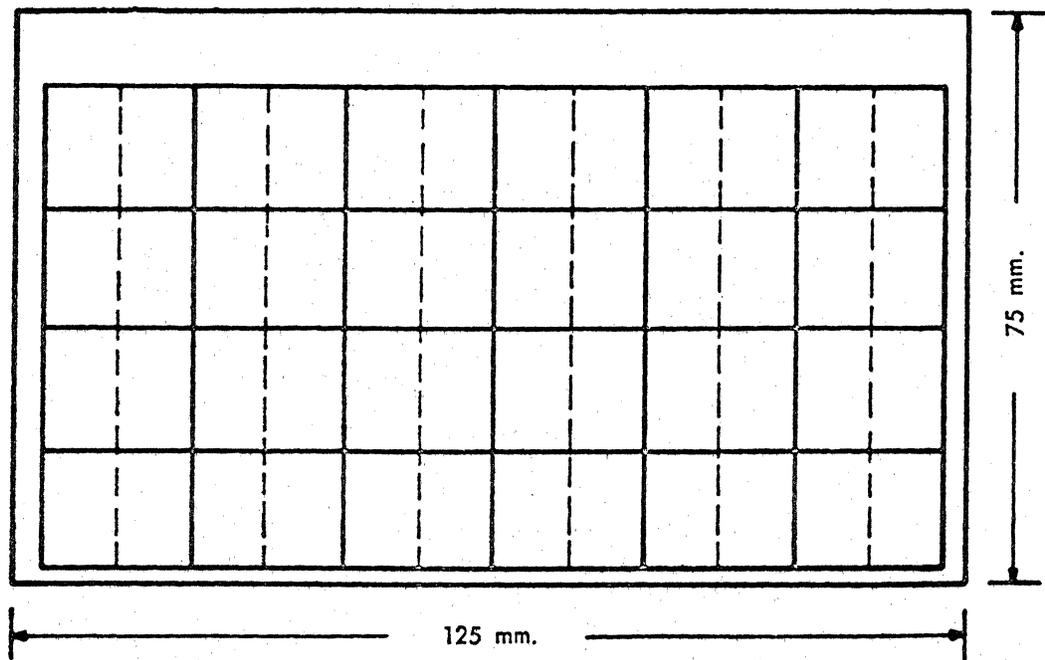


Figure 8-9. Microfiche, 75x125mm, 48 Frames.

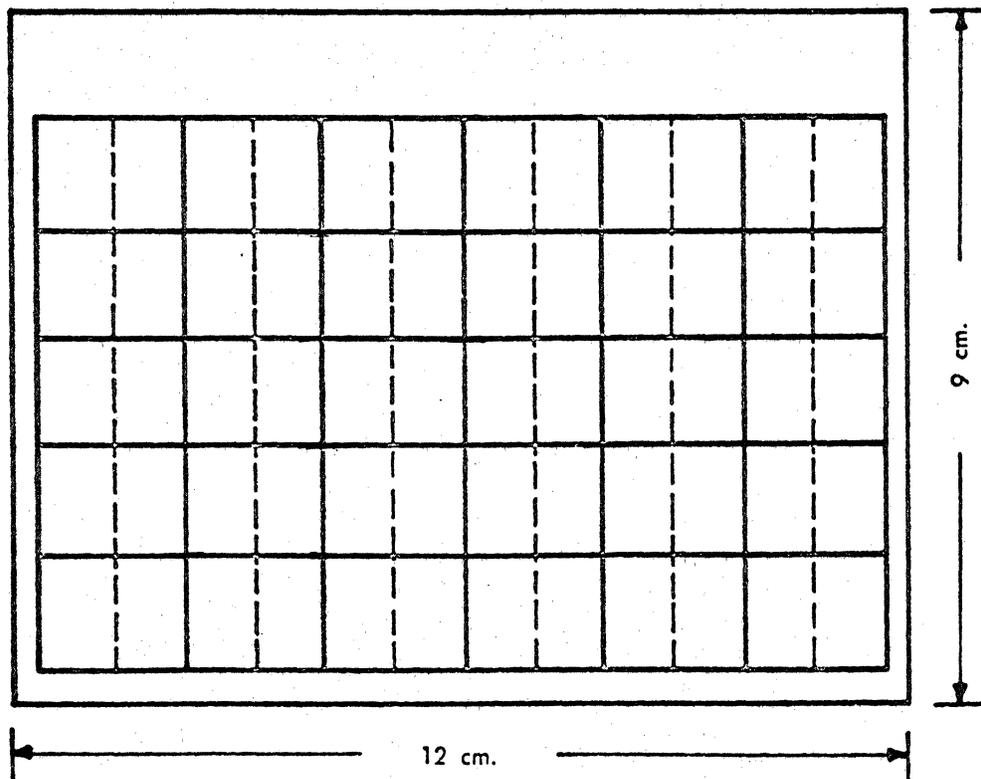


Figure 8-10. Microfiche, 9x12cm, 60 Frames

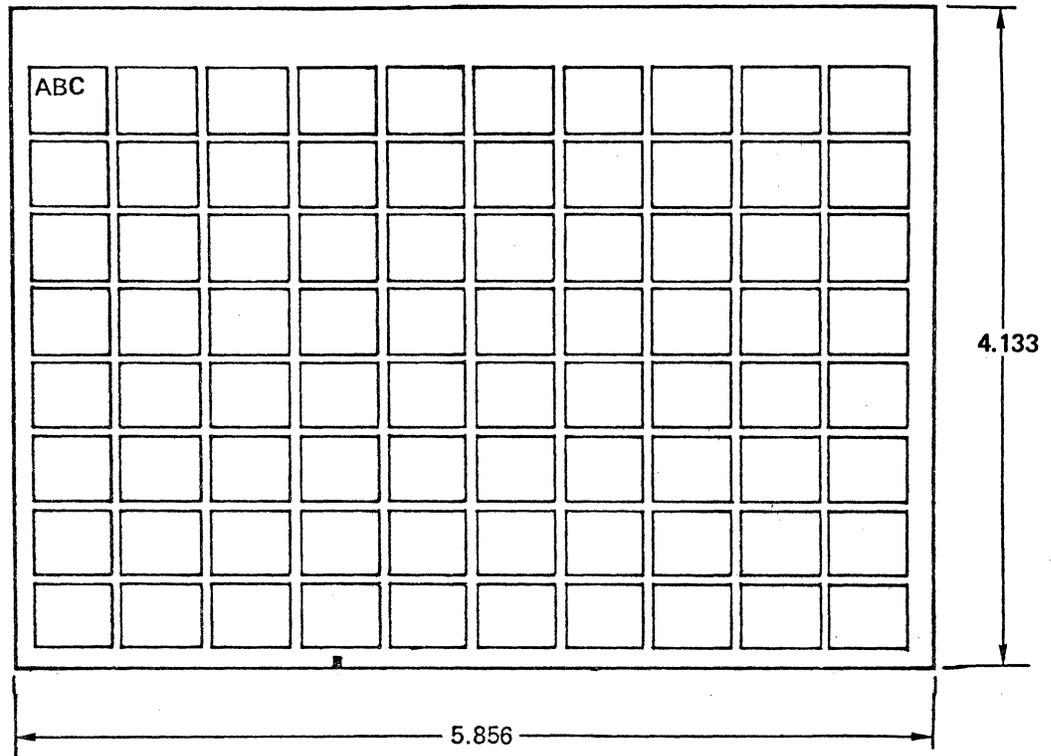


Figure 8-11. Microfiche, 4x6 inches (105x148.75mm), 80 Frames, 25X Reduction.

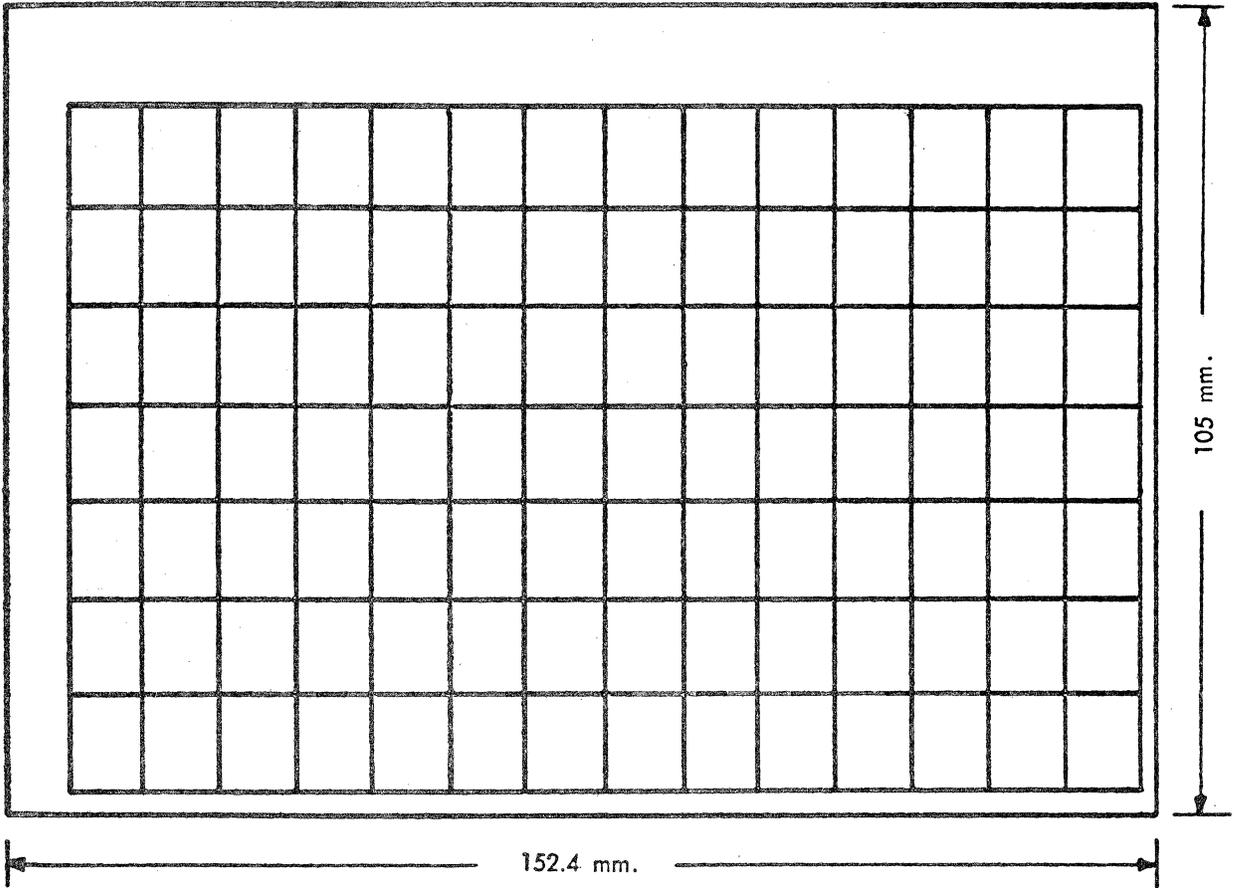


Figure 8-12. Microfiche, 105x152.4mm, 98 Frames.

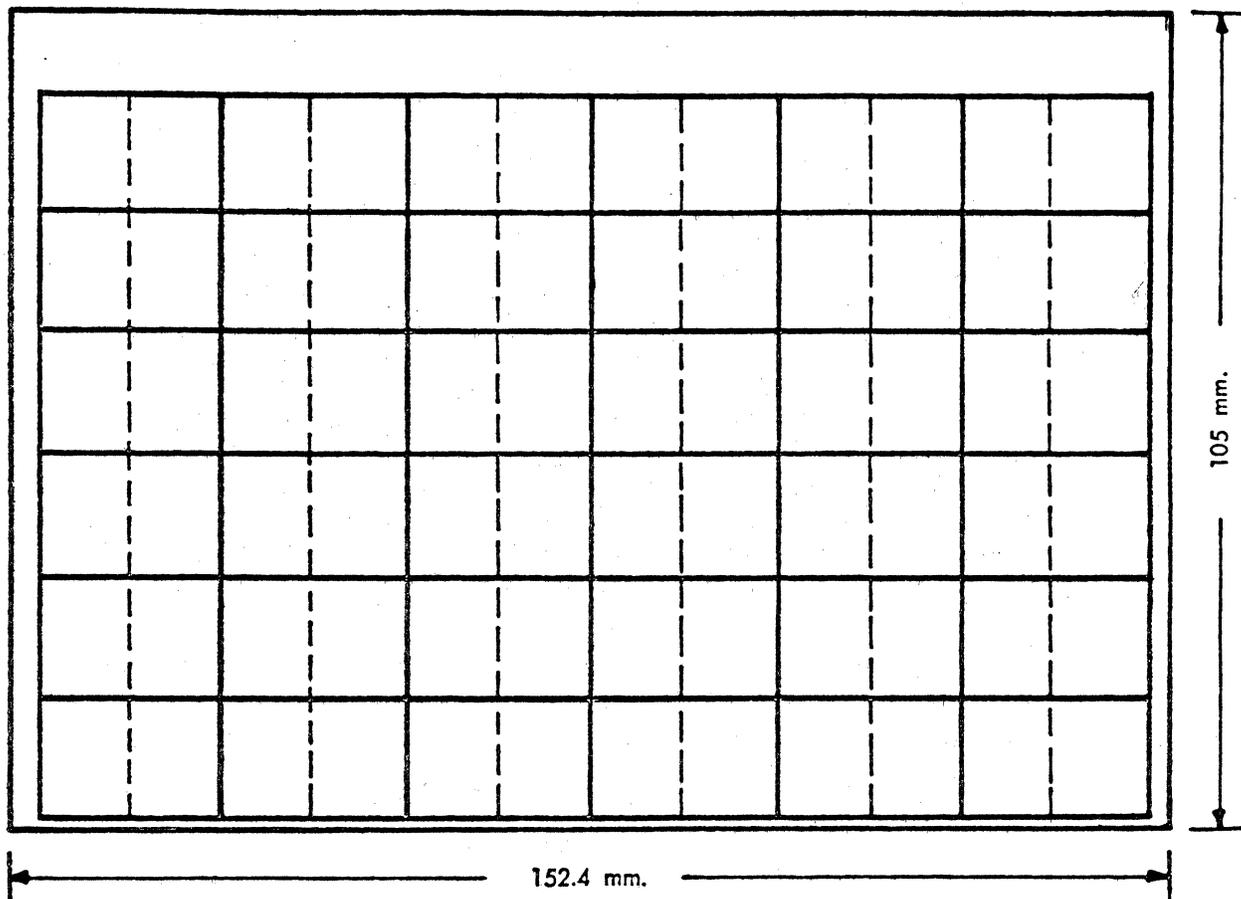
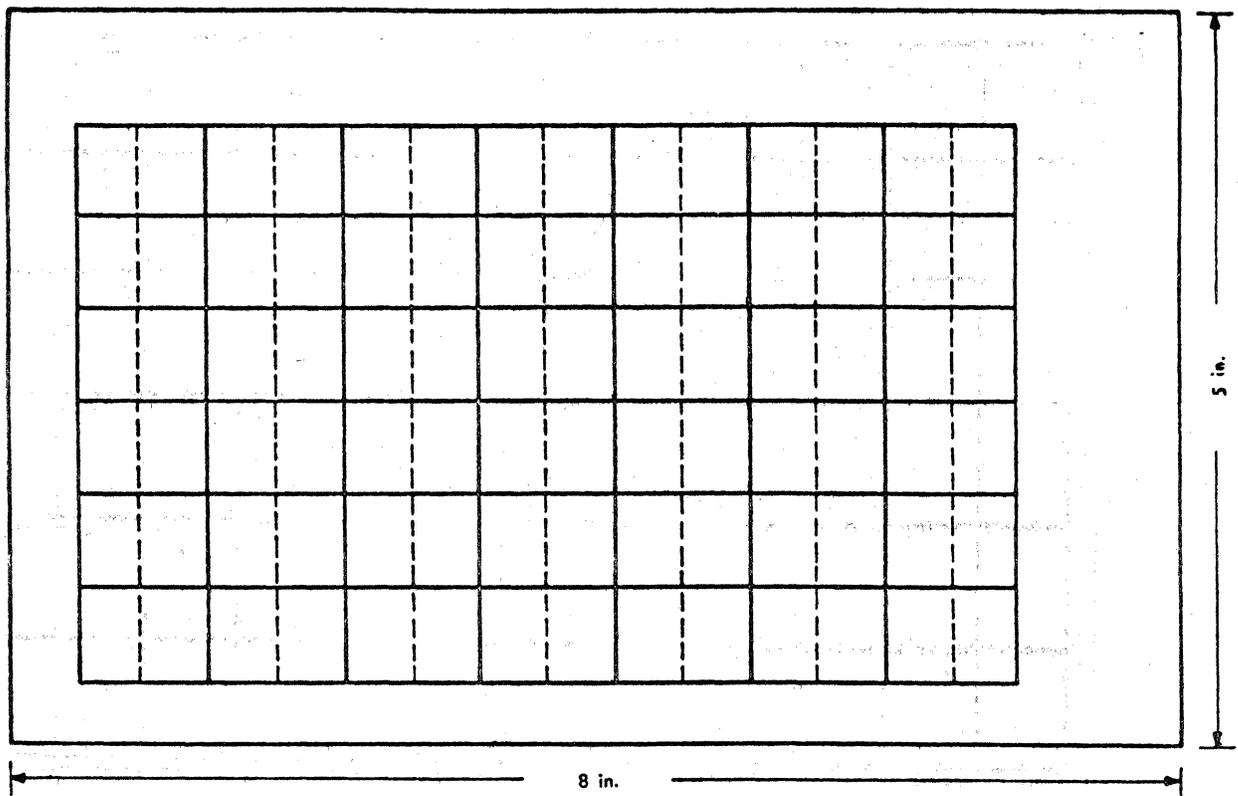


Figure 8-13. Microfiche, 105x152.4mm, 72 Frames



This format was used at one time by NASA. Although no longer used, several million are still in existence.

Figure 8-14. Microfiche, 5x8 inches, 84 Frames.