Film and Image Analysis Manual

PRODUCT SERVICE

DatagraphiX

6900N10, Rev. B

DATAGRAPHIX FILM

AND

IMAGE ANALYSIS MANUAL

January 1972

DatagraphiX

Stromberg DatagraphiX Inc ■ a General Dynamics subsidiary

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PREFACE

This manual has been prepared by Product Service Department, DatagraphiX, Inc. Its purpose is to provide the reader with a ready reference to information pertaining to microfilm, its processing and developing and image analysis. Six major topics are covered and a comprehensive examination is provided to assist the user in developing his own knowledge and proficiency.

Due to the complexity and the broad range of the topics covered, this manual will serve as a guide to further study of film processing, quality control and image analysis techniques. The reader is encouraged to refer to technical libraries and product specification data and other related sources of technical information.

For assistance in understanding the content of this manual, the reader is encouraged to contact or write the Customer Technical Support Group, Product Service Department 7100, DatagraphiX, Inc., Post Office Box 2449, San Diego, California, telephone 714-291-9960.

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SECTION I

FILM FORMATS AND STRUCTURE

1-1. 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.

1-2. RECORDING METHODS

Microfilm is recorded by the following:

1. Planetary Camera - a type of microfilm camera in which the document being photographed and the film remain in a stationary position during the exposure. The document is on a plane surface at the time of filming.

2. Rotary Camera - a type of microfilm camera that photographs documents while they are being moved by some form of transport

mechanism. The document transport mechanism is connected to a film transport mechanism, and the film also moves during exposure so that there is no relative movement between the film and the image of the 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 formats on different sizes of roll microfilm.

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. This camera has a sprocket with a registration pin to keep the frame and sprocket hole distances constant. Camera is said to have pin registration.

1-3. RATIOS OF REDUCTION AND BLOW-BACK

With the many types of COM systems in existence and various formats now in use, there is some confusion as to what the words blow-back and "reduction-ratios) really mean. The confusion results from the use of the word reduction for blow-back and vice versa.

To clarify the concept of reduction ratio, we shall look at the evolution of its use in COM. The original computer printout came on 11" x 14-7/8" paper. The characters were 0.1" high with six lines to the inch. There are 132 characters per line with 0.1" character width. When this was introduced, it was quite different from the normal $8\frac{1}{2}$" x 11" typewritten page and a short adjustment period followed. When COM entered the market place with a microfilm printer instead of an impact printer, the natural format to adopt was that of the impact printer. Using the 11" x 14-7/8" format and 16mm unsprocketed film, DatagraphiX introduced 25X film. The number 25 came from the fact that the characters which were formerly 0.1" were now 1/25 that size or .004" high on film. The same formula holds for 42X.

With this knowledge, let's look at why the confusion exists. The first viewers that were made tried to bring the characters back to full size (0.1") like the source document microfilm readers of the last 20 years. How many 11 x 14-7/8 viewer screens did people make? Not many. Designs made the screens smaller and the "blow-back" ratio was only 20X, 18X or 24X. Still the "reduction ratio" remained the same.

Presently, DatagraphiX produces 25X and 42X size characters but even these vary in the field. The variance is caused by the different sizes on the tube face (.019" to .030" character heights). Further, the blow-back ratios are 19X and 31X for the 1400 viewer. It isn't difficult to understand, however, you can now see why the confusion exists.

1-4. 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 ½ frame and the back of the document on the other ½ 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 ½ 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 side previously left unexposed.
5. Two Up - Two frames recorded across width of film by moving either film or lens.

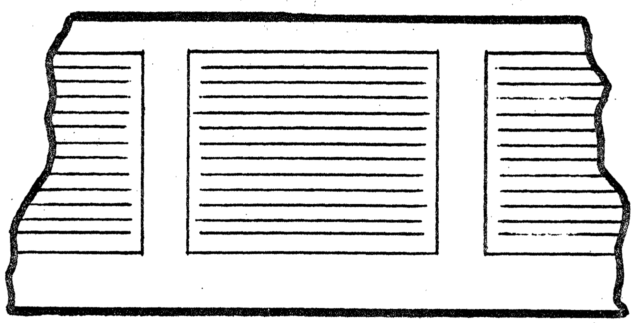


Figure 1-1. 16mm Microfilm, Comic or 0^{o} Rotation, 25X Reduction.

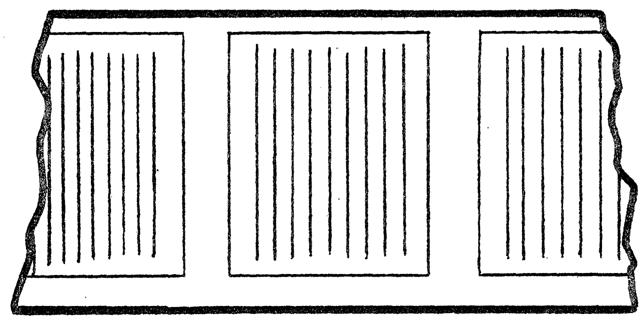


Figure 1-2. 16mm Microfilm, Cine or -90^{o} Rotation, 25X Reduction.

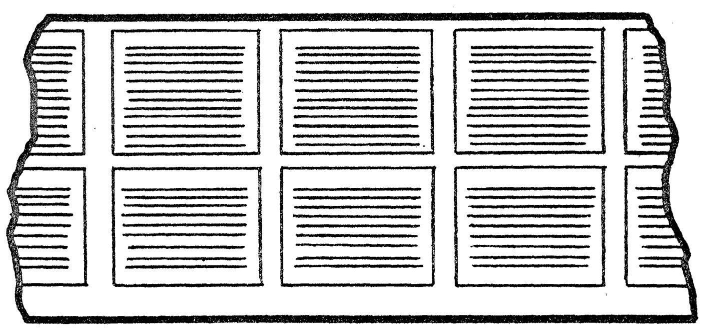


Figure 1-3. 16mm Microfilm, Two-Up, Comic, 42X Reduction.

1-5. 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. (Figure 1-1).

* 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. (Figure 1-2).

1-6. 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 <u>negative</u> image is one in which the values of light and dark of the original subject are inverted. A <u>positive</u> 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.

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.

<u>Note 1:</u> 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.

1-7. MICROFORMS

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.

1-8. 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 many major newspapers are 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 1-1, 1-2, and 1-3, at the beginning 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.

1-9. 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.

1-10. 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 paperwork 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 1/48th 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 $8\frac{1}{2}$" 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 reducation 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 1-4 through 1-14 show many microfiche formats.

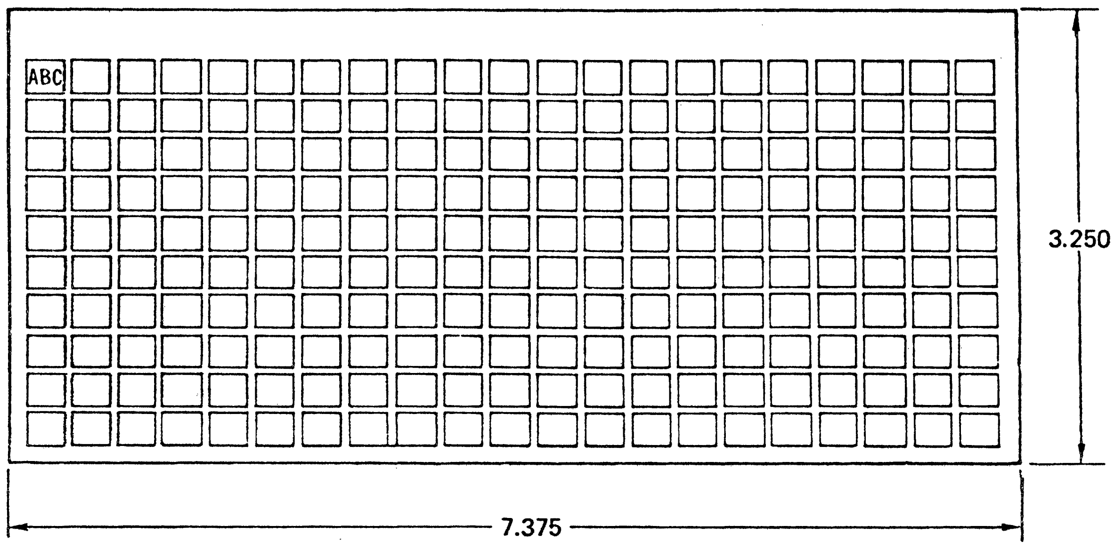


Figure 1-4. Microfiche, 3-1/4 x 7-3/8 inches, 210 Frames, 42X Reduction.

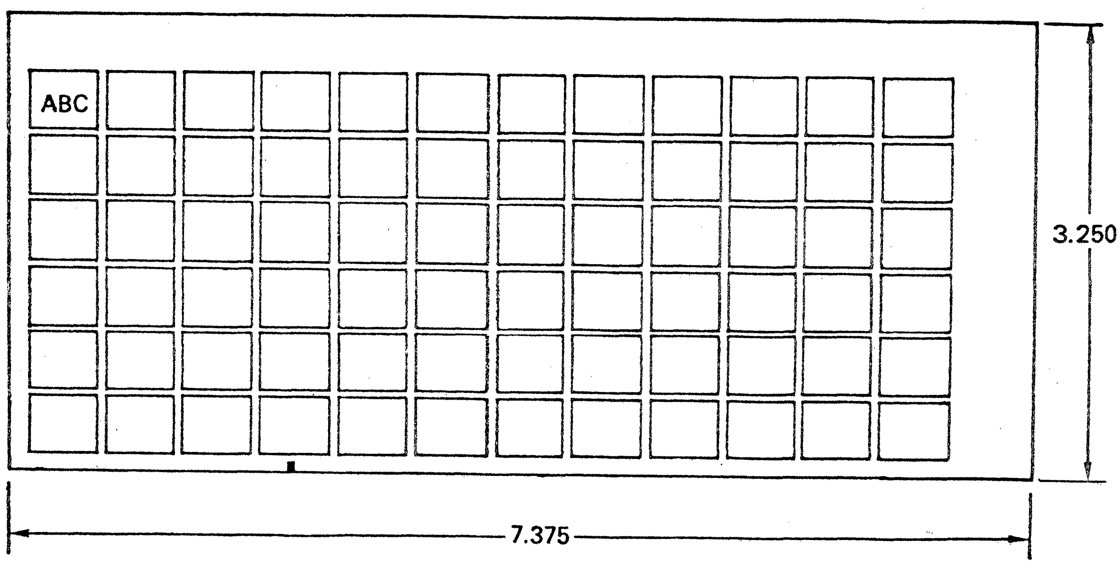


Figure 1-5. Microfiche, 3-1/4 x 7-3/8 inches, 72 Frames, 25X Reduction.

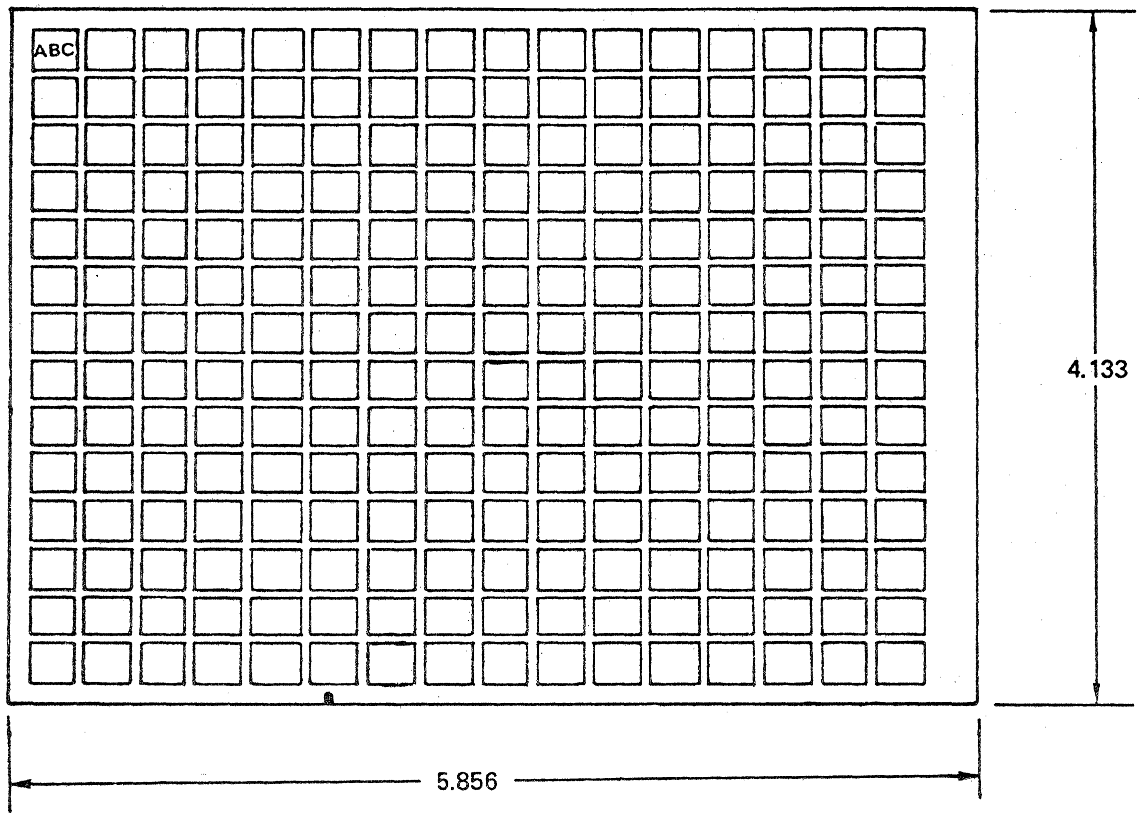


Figure 1-6. Microfiche, 4 x 6 inches (105 x 148.75mm), 224 Frames, 42X Reduction

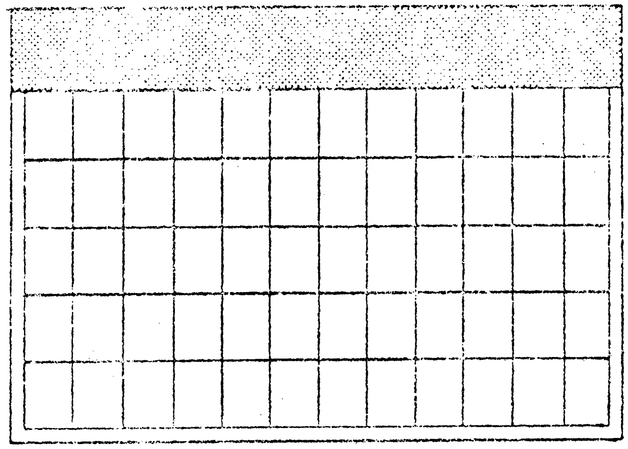


Figure 1-7. COSATI Microfiche Format, 105 x 148mm, 60 Frames.

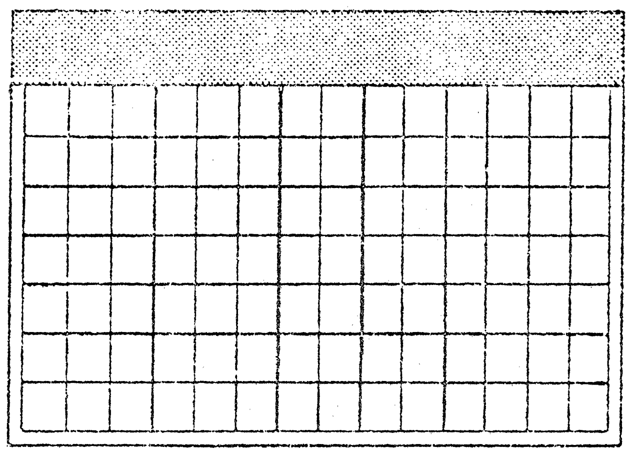


Figure 1-8. NMA Microfiche Format, 105 x 148mm, 98 Frames

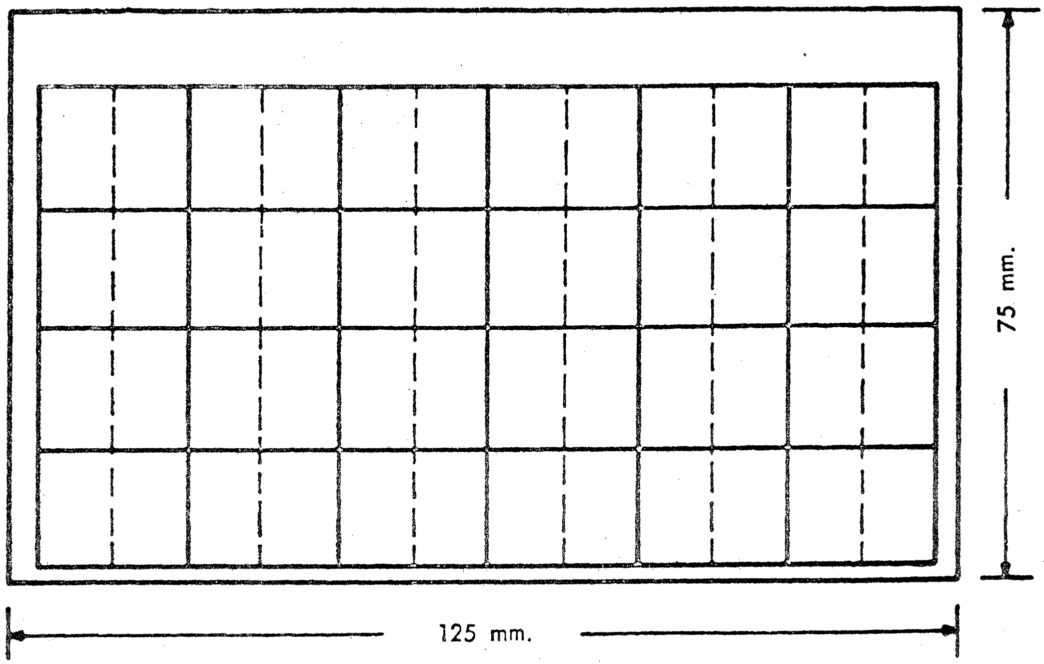


Figure 1-9. Microfiche, 75 x 125mm, 48 Frames.

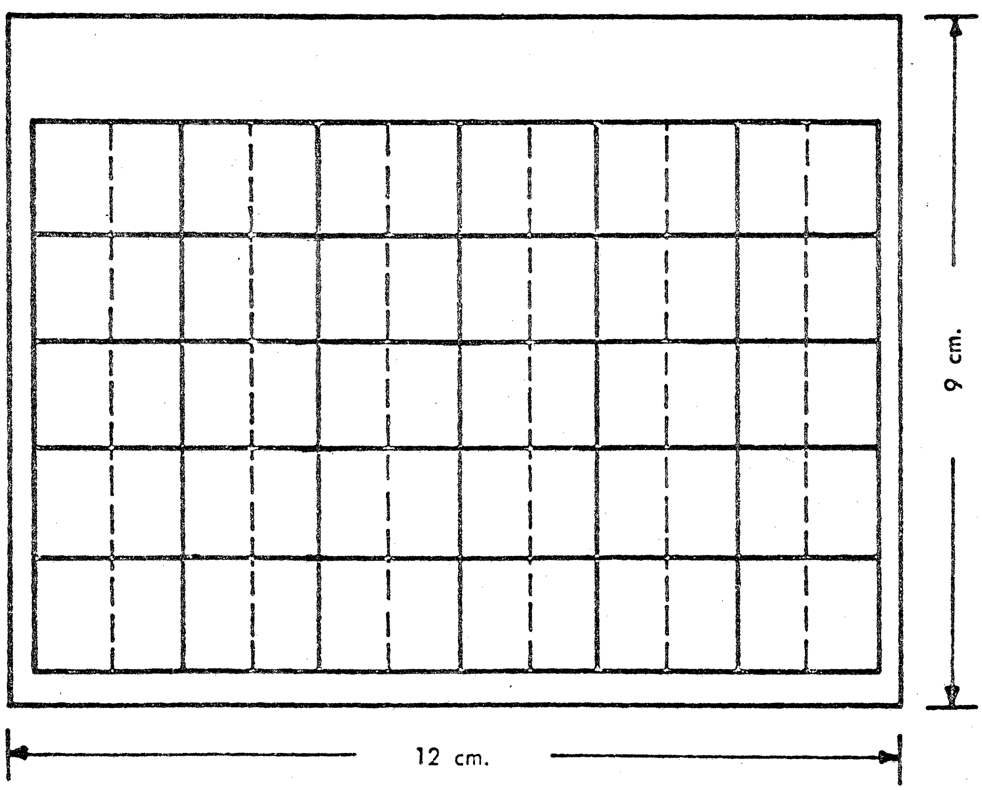


Figure 1-10. Microfiche, 9 x 12cm, 60 frames.

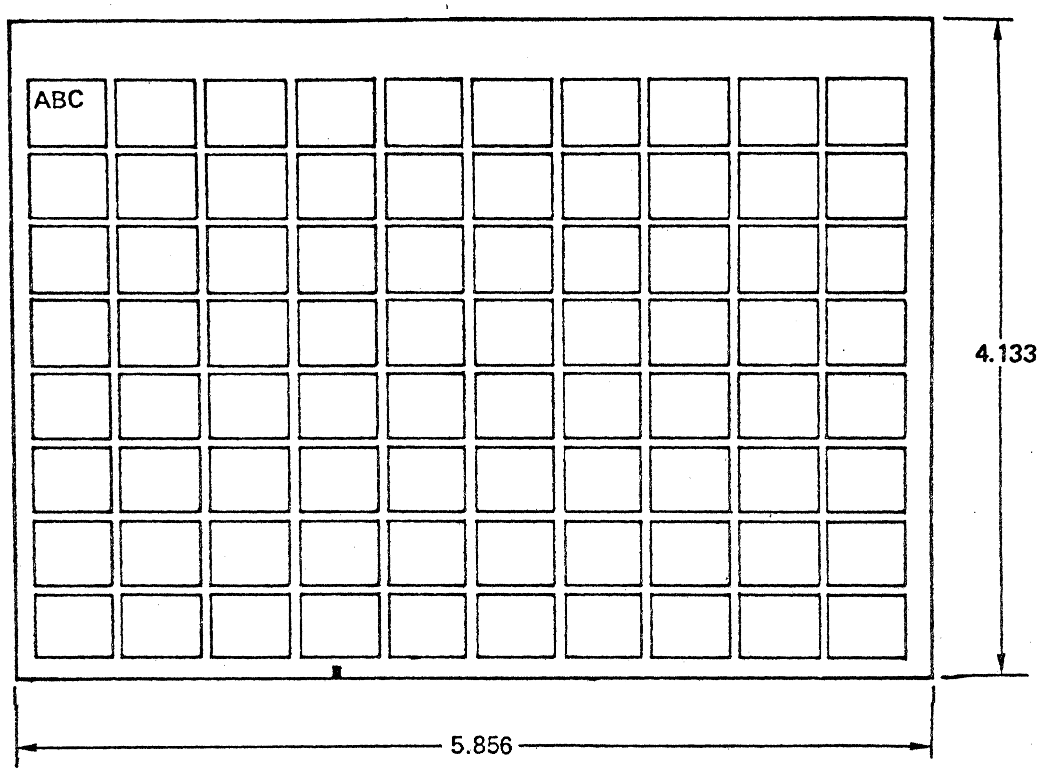


Figure 1-11. Microfiche, 4 x 6 inches (105 x 148.75mm), 80 Frames, 25X Reduction.

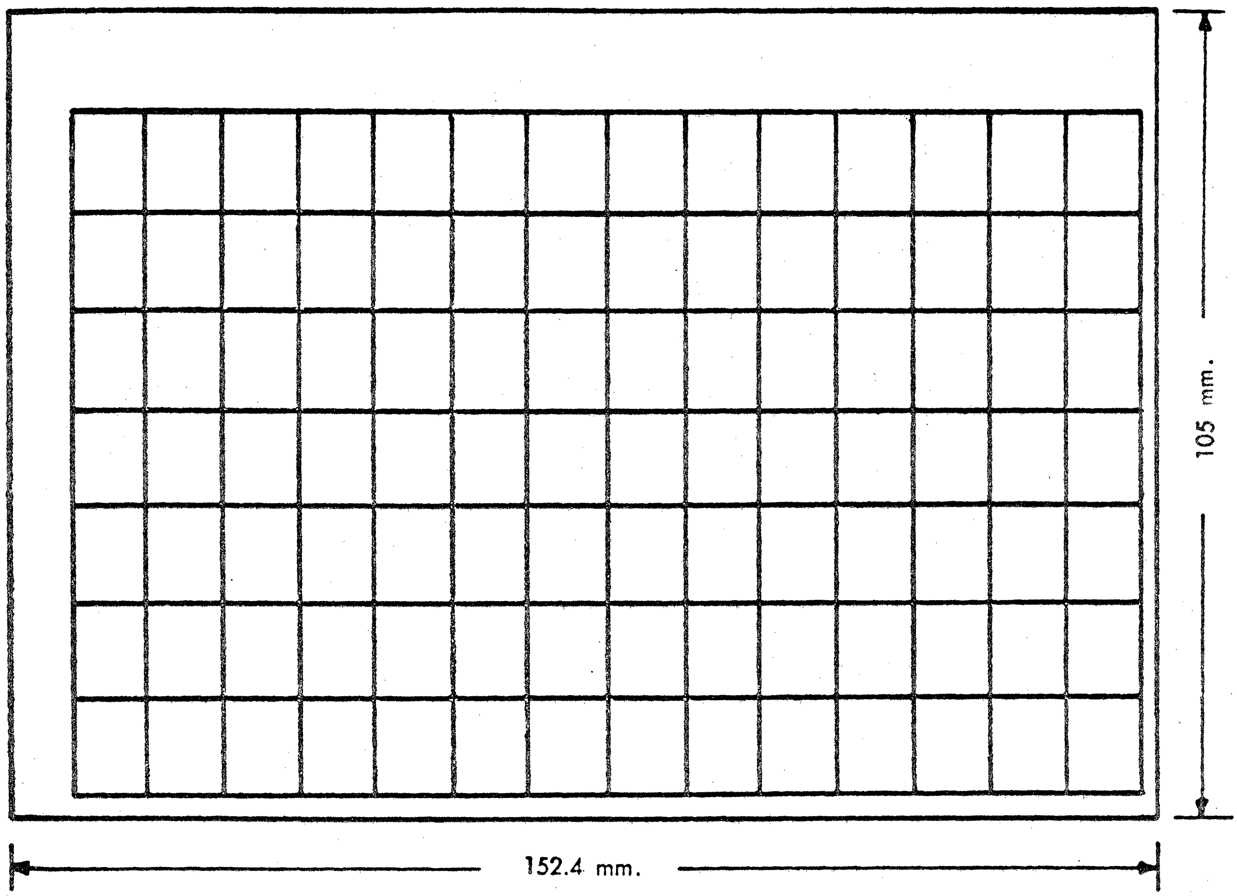


Figure 1-12. Microfiche, 105 x 152.4mm, 98 Frames.

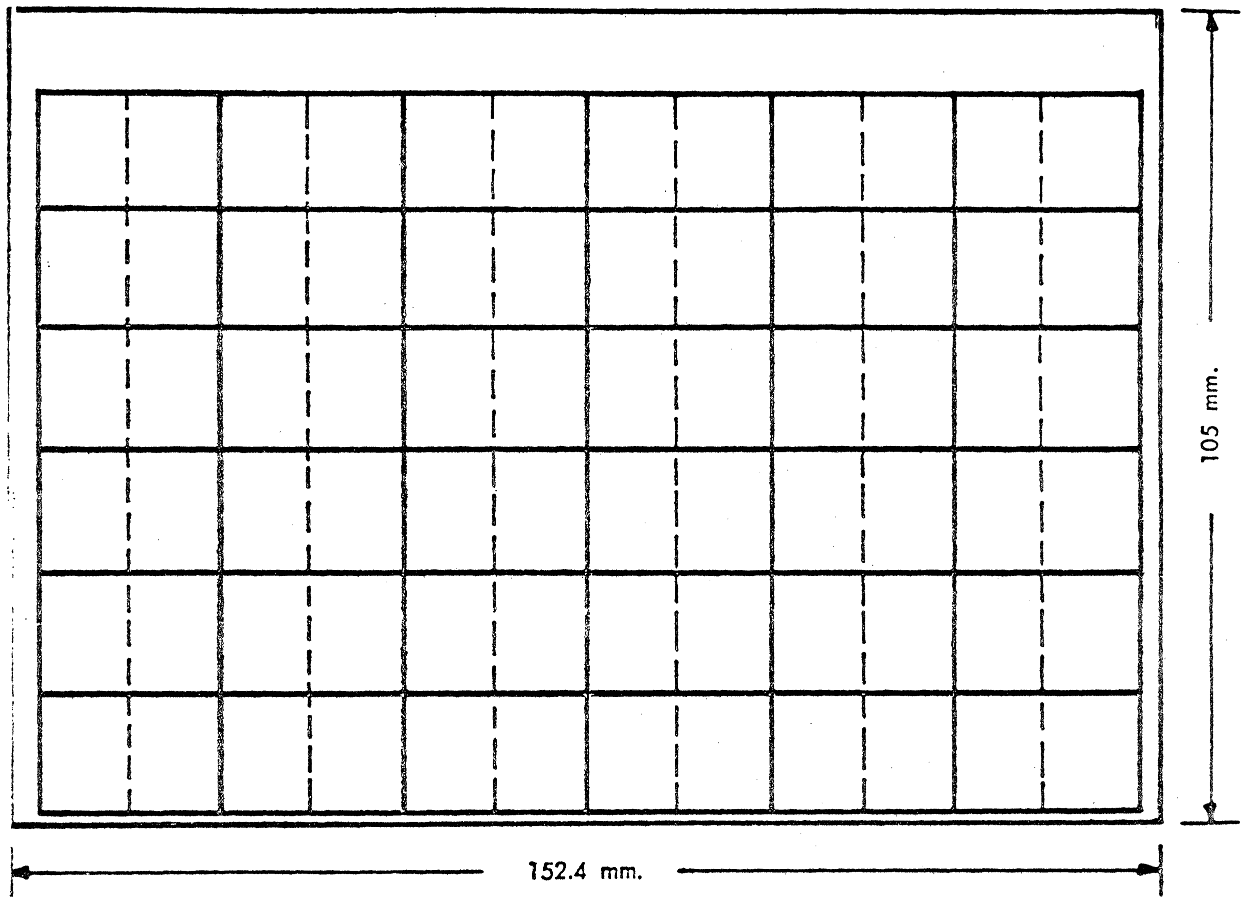
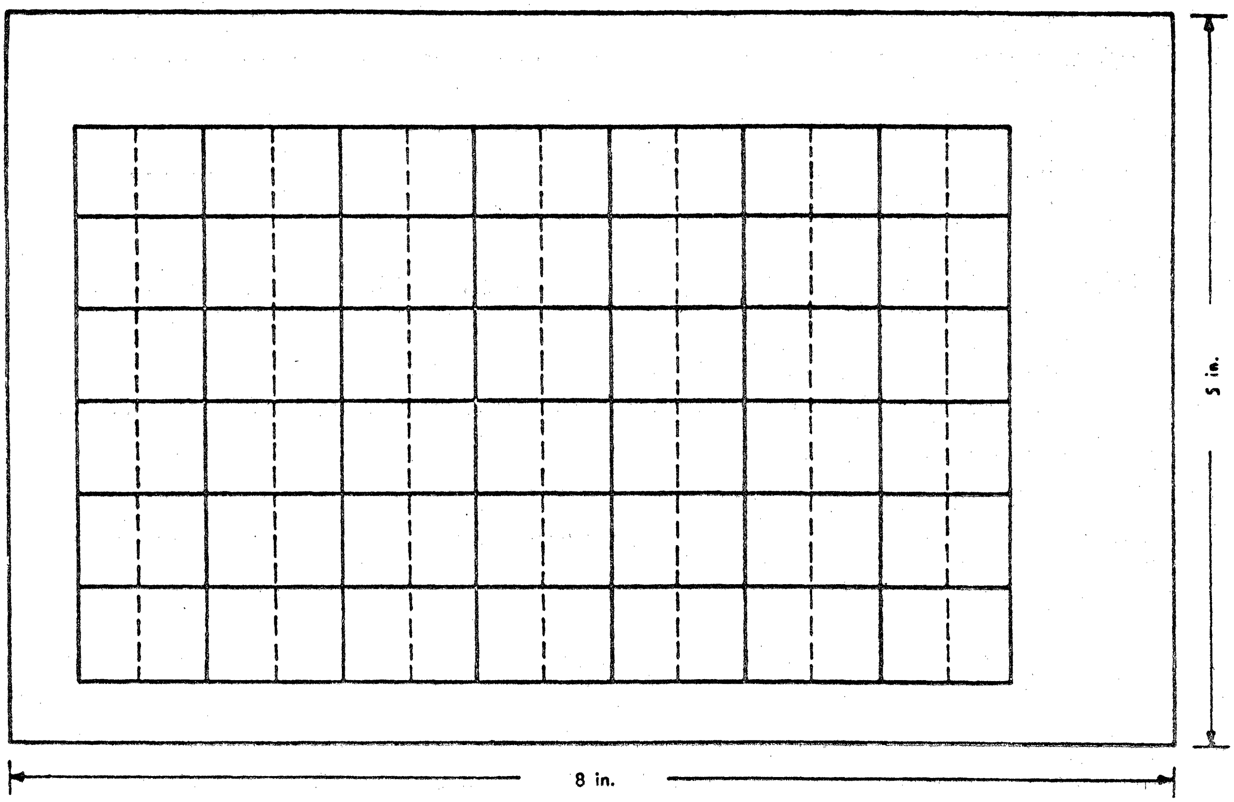


Figure 1-13. Microfiche, 105 x 152.4mm, 72 Frames.



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

Figure 1-14. Microfiche, 5 x 8 inches, 84 Frames.

1-11. 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 noxious but not 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 using vesicular film to record CRT data. A film still in development uses a thermoplastic that accepts CRT data. 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 vesicular film, 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.

1-12. 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, cellulose acetate butyrate or polyester. 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 cannot 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.

1-13. 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 halide employed are the chloride, bromide and iodide. The silver halide is produced by adding silver nitrate to a solution of the halide, i.e., potasium 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, the 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 on 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 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.

1-14. 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 or lightly tinted
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.

Polyester is sometimes used as a film base material where strength is an important factor. Mylar is the most commonly used polyester base and is called by different names; for example,

Eastman Kodak - Estar

Dupont - Cronar

The biggest drawback to the use of polyester base material for silver film imaging is that it gathers static electricity and the discharge exposes the film. With high speed cameras in medium humidity (40% RH) environments, the polyester base material does not give good performance.

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.

1-15. FILM STRUCTURE

All films have a similar structure whether silver, diazo, vesicular or dry silver. The general structure is shown in Figure 1-15.

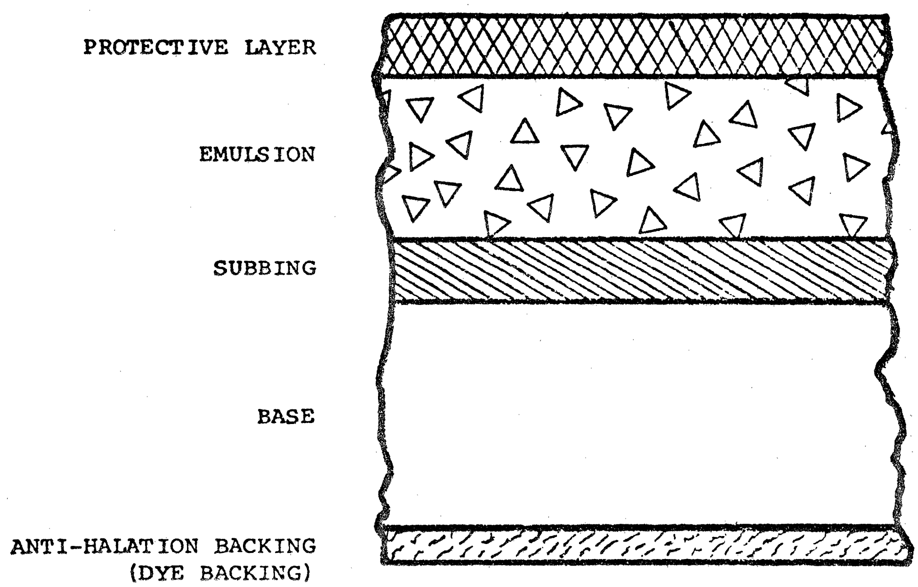


Figure 1-15. Typical Film Structure.

A. Protective Layer

A clear material used to reduce the abrasion or staining of the emulsion.

B. Emulsion

1. Photosensitizer - the light sensitive material. This is normally, in microfilming, silver halides and salts that produce silver images. Diazonium compounds are formed into either light scattering centers or coupled to form a dye image in diazo and vesicular films, respectively.

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.
   Vesicular film: a saran type plastic.

C. Subbing

A clear adhesive which holds the emulsion to the base.

D. 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).

E. Backing

A material to reduce reflected light (anti-halation) or to reduce static electricity (anti-static). Both may be part of the film. DatagraphiX' new silver film has an anti-static backing but no anti-halation backing.

The base stock is usually manufactured from mylar (polyester) or triacetate material. Each base material has some advantages over the other when used in DatagraphiX equipments. Mylar is a very strong material and demonstrates high dimensional stability. More precisely, it has a high Young's Modulus and low plastic flow coefficient. Mylar is also very stable under relative humidity and temperature changes which makes is desirable for a film base. However, triacetate base films are commonly used in DatagraphiX systems because they are less susceptible to static. Triacetate base films are not as susceptible to static as mylar. It also is far easier to cut triacetate base films which becomes important when 105mm fiche are being generated. One last advantage that acetate has over mylar is low light piping. This phenomena can be visualized as light entering the edge of the film and being transmitted without much attenuation toward the center of the film. A bent piece of lucite rod with a light on the end would illustrate the phenomena of light piping.

The present base stock for Stromberg DatagraphiX silver films is 5.5 mil triacetate. This has been selected to be most compatible with all of the recorders, viewers, printers and copiers. Figure 1-15 is a simplification of a film cross-section. Typical of silver films is a halation protection of some type. Figure 1-16a and Figure 1-16b show two types of halation protection.

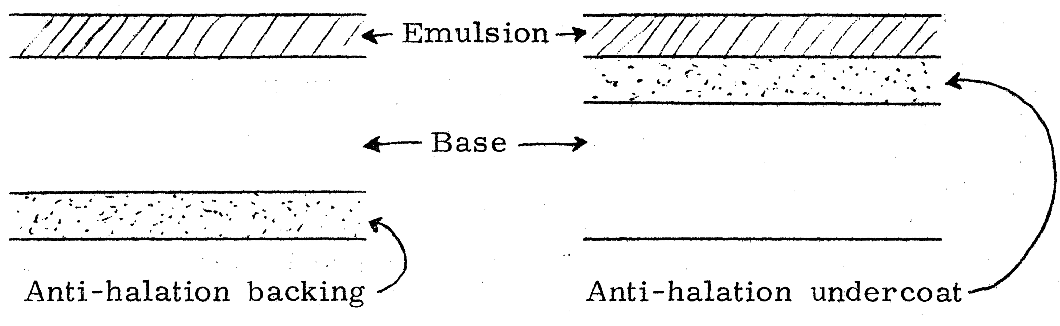


Figure 1-16a

Figure 1-16b

The halation seen in films is the result of light scattering (reflected) off the backing and imaging the film; shown in Figure 1-17 is a typical light scattering in a silver film without halation protection.

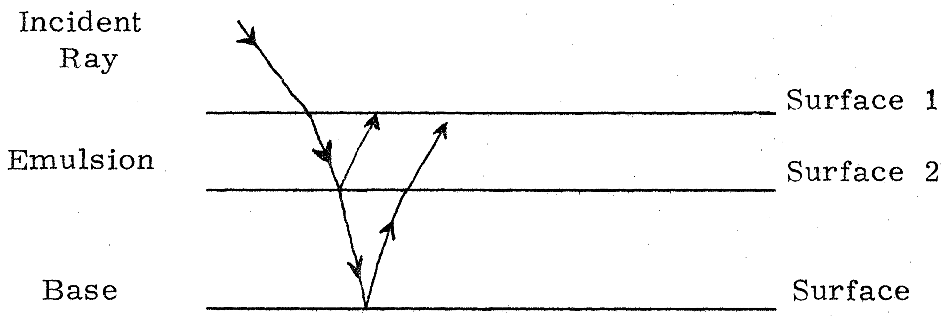


Figure 1-17 (No Halation Protection)

The light is refracted at the base Surface 2 and is internally reflected at surface 3 back to the emulsion where the silver is exposed. The purpose of the anti-halation undercoat or anti-halation backing is to attenuate the intensity of this refracted-reflected ray so that there is no secondary exposure. Figure 1-17a gives the picture of a film with an anti-halation backing.

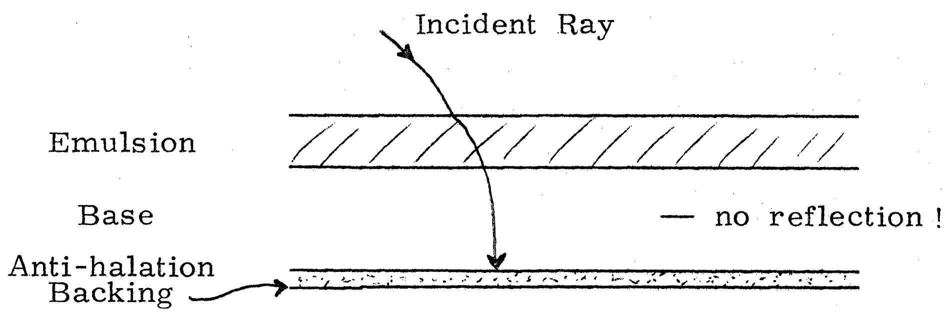


Figure 1-17a

Different types of backing are used in practice. A commonly used anti-halation backing has a dark-blue appearance. Other films also frequently have a black carbon backing called "rem jet" backing which has to be scrubbed off mechanically and pollutes the developer. Since they look alike, one should take care not to confuse the two types.

The mechanical, physical, electrical, chemical and optical properties could be discussed in detail, but the value of this information doesn't warrant time spent here. Such parameters as coefficient of thermal expansion, kinetic coefficient of friction, surface resistivity and others offer very little in the way of useful field information and will not be discussed here. Of importance, however, is the film's behavior as a result of having different environmental conditions. It is hoped that without too frequent reference to these technical parameters, some common film behavior can be satisfactorily explained.

Film curl is found to some degree in all silver halide films. A film that is absolutely flat has a curl of zero. By convention a positive curl means that the edge of the film is bent toward the emulsion side and negative curl the edge of the film is bent toward the base. Curl can result from an environment that has caused stress between the emulsion and the base. Holding the emulsion onto the base is an adhesive. If the base expands at a different rate than the emulsion for some given change in temperature or humidity, the film curls. This situation can be commonly found in a bi-metallic strip. Most films have been optimized at 70° F, 50% R.H. for curl (e.g., curl = zero at 70° F and 50% R.H.) If the film is taken below the optimized conditions, say positive curl results and above optimum conditions "reverse" or negative curl results. It should be clear that if one is trying to image a non-flat film or make hard copy from a non-flat film the image is distorted.

Improper storage temperature or too high a drying temperature can cause the film to curl.

Another problem commonly encountered is the static exposure. When film is unwound from a roll at high speed and transported through a camera, the residual static charges eventually discharges and this static electricity exposes the film. The appearance of static can be in the form of "lightning bolts" shapes or small dots, depending on the direction of the discharge. Figure 1-17b illustrates the two most commonly seen static discharges.

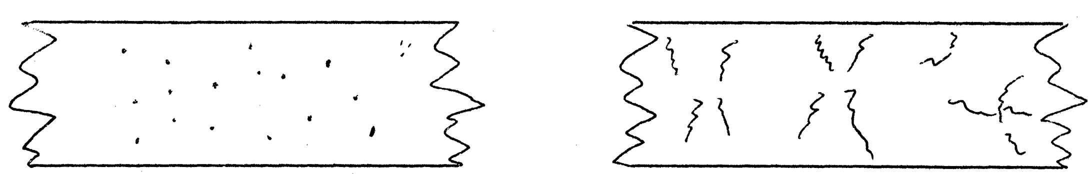


Figure 1-17b (Static)

Static electricity can easily be generated in a dry atmosphere: example -- leather soled shoes across a nylon rug . . . . . . then touch the door knob!!

The same is true of film. Under low relative humidity condition, say below 35% R.H., the film will tend to generate and discharge electricity, thus resulting in unwanted exposures.

Humidity is the percentage of water by weight to a given amount of air. More useful is the relative humidity which is the ratio of the vapor pressure due to the water vapor to the saturation vapor pressure at a given temperature. When saturation occurs, the air is no longer capable of keeping more water and any extra water will result in precipitation. The name for 100% saturation of a vapor is known as "dew point."

Most films put a conductive layer either on the back or underneath the emulsion. This layer helps to dissipate the charges instead of letting them accumulate and discharge. Figure 1-18 illustrates the film with anti-halo backing and anti-static protection.

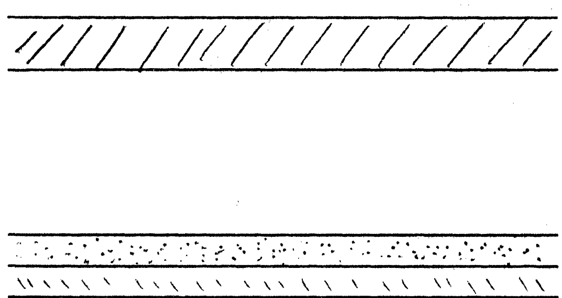


Figure 1-18 (Film Cross-Section)

The emulsion is composed of silver halide suspended in gelatin. The ratio of silver to gelatin determines the hardness of the film.

<u>Equation 1</u>

$$\text{Hardness} = \frac{\text{Amount Silver}}{\text{Amount of Gelatin}}$$

Film hardness becomes very important in the Stromberg DatagraphiX system. The Mark Systems on-line processor in the DatagraphiX 4060 doesn't have a formal drying stage and the film must dry before it reaches the hard copy unit. If film remains tacky it will stick to parts of the hard copy unit and jamming will result. The DatagraphiX film is sufficiently hard to be dried by the warm ambient air within the machine.

1-16. 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.

1-17. 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^{o} F.
  - Relative Humidity - 25% to 60%.
* Archival permanence:
  - Temperature - 60^{o} to 80^{o} F.
  - Relative humidity - 40% to 50%.

Storing film at temperatures above 100^{o} 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.

1-18. FIRE PROTECTION STANDARDS

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

A. Dry Heat

1. 250^{o} - no effect.
2. 300^{o} - some warping but still printable.
3. 350^{o} - 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.

1-19. 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.

1-20. CARE DURING USE

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

SECTION II

PROCESSING

In this chapter we shall discuss general photographic film processing and some specifics about DatagraphiX processing. For most applications today, the wet process is used -- although dry-silver processing is under development. We shall concern ourselves here with conventional black and white film processing.

We begin our discussion by looking at the types of black and white processing. For simplicity we shall assume that only two kinds of film fit this category: film with dark characters and clear background, and film with clear characters and dark background. It is quite common to hear the terms negative processing, positive image, or reversal processed. These can lead to complete confusion unless the terms and the processes are thoroughly understood. Let's begin by looking at the image on the tube face. The characters and lines are bright and the background is dark. If one processes this film in a standard negative process, developer, fixer, wash, the film will have dark characters on a clear background. The film has used the light rays to make the characters dark. The blackness of the image is directly proportional to the amount of silver that is in the film. Now taking the same CRT tube and exposing the film and reversal processing it yields a film with clear characters and a dark background. This film is said to be reversal film.

As long as one uses the DatagraphiX-CRT exposure tubes, this convention is maintained. However, when the original image from a tube or paper has dark characters and light background the films will have the opposite appearance for negative and reversal processing. It is easier to understand what happens in the processing reactions and then determine the image polarity of the film.

Of the two types of processes, negative and reversal, negative processing is easier to understand. The first solution in negative processing is the developer. It is not possible here to describe all of the properties of developers, but basically the following criteria have to be met. (Mees Ch. 13, pg. 278, Third Edit.).

1. Reduces silver ions to metallic silver.

2. Reduces silver-halide grains at a higher rate than the unexposed silver-halide grains.

3. Fairly soluable in water and alkaline solutions.

4. Be reasonably stable and have resistance to aerial oxidation.

5. Colorless and soluable oxidation products.

6. Be innocuous and non-toxic.

For DatagraphiX applications, items one and four are most important -- although all items are desirable.

The emulsion has a silver-halide compound which is sensitive to light. It is the purpose of the developer to make the image visible to the eye. To accomplish this, the silver-halide must be reduced to metallic silver. Chemically, this requires the developer molecule to give up one or more electrons to reduce the silver-ion.

2-1. 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.

$$Ag^{+} + \text{Electron} = Ag \text{ (metal)}$$

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. <u>Developing Solutions</u>

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

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

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

2. Developing Agents - The developing agent, normally metaquinone or hydroquinone, is a mild reducing agent. Ag^o acts as a catalyst causing reaction with other atoms. 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 (or other chemicals) 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.

2-2. 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.

2-3. 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 thiosulfate 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.

2-4. DRYING

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

2-5. 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.

2-6. 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.

2-7. SHELF LIFE

Some photographic chemicals have a shelf life of 2-3 months @ 60^{o} - 70^{o} F, but only a few days @ 90^{o} - 95^{o} F. Chemicals supplied by DatagraphiX for the 156 are stable from 20^{o} F to 110^{o} F, but the lower the temperature, the less the aging.

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

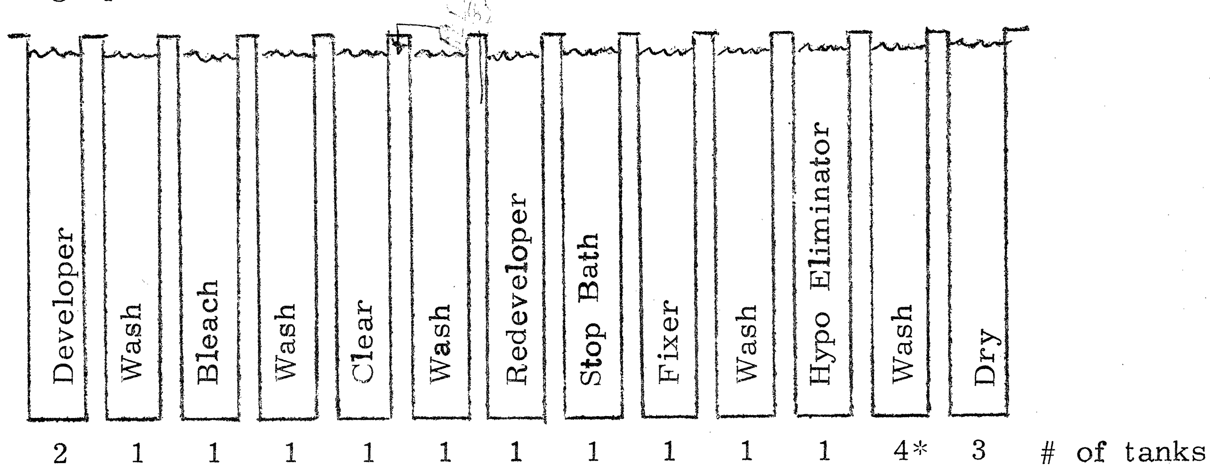
Silver film has been certified in order to set standards for vehicles, sensitizers and emulsions. Depending upon the components of a given silver film, it is certified from the standards for a certain period of archival life, usually from 20 to 40 years.

2-8. PROCESSORS

Before going into the reversal type processing, we shall discuss another type of negative processing. Instead of using the conventional three bath processing, developer, fixer and wash, one can substitute developer, stabilizer, clear solutions. This type of processing is more convenient since a wash water supply isn't necessary. However, there are certain drawbacks in using a stabilization process. For one, the silver halides which are normally removed by fixing and washing remain in the emulsion, converted of course to relatively inert compounds. The second drawback to this process is that one cannot obtain an archival film. We shall not concern ourselves with the chemical reactions of stabilizers. The clear solution does remove most the reactive chemicals and also removes much of the water in the emulsion. This reduces the requirement for an extensive drying system. This stabilization process can be found on the DatagraphiX 4060 recorder.

Not of immediate concern to us is a monobath solution which does the developing and fixing all in one. In general, some image quality losses occur when monobath processing is used.

Reversal processing differs from negative processing in that the exposed areas become clear and the non-exposed areas become dark. Shown in Figure 2-1 is the proper sequence for standard reversal processing on the DatagraphiX 89.



*Sometimes a "Rinse" is substituted for the 4th wash tank.

Figure 2-1. Reversal Processing Sequence

Although photoflo is not shown in Figure 2-1, in practice it is often used with hard water to reduce water spotting. Note that after the developer comes a bleach. The bleach takes the developed metallic silver in the image portion and removes this, leaving the undeveloped silver halide in the emulsion. The wash in between each type of solution is to reduce chemical carry-over from tank to tank. Clearing bath removes the very corrosive bleach solution. It is common before redeveloping to re-expose, thereby intensifying the density to be developed. From the redeveloping station to the dry is almost our standard negative processing. We have redeveloper as developer, a fixer, a hypo eliminator agent which is a chemical wash to remove the thiosulfate ions, wash, a photo-flo solution to aid drying and finally the dryer section.

The importance of following the correct processing procedures given in the handbooks is extremely important. Film processors require cleaning and care to handle the silver film in an acceptable manner. In this chapter we shall discuss the DatagraphiX-156 and associated processing problems. To fully understand the exposure-development scheme the third chapter on film parameters and sensitometry should be read.

To understand the basic processor operation one has to understand the principles by which the machine operates. The maintenance manual for the DatagraphiX-156, HMO225, gives a detail explanation of the processor operation and should be referenced frequently. The DatagraphiX-156 handles any film width up to 10 inches. Each piece of film is carried by soft rubber rollers through the chemical baths and dryer section. In general, these rollers do not scratch the film. They can, however, scratch film if foreign particles -- such as dirt and rust -- are impregnated in the roller surface. Dirt can be kept out of any processor by filtering the water at all times and running the processor in a fairly dust-free environment.

It is convenient to analyze the processor by looking at the systems that go to make it up:

1. Transport System
2. Water Supply System
3. Recirculating System
4. Replenishment System
5. Level Sensing System
6. Solution Heating System

7. Dryer Heating System

8. Sump & Drain System

The details of each system are given in HMO 225, but will briefly be discussed here. The transport system is composed of a chain-driven friction clutch assembly which pulls the film through the solutions. Each clutch must be adjusted and locked to insure proper film advancement. If the clutch is too tight or too loose there is a possibility of film jamming or abrasion. In addition to the clutch adjustment, the rollers in the plenum sections must have proper contact to pull the film through the solutions and squeeze the water from the film in the dryer section.

The water supply system is more than just a hose supplying wash water. When the water enters the processor the water temperature is about 105^{O} F. It supplies the wash down hose and then enters the heat exchanger. Here solutions at 110^{O} F give up heat to the water at 105^{O} F and bring the water temperature to 110^{O} F for the wash. Meanwhile, the developer and fixer are kept from overheating by the cooling effect of the water. The wash water now at 110^{O} F enters the wash plenum and is sprayed onto the film.

There is a recirculating system for each solution and the dryer section. For solutions the recirculating pump, running at seven to eight gallons per minute, keep the plenum sections full of fluid so the film does not touch the sides and proper chemical treatment results. Improper recirculation due to air bubbles, low flow rate or clogged recirculating line can result in improperly processed film. The effect is different for each solution and should be understood by the operator. The dryer air recirculating system moves the warm air, 125^{O} F, across the film through a blower, air-jet assembly.

In each of the recirculating systems, the solutions or air must be kept fresh. To accomplish this, a replenishment system is incorporated. For the developer and fixer solutions an auxiliary pump, reservoir and flow meter are used to keep the chemicals at proper working strength. The wash section is supplied with tempered water from outside the machine and the fresh air is supplied by environment. All replenishment systems must be working properly to give high quality film images.

A very important system in the film processor is the level sensing system. There are three level sensors located in the developer, fixer, and sump tanks, respectively. In the developing and fixing tanks the level sensor keeps the fluid level high enough for correct recirculating volume. When level is too low, bubbles form in developer and fixer plenums. Also, too much heat builds up in plastic tank near the heaters and tank will warp. The third level sensor, located in the sump tank controls the sump pump.

High level reading turns pump on and low level turns pump off. Older model DatagraphiX-156 processors have a pressure sensor whereas the newer models have a low-voltage sensor.

The developer and fixer solutions are mixed at room temperature and must be heated to 110° F for proper development processing. The heaters are located in the bottom of both the fixer and developer trays and are thermostatically controlled. The actual developer temperature is indicated on the control panel.

The heating system for the dryer section is similar to the solutions system, but has a thermostat for low level and a thermostat for high level shut off. Standard drying temperature is 125° F for a transport speed of 5 feet per minute.

Last system to be briefly discussed is the sump and drain system. The developer and fixer solutions drain by valves located at the rear of the processor. The wash tray drains by removal of the stand pipe. All of the solution trays have an overflow opening at the lip of the tray which allows excess solution to empty into the sump tank. From the sump tank the fluids are pumped into the drain.

At this point it cannot be overemphasized the importance of reading HMO225. Also, checking a processor system by system is extremely instructive. At lease 20 hours should be spent trouble shooting the processor in training lab before field service is attempted.

There are two other off-line processors that are frequently used with DatagraphiX recorders: DatagraphiX-89 and the Prostar. There are certain advantages in using these processors instead of the DatagraphiX-156. The DatagraphiX-89 is capable of both negative processing and reversal processing. Many customers requiring 16 and 35mm reversal film don't have any choice between the three processors since the 89 is the only DatagraphiX machine capable of full reversal processing.

The DatagraphiX-89 manual is simply a reproduction of the manufacturer's brochure, but is accurate and fairly complete. There are several noticeable differences from the DatagraphiX-156. The mixing valve is built into the machine, there are fifteen tanks instead of three, a low-pressure air line must be supplied to the machine for drying and about 150' of leader is necessary for the running of film. With all this extra configuration, the DatagraphiX-89 can process film five to six times as fast as the Prostar or DatagraphiX-156 which is a definite advantage with 400' or 1000' magazines are being used frequently. During normal operation, the processor runs at about 24 feet/minute and 90° F for the solutions. The wash water is also at 90° F. For a detailed description of this processor, reference the maintenance and installation manual

The Prostar is the smallest processor. It is capable of processing both 16mm and 35mm at 5 feet/minute. It should be used with a stiff self-threading leader to assure proper transport. The Prostar can be fitted to scrub the rem-jet carbon backing off and can be fitted to partial reverse process film. The partial reversal process is important here since the Stromberg DatagraphiX system does presently use it. The DatagraphiX 158 processes 105mm film in partial reversal mode to facilitate diazo duplication.

There are many important parameters to be discussed concerning proper processing procedures. It seems appropriate, however, to present these in the next chapters where we enumerate and briefly explain the methods of analyzing the film images.

2-9. 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.

2-10. MIXING CHEMICALS

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

<u>Acid and cyanide.</u> 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.

2-11. FILM DEVELOPING FAULTS

The following film defects are commonly found and easily corrected. Under each defect, section (a) gives the cause and section (b) gives the most probable solution.

1. Lack of contrast
   a. Overexposure or overdevelopment or developer too hot.
   b. Develop correctly. Overexposure would result in film being fogged and loss of contrast. Developer strength can be measured by a step wedge. Check transport speed.

2. Fog
   a. Light leak, inadvertent exposure; old film or improperly stored film; developer too strong or too hot.
   b. Check for stray light and develop correctly. Check age of the film, if available, and general storage conditions.

3. Yellow fog (dichroic-fog); green or metallic in reflected light and red in transmitted light.
   a. Prolonged development in exhausted developer. Fixer contamination of developer or too much carry-over of developer to fixer.
   b. Develop correctly, investigate for contamination. Check replenishment rates and roller-squeegee in 156 and 158 processors.

4. Small black spots
   a. Undissolved particles of developer or alkali which have stuck to the emulsion. Small splashes of developer on emulsion before development.
   b. Assure correct developer mixture, assure no crystalline formation in developer, water filtration. Eliminate splashing or spraying of developer onto film prior to entering developer bath.

5. Pinholes (small clear dots on film)
   a. Dust on emulsion of film. Small bubbles are caused on the emulsion surface by carbon dioxide liberated by the fixer on the alkali of the developer. Fixer too strong.
   b. Assure no excessive dust or dirt in processor. Proper solution mixing ratios and replenishment rates. Temperature of fixing bath must be checked.

6. Emulsion layer crazed with a pattern of numerous irregular lines (reticulation).
   a. Abrupt swelling and contraction of the gelatine layer:
      (1) going from a very acid to a very alkaline solution or vice versa.
      (2) going from a warm to a cold solution or vice versa.
   b. Check acidity and temperature of each bath.

7. Covered with a network of density patches with or without honeycomb appearance.
   a. Inadequate agitation of developer or improperly diluted or mixed developer.
   b. Better agitation and correct solution mixture. Check replenishment rates.

8. Milky appearance
   a. Incomplete fixing: too short a time or fixer exhausted. Overall matte white appearance can be caused by using water that is far too hard.
   b. Re-fix thoroughly and do not use exhausted fix bath or one at too low a temperature or too low a replenishment rate. Use soft water. Check processor speed.

9. The emulsion surface has a granular appearance.
   a. Developer and/or fixer made with over hard water. Over hard wash water.
   b. Use soft water.

10. Fine crystal or deposit on film.
    a. Insufficient final wash. Residual salts drying on film.
    b. Wash properly. Check processor speed.

11. Dark tree shaped markings
    a. Static electricity due to friction from winding. Rapid winding in dry arid conditions.
    b. Wind slowly; check camera conditions. Increase room humidity.

12. Scratches or abrasions on the film.
    a. Look for dirt, etc., on rollers, film gates, etc. "clinching" roll film.
    b. Clean all dirt or potential sharp objects from film path. Do not wind loose spools.

13. Brown colored fog.
    a. Solution oxidation; forming scum on film.
    b. Remove scum; change solutions, mainly developer.

2-12. HAZARDOUS CHEMICALS USED IN FILM PROCESSING

CHEMICAL	DANGER	EMERGENCY TREATMENT
Acetic Acid, Glacial	Causes bad burns on contact with skin.	Wash affected areas with water.
Acetone (film cement)	Highly flammable	
Acids (see specific acid on this list.)	Burns	Wash acid off with large quantities of cold water.
Alcohol (Ethyl, Methyl and Isopropyl)	All are flammable. Methyl alcohol is poison.	
Ammonium Hydroxide	Extremely irritating to eyes and mucous membranes.	Wash with floods of water.
Carbon Tetrachloride	Will cause asphyxia-tion. Do not use.	Remove patient to fresh air and keep warm, not hot.
Chrome Alum Potassium (Potassium chromium sulfate)	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. Leave closed rooms or re-stricted areas immed ately if presence of cyanide gases are sus-pected. DO NOT MIX CYANIDES WITH ACIDS.	SPEED IS ESSENTIAL. Artificial respiration if patient is unconscious or breathing with difficulty.
Formaldehyde	Poison - Suffocating odor. Intense irritant to mucous membranes. Keep from contact with the skin.	Artificial respiration if necessary.

CHEMICAL	DANGER	EMERGENCY TREATMENT
Hydroquinone	Does not present a serious hazard.	
Mercuric Chloride	Extremely poisonous. Extremely dangerous to handle and use.	
Methylamino phenol Sulfate (Metol, Elon)	Toxic to skin of some people.	
Nitric Acid	Causes painful burns. Poison. Reacts violently with alcohols.	Wash affected areas with large quantities of soap and water.
Paraformaldehyde	Poison, toxic fumes.	
*Potassium Bichromate	Poison if taken internally. Can cause skin eruptions.	Wash exposed parts with water.
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.	Dilute solutions are mildly irritating.
Pyrogallic Acid (1, 2, 3 Trihydroxy benzene)	Skin irritant	
Silver Nitrate	Causes bad burns	Wash affected parts with water.
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.	Wash affected areas with large quantities of water.

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

SECTION III

DUPLICATING FILMS

3-1. DIAZO FILMS

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.

3-2. 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.

3-3. 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.

<u>The vapor diazo process.</u> 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.

<u>The moist diazo process.</u> 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.

<u>The thermal diazo process.</u> 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 vesicular 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.

3-4. DIAZO FILM 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.

3-5. 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.

3-6. 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 expectency 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

Resolving power of diazo material is limited by the size and structure of the diazo coating. The structure of diazo coatings is molecular for each grain is made up of a number of molecules. The size of a typical diazo dye molecule is about 15 angstroms (one angstrom equals one millionth of a millimeter). 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.

3-7. 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. In the vesicular process, 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 from 3400 A^o (Angstrom units) to 4400 A^o, 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.

3-8. 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^o to above 4400 A^o with maximum photosensitivity at 3850 A^o. Vesicular film is not photographically sensitive to ordinary levels of visible light for short periods of time. The time required to expose vesicular film depends on the intensity of the light source, that is, the time required to get 200 milliwatt/seconds/cm^2 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 diffeses during the prolonged exposure. Temperature of the film over 110^{o} F during exposure will also cause a high diffusion rate of the latent-image-forming gas with a subsequent reduction of the maximum density. The latent image diffusion time varies with different vesicular types.

In summary, it can be said that upon exposure to ultraviolet light, the diazonium compound suspended in the plastic 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.

3-9. DEVELOPMENT

The film is developed by applying sufficient heat momentarily to soften the emulsion vehicle whose strands are pushed out by localized internal gas pressure to form a bubble, or vesicle. At the perimeter of this vesicle, the polymer strands have been forced into close alignment with each other.

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 the vesicular image is approximately 0.13 $cal/cm^2/mil$ (total thickness which includes the base material plus emulsion thickness). The only basic requirement is that the vesicular emulsion layer come to a temperature of 240° F. The temperature of the heat source to achieve this requirement will depend upon the dwell time and the 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 except under conditions of heat above 160° F for a short period of time.

3-10. FIXING

After exposure and development, the unexposed or clear sections of the vesicular film still retain light-sensitive diazo. 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 diazo 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. As a general remark, 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, the 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.

3-11. BENEFITS OF VESICULAR SYSTEM

<u>Complete dry process.</u> No chemicals, no ammonia, no hypo, no fumes, no muss, no fuss. Image is reproduced instantly by light and heat alone.

<u>Desk top convenience.</u> No special requirements. Vesicular equipment plugs into conventional current and can be installed on desk tops alongside office workers who use it. Reproduction is automatic. Film is ready for viewing or printing as it comes out of the machine.

<u>No darkroom.</u> Vesicular film can be handled in ordinary room light. There is no danger of accidental exposure of vesicular film.

Superior image. Produces superior image for viewing, projecting, and hard copy print-outs. Blacks are blacker. Whites are whiter. Lines are crisp, sharp and clean. Tone and contrast are comparable to standard film.

Permanent image (archival quality). Never fades. Can be exposed millions of times. Image is physically imbedded in plastic. Impervious to fingerprints, most common solvents, oils, greases, water, radiation, and time. High degree of dimensional stability.

No grain. Vesicular film has no "grain" in its emulsion. Thus vesicular film-copies and print-outs are sharper than those made with conventional type photo films which add a "grain" of their own to the copy.

Faster duplication. For creating microfilm copies, vesicular is unexcelled in speed of duplication.

Superior quality base material (physically durable). Polyester base is much more durable than acetate, has extremely high dimensional stability. Vesicular film does not tear in hard use.

Easily cleaned. Vesicular film is washable with soap and water without degrading the record.

Easy to splice. Splices to all types of film easily and permanently (using Prestoseal Tape System).

Resists curling. Vesicular film resists curling and dog-earing with use. With other films, the problem of curling and brittleness is a big one and large research expenditures have been made in this area over the years by the photographic industry. Vesicular film does not have this problem.

Saves storage space. Stronger polyester base permits use of thinner film (e.g., 3 mil vesicular for 5 mil acetate), thereby allowing 1/3 more film to be wound on each reel.

3-12. GENERAL INFORMATION

A. Resolving Power

The resolving power of all vesicular films used to duplicate micro-transparencies is greater than 200 line pairs/millimeter. Some vesicular emulsions have resolving power of more than 500 line pairs/millimeter. Highest resolving power is attained if a point light source is used within a range of 3600 to 4000 A^{o}. Resolution is also affected by the time and temperature of development. In general, short exposure and development times produce greater sharpness. These factors are controlled by the manufacturer in the design of vesicular exposing and developing units. Vesicular is one of the very few films on the market that can be used to duplicate holograms, which have a resolution in excess of 1000 line pairs/millimeter.

B. Exposure Latitude

The latitude of vesicular 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 300 feet per minute on some equipment now available; research has shown that the film itself can be used at 500 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 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. Several companies, such as Xidex, DatagraphiX, Kalvar and Canon, manufacture and market equipment for roll-to-roll duplicating and for microfiche duplicating. The high resolution of the material, its contrast characteristics, the fact that the process is completely dry and the speed with with duplicating can be done under conditions of ordinary room light are all advantageous.

3-13. VESICULAR FILM FAULTS

When evaluating vesicular film and a defect is apparent, the duplicator and silver master must first be eliminated as the cause. Be sure to check the duplicator for:

1. Binding/sticking rollers, idlers, reels, cylinders, etc.

2. Defective drive motors and speed controls.

3. Line voltage fluctuations.

4. Film tracking.

5. Threading or misalignment of silver master or duplicate film.

Check the silver master for:

1. D-max and D-min suitable for duplication. Image density is best just short of "filling-in."

2. Be sure that silver does not have a high fog level. Low density background on the duplicate film may result if fog on the silver is too high.

3. Dirt on silver film master may reproduce clear or unwanted images on copy film.

4. Clear spots on the silver in undesirable areas will reproduce dark on copy film and may obliterate vital data.

Once the obvious errors have been eliminated and film still exhibits undesirable characteristics, a systematic review of certain details may reveal the cause(s) of the defect. The following identifies the defect, the cause and the most probable solution.

1. Density variations (exposure)

    a. Under/over exposure. May be in spots, along the edges, or the whole film.

        (1) Overexposure. The characters appear too dark.

        (2) Underexposure. Background density not dark enough, appears faded.

b. Adjust exposure setting.

Note: Under/over development will give much the same appearance as under/over exposure except underdevelopment appears similar to overexposure and overdevelopment appears similar to underexposure.

2. Dirt or debris adhering to film.

   a. Dirt from silver master, dirty cylinder or heat drum.

   b. Check all elements including the ambient conditions for dirt or debris.

3. Clear spots on film.

   a. May be dirt or debris between exposure source and sensitized layers on film.

   b. Clean dirt from duplicator or film.

4. Lack of overall density.

   a. Washed out, faded, or hazy appearance.

   b. Exposure to unwanted U.V. light source prior to use.

      Film may have been stored at elevated temperature for excessive periods of time.

5. Disappearing image - fade out.

   a. Improper clearing or fixing of the film.

   b. Assure that image is fixed or cleared as soon as possible after exposure and development if it is to be placed in a viewer within 24 hours.

Note: Even properly cleared/fixed film, when subjected to heat in excess of 150^{o} F may clear or fade.

At times film may change color when placed in viewer. There is no loss in density, only a color change. This is classified as "cosmetic only."

6. Double image.

   a. Fuzzy image caused by slippage of the silver master at the time of exposure or original and duplicate are not in contact emulsion to emulsion.

   b. Eliminate slippage or orient films together properly.

7. Dwell.

   a. Light spots or highlights in density due to short dwell time on the heat drum. Too long a dwell time may give film a cooked appearance.

   b. Adjust wrap around the heat drum.

Because unprocessed vesicular film need not be kept in darkness, it may be examined in room light. Certain apparent faults in the raw film which would not be seen in darkness may be visible to the operator.

These marks are "cosmetic" because they affect only the appearance of the raw film and do not in any way affect the appearance or function of the printed image.

In most cases, these cosmetic effects disappear entirely on exposure and development. For this reason, film containing flaws of this nature should be processed before any attempt is made to evaluate such flaws.

Typical types of flaws that may be occasionally encountered are:

Contact Patterns: Same appearance as "wet film." Result from pressure; disappear when film is unwound.

Turbidity: Apparent haze. Disappears when film is developed.

Cinch Marks (tiny scratches in turbidity): Appear to be microspots. Will not show in projection in a viewer.

Minute Scratches on Base: Will not show on development.

Wrinkles: Will disappear on development.

Pock Marks in Base: Will not affect image.

Gauge Band (a band of pock marks): Will not affect image.

Haze Spots and Diffused Whitish Areas: Will disappear on development.

Some specific items that can cause defects in the film are lamps, cylinders, and heat drums. Particular attention may be necessary to detect and eliminate these as the "cause and effect" of what appears as a film defect.

1. Lamps - Lamps deteriorate slowly with age. They may become dark or cloudy on the glass envelope. This will cause a reduction in UV output (called actinic efficiency) to the film surface. If suspected, change the lamp or switch lamps between the exposure and clearing stations and evaluate the results and take appropriate action. Replace bad lamps.

2. Cylinders - Cylinders may have abberations which will print on film. Visual examination of the cylinder cannot be considered as conclusive. Marks on film due to cylinder defects will have "periodicity." They repeat at exact intervals corresponding to the cylinder diameter. Defects may appear as marks across the film and have a low density or may be clear. These are called striations. Circular areas are caused from seeds, blisters, etc., in and on the glass. Replace a defective cylinder.

   Cylinders must be kept clean. As necessary, the cylinder may be cleaned with a commercial antistatic cleaner free of silicones. <u>Do not</u> use soap and water or any other abrasive material. Plain water is acceptable. Dry with a lint-free cloth. <u>Do not</u> allow cylinder to air dry.

3. Heat Drums - Heat drums have a tendency to collect dirt and debris. Adhered dirt may cause defects to appear on the film as spots or circular areas. At times, film may appear to be "embossed," that is, many minute clear areas. This may be due to a dirty or damaged heat drum. Clean the drum with a material such as alcohol. Do not use any material which is abrasive or will leave a residue on the drum.

SECTION IV

THE ELECTRO-GRAPHIC PRINT

4-1. THE PROCESS

The electrostatic process used in the DatagraphiX 3500 is capable of producing excellent copy from either original silver film or the vesicular duplicate. As in the standard photographic process, the "normal" development produces an image of reverse sign to the film image. That is - a film image containing white (clear) characters on a dark (opaque background will produce an electrographic print with dark (opaque) characters on a clear background).

The paper which is coated with zinc oxide is first charged (bombarded) with positive and negative ions. This occurs simultaneously as the paper passes through the charge grid area.

The negative charge of -6000 volts is applied to the zinc oxide coated surface while the positive charge of +5500 volts is applied to the back of the paper. A net static voltage of -500 volts ±. The surface of the paper is then exposed to light (the projected image). Areas of the zinc oxide struck by the light are energized and lose a substantial portion of the negative charge absorbed by the zinc oxide (Figure 4-1).

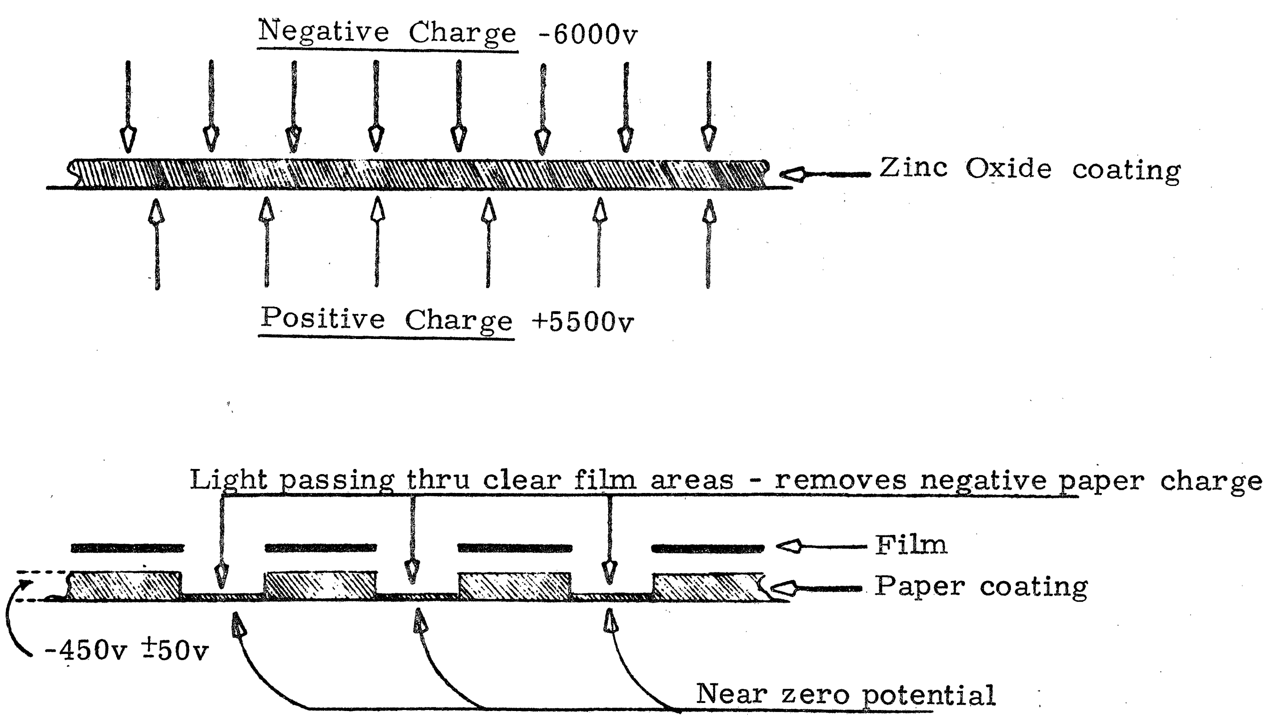


Figure 4-1.

The paper surface is then saturated with toner (a carrier containing negative charged carbon or plastic particles). These particles being negatively charged are repelled by the unexposed areas of the paper which are still negatively charged and attracted to the exposed areas where the negative charge is reduced or removed (zero potential) (Figure 4-2).

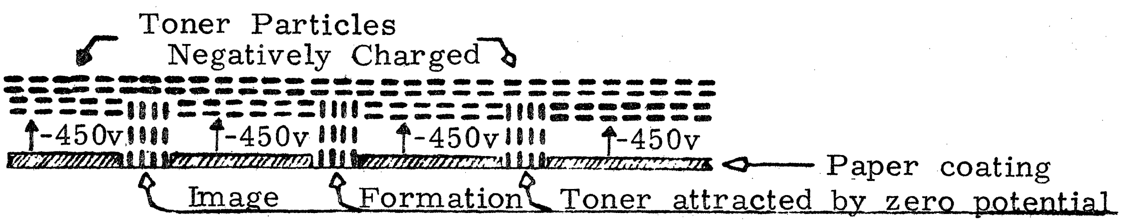


Figure 4-2.

It should be noted that in areas of extremely low humidity the positive charge applied to the base of the paper could theoretically be eliminated and only the negative charge applied to the surface. This phenomenon is possible due to the positive static charge picked up by the paper during transportation in low humidity.

The following graph illustrates the loss of charge (net static) potential (negative) from initial charge through exposure:

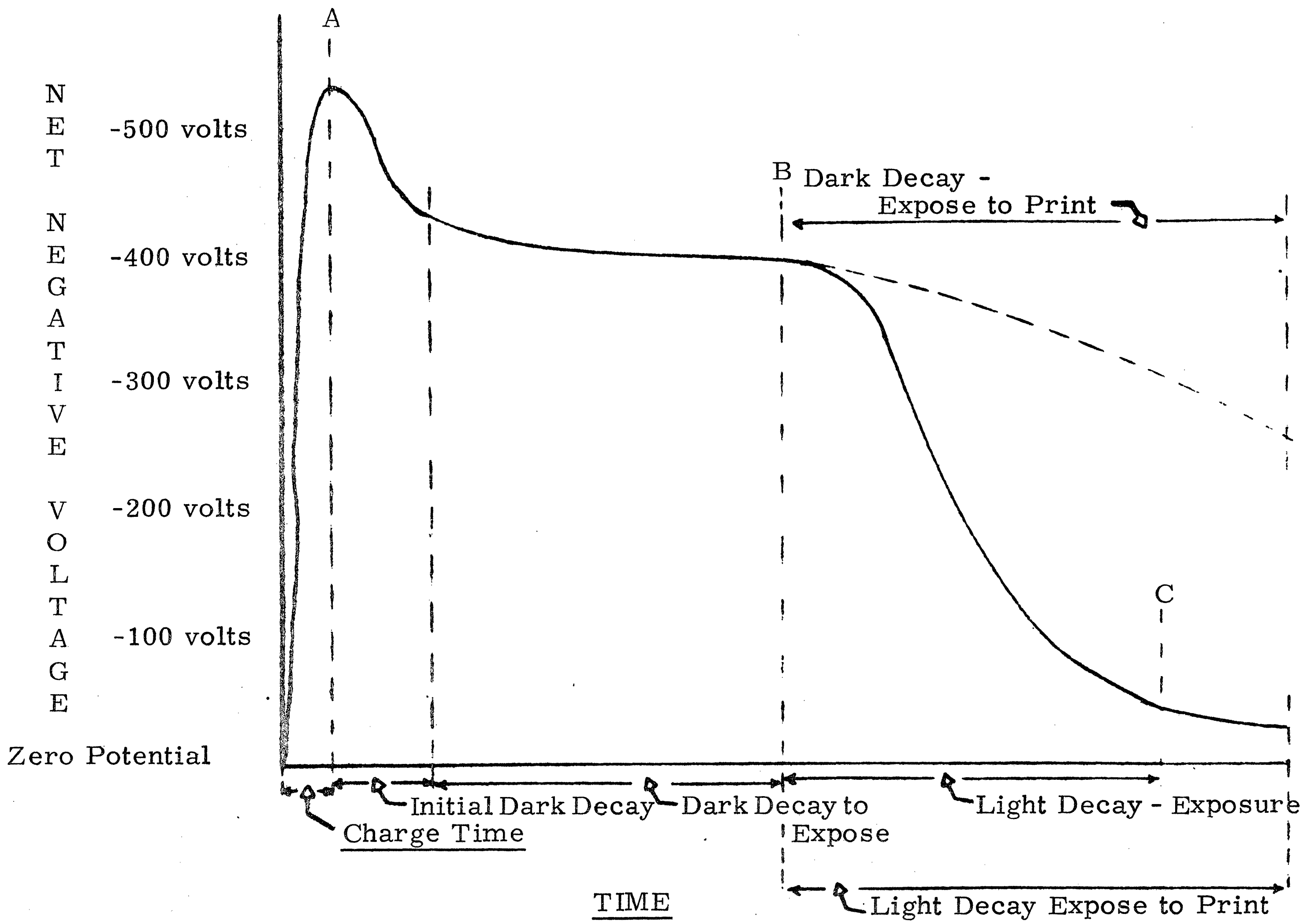


Figure 4-3. Negative Net Charge Loss

NOTE: Immediately following the corona charge there is a very sudden loss of negative potential (point A above). The subsequent loss prior to exposure (dark decay) is quite gradual (points A-B above). Exposure to light causes a very rapid loss of negative potential toward zero potential (points B-C above). The amount of decay (loss) will vary with the amount of light and the period of exposure. Correct exposure should reduce the negative potential to not more than -50 volts.

A substantial initial loss is experienced immediately following paper charging; then the drop stabilizes and reduction (loss) of charge is nominal over a long period of time.

In the direct image (sign to sign) process the only difference is in the carbon charge and its attraction to the paper. The carbon charge in this case is POSITIVE.

Using the graph on page 3 and the attraction of opposites it can be seen that in the direct process the carbon would be rejected by the exposed areas (near zero negative voltages) and attracted by the unexposed (high negative voltages) areas. Thus the image would be the same sign as in the original.

4-2. BALANCING THE IMAGE

As in the photographic process the normal (reverse) print image is inversely proportional to the film image.

For example, a wide light character on the film will appear as a wide dark character on the print. A thin dark character on the film will appear as a thin light character on the print.

Exposure must be balanced for material within the image area (regardless of line weight) to obtain a legible print, or must be exposed for one particular segment of the image.

Whenever extremes of density (such as caused by tube fall off or poor form slide density) exist, balancing of the image will be impractical (i.e., given areas of the image will be too light or too dark for overall legibility).

The characteristics of the electrographic process are such that image balancing is more difficult and critical than with the silver process. A narrow sharp original character will produce a better image than a broad fuzzy character due to the tendency of the carbon to be attracted to the edges of the zero potential area. That is - the areas of greatest differential as illustrated below.

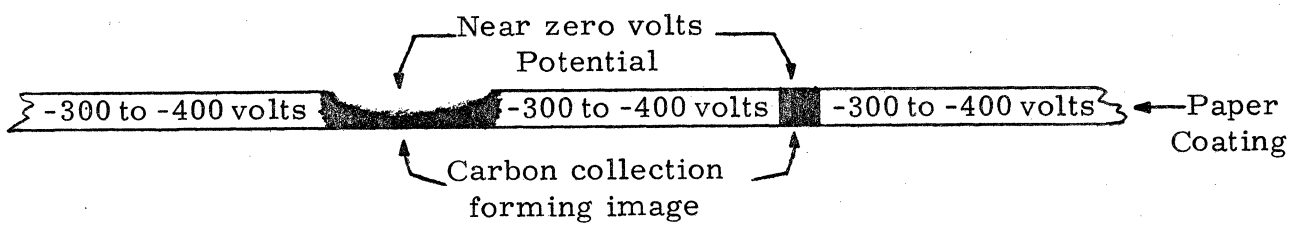
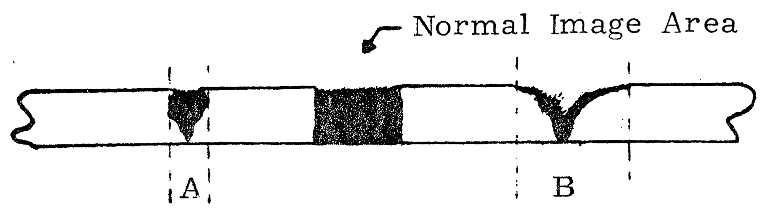


Figure 4-4.

4-3. EFFECTS OF VOLTAGE POTENTIAL LOSS

Whenever the charged paper is subjected to zero or near zero potential (such as in grounding) prior to image exposure and the area is then exposed to light, the resulting loss of negative potential will cause a black line or mark in the area of negative voltage loss.

If the grounding occurs after exposure, the resulting voltage loss will frequently result in a weakening of adjacent image density due to spreading of the carbon particles. This will generally show as a line or lines of weak (light) characters.



A - Represents grounding prior to exposure causing dark areas.

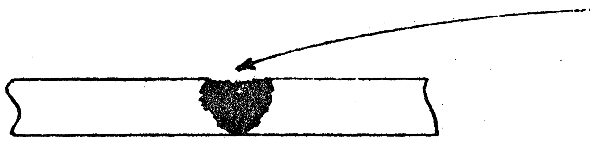
B - Grounding after exposure causing lightening or loss of data (image).

4-4. THE LATENT IMAGE

A latent image is the image formed during exposure but which cannot be observed until development.

In the electrographic process, the zinc oxide coating on the paper is the carrier of the negative potential charge. When the zinc oxide is subjected to light, the negative charge is permitted to penetrate the carrier toward the paper base (zero potential) thus reducing the charge between maximum and zero, depending on the volume of light and the exposure time.

As previously stated, the electrostatic process requires a sharp narrow exposure band for optimum development. If the exposure is too high or too long, the zero or near zero potential tends to spread away from the image area into the background. This results in a broad, fuzzy, weak appearing image rather than a strong, narrow sharp image.



NOTE: The longer the exposure, the broader the image and the lighter the image center. This is caused by the charged carbon being attracted toward the image edges (point of greatest differential) (Figure 4-6).

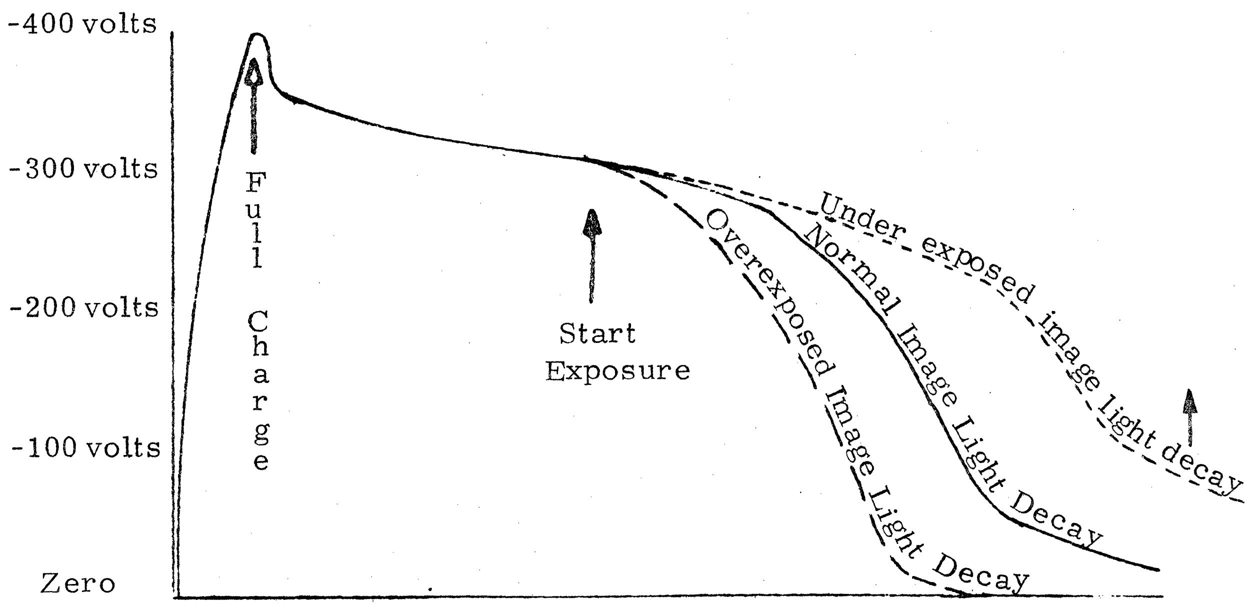


Figure 4-6.

SECTION V

OPTICS

5-1. REFLECTION

Using a fully silvered mirror, consider a monochromatic pencil beam of light incident on a mirror face. The angle of incidence Θ_i, measured from the perpendicular to the mirror surface, is equal to the angle of reflection Θ_r.

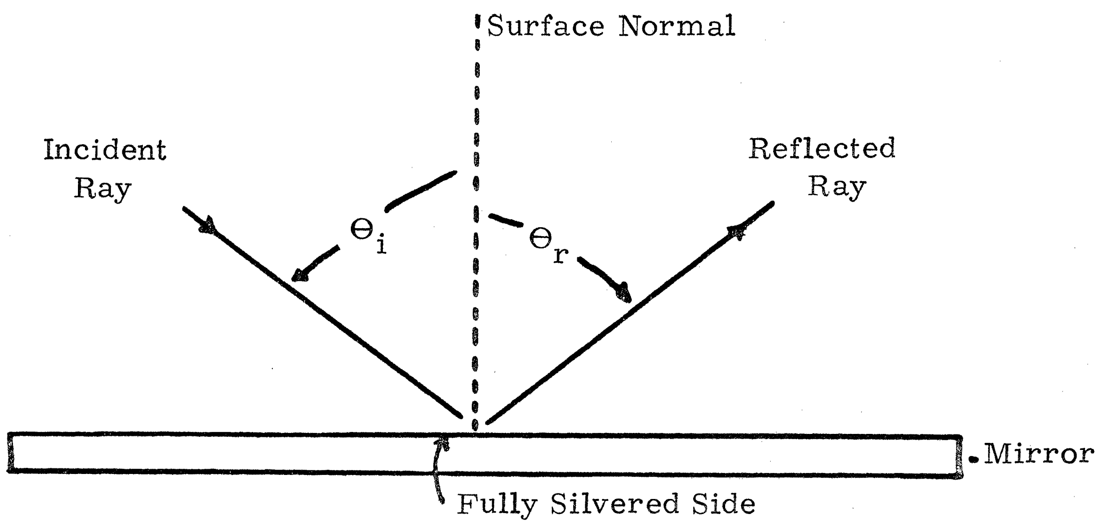


Figure 5-1. Reflection from a Plane Mirror

This is the law of reflection. All the rays travel in straight lines from this plane mirror no matter whether $\Theta_i = 1^o$ or 89^o. The equation from the law of reflection is simply stated.

<u>Equation 6</u> $\Theta_i = \Theta_r$

Another important law is Snell's Law of Refraction. An easy way to observe Snell's law is to place a straight rod in a pool of water. Even though you know the stick is not bent by the water, it appears to be.

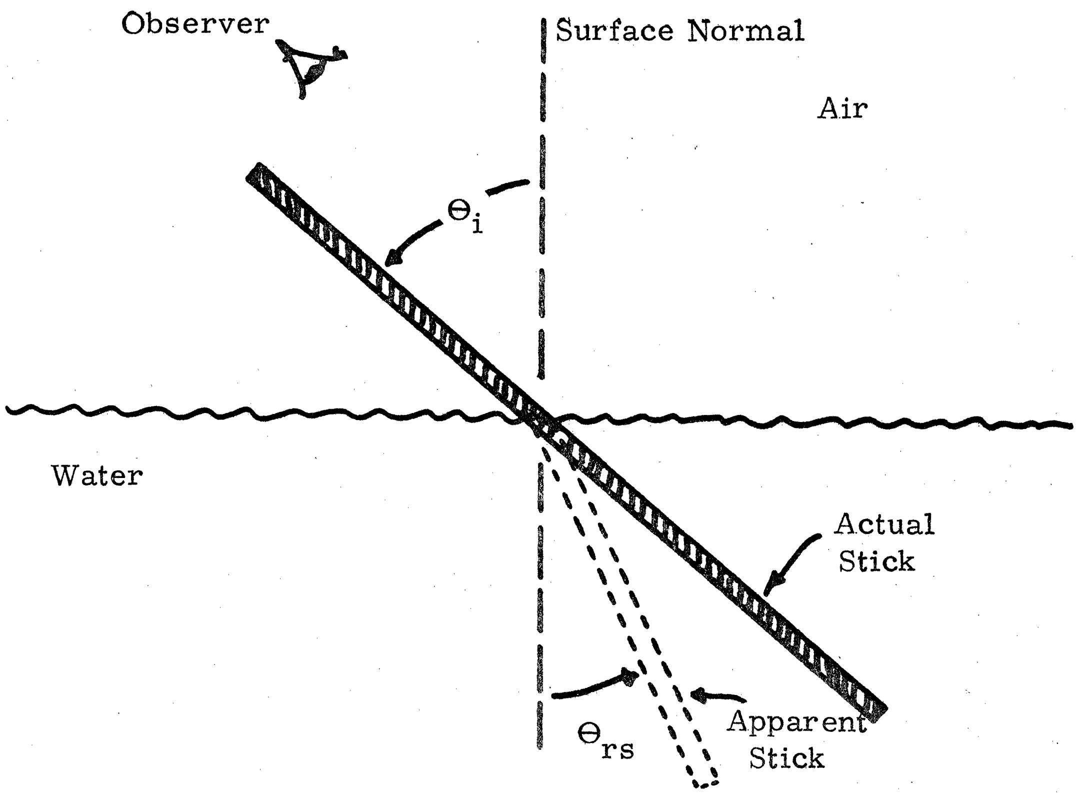


Figure 5-2. Refraction

The relationship between these two angles is not so obvious.

Table 1 is a list of the angles of refraction for an air-water interface. Interestingly enough, this table was compiled by Ptoleny in 140 A.D.

Angles in Air	Angles in Water
10°	8°
20°	$15\text{-}1/2^{\circ}$
30°	$22\text{-}1/2^{\circ}$
40°	28°
50°	35°
60°	$40\text{-}1/2^{\circ}$
70°	45°
80°	50°

TABLE 1

Table 2 is a modern day tabulation of the same experiment:

Angles in Air	Angles in Water
10°	$7\text{-}1/2^{\circ}$
20°	15°
30°	22°
40°	29°
50°	35°
60°	40°
70°	48°
80°	$49\text{-}1/2^{\circ}$

TABLE 2

It wasn't until a Dutchman named Snell found that the relationship was:

Equation 7 $$\sin \Theta_i = \frac{N_d \sin \Theta_{rs}}{N_a}$$

where Θ_i is the angle of incidence, N_d is index of refraction in the denser medium, N_a is the index of refraction in the rarer medium and Θ_{rs} is the angle of reflection measured from the surface normal to the ray. Note here that the sine component of the wave is the horizontal component and the cosine is the vertical component. Every lens bends the rays of light and the light rays obey the law of refraction. Using two mediums of the same index of refraction, $N_i = N_z$, Snell's law reduces to:

Equation 8 $$\sin \Theta_i = \sin \Theta_{rs}$$

which further reduces to:

Equation 9 $$\Theta_i = \Theta_r$$

which indicates that there is no refraction.

Looking at Table 2, where the values for incident and refracted angles have been listed for a ray going from air to water, it is interesting to note that the ray will not be refracted more than about 50^{o}. Question: If a pencil ray of light is incident in the water on the water-air surface, will it refract into the air? The answer is no. Shown in Figure 5-3 is the phenomena known as total internal reflection. Here, the ray when incident at an angle greater than 50 degrees will be totally reflected back into the water.

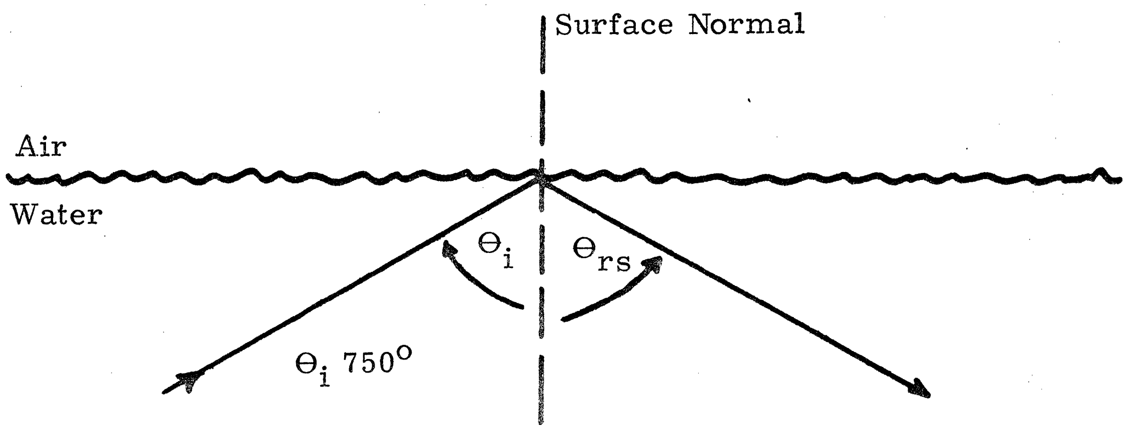


Figure 5-3. Total Internal Reflection

5-2. RAY TRACING

Although most of your work will not require lens examination, an understanding of how the light passes through a lens is helpful when trouble shooting. Since "geometrical optics" uses straight line paths for light rays we begin by applying the ray tracing techniques to mirrors and lenses. Mirrors are more simple to understand than lenses, since they are only involved with the law of reflection. For a plane mirror, the ray tracing is extremely simple as shown in Figure 5-4.

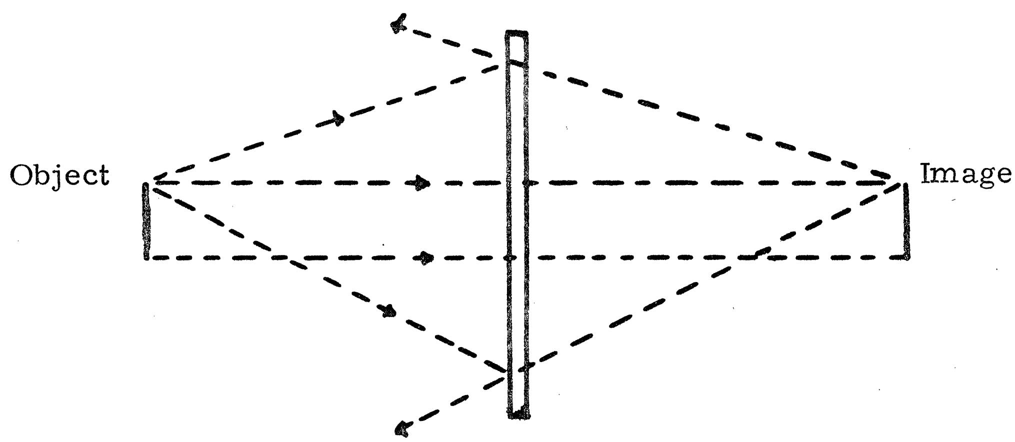


Figure 5-4. Image Object Rays

The image I appears to be directly behind the mirror and an equal distance from the mirror as the object.

There are several conventions and specific terminology used in ray tracing. First, when using lens formulae, the sign convention must be established. The convention, though not universal, states that a distance measured from a lens or mirror to real image or object is positive and one measured from a virtual image or object is negative. The meaning of real and virtual will be explained below.

Looking at Figure 5-5 one can trace the rays from object A and construct the axial image position A'. Image A' is said ot be virtual since the rays of light do not actually pass through pt. A'. It is only the method of ray construction that gives us the apparent image position.

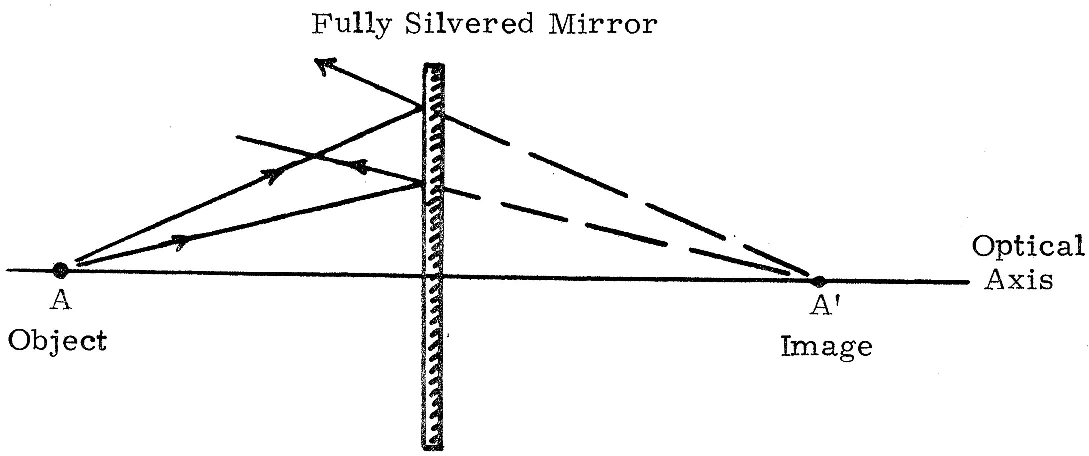


Figure 5-5. Axial Ray Tracing

The geometrical properties of conic sections are useful in lenses also. Shown below are several kinds of lenses.

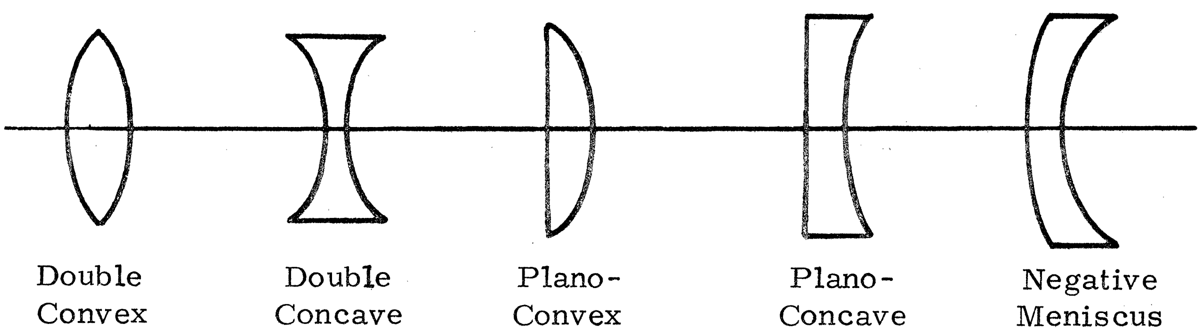


Figure 5-6. Lenses

The curve surfaces can be any one of the conic surfaces depending on the use required. In lens design, many elements are put together to achieve proper imaging. This type of lens is said to be multi element lens systems, but first let's do some ray tracing through simple thin lenses.

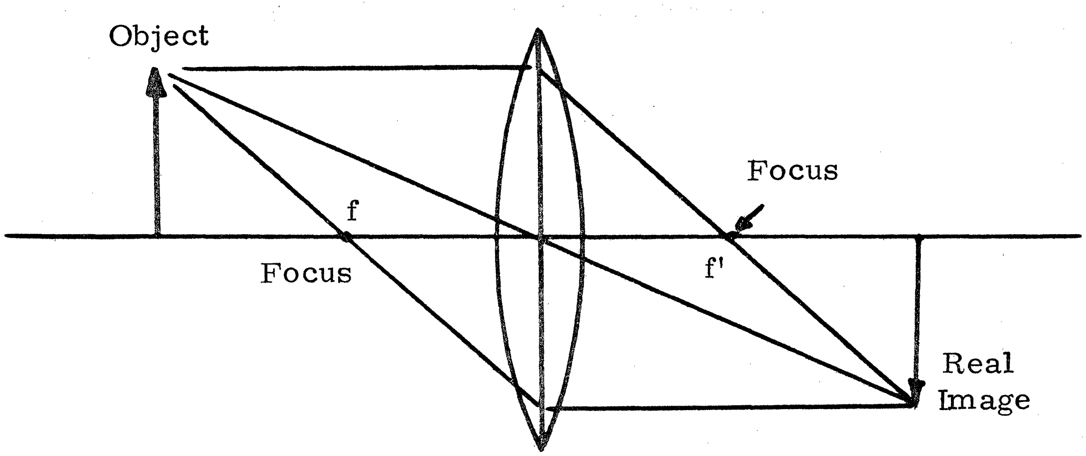


Figure 5-7. (Double Convex Converging Lens)

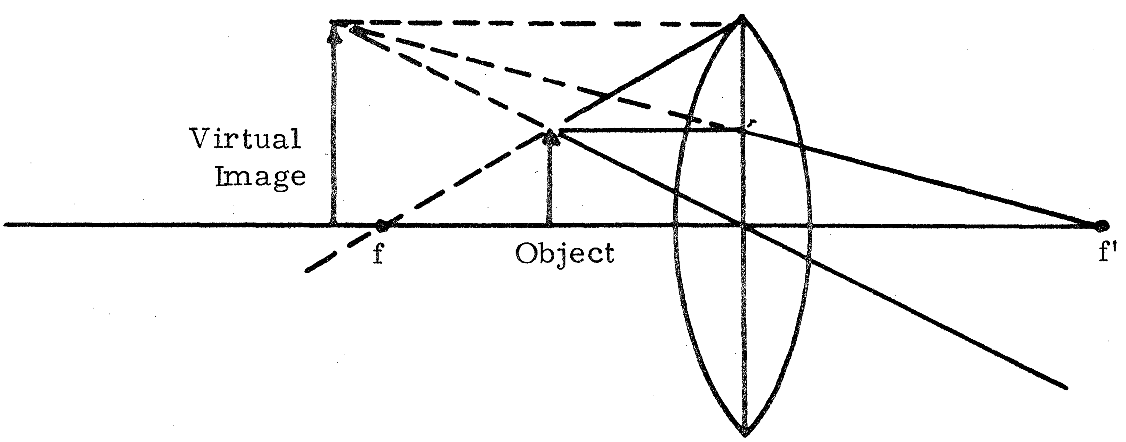


Figure 5-8. (Virtual Image)

The difference between a real image and a virtual image is that the real image will focus on a film or paper, but the virtual rays diverge. Your eye can see a virtual image. Can you explain this?

For a symmetric lens (one with equal focal lengths on both sides), the image location can be obtained using the lens formula:

Equation 10 $$\frac{1}{O} + \frac{1}{I} = \frac{1}{f} \qquad \text{(GAUSSIAN FORM)}$$

Where O is the distance from the lens to the object, I is the distance from the lens to the image, and f is the focal length of the mirror. If one measures the object and image distances from the focal point, the equation simplifies to:

Equation 10a $$S_i S_o = f^2 \qquad \text{(NEWTONIAN FORM)}$$

Where S_o (object distance) is positive when the object is to the left of the focus f and S_i (image distance) is positive when the image is to the right of the focus f^1. For a diverging lens a negative sign must be inserted in front of f^2 in equation 10a.

Another convention is used when computing the magnification. Using Figure 5-5, and the triangle common to the image and object, the magnification can easily be shown to be:

Equation 11 $$m = \frac{y_i}{y_o} = \frac{-I}{O}$$

where y_o is the height of the object and y_i the height of the image. Again one should remember the sign convention of real image and object distances positive since it can indicate whether the image is upright or inverted. A positive magnification factor indicates an upright image, and negative an inverted image.

The ray tracing method used for one lens is valid for lens combinations. For simplicity we shall take two double convex lenses.

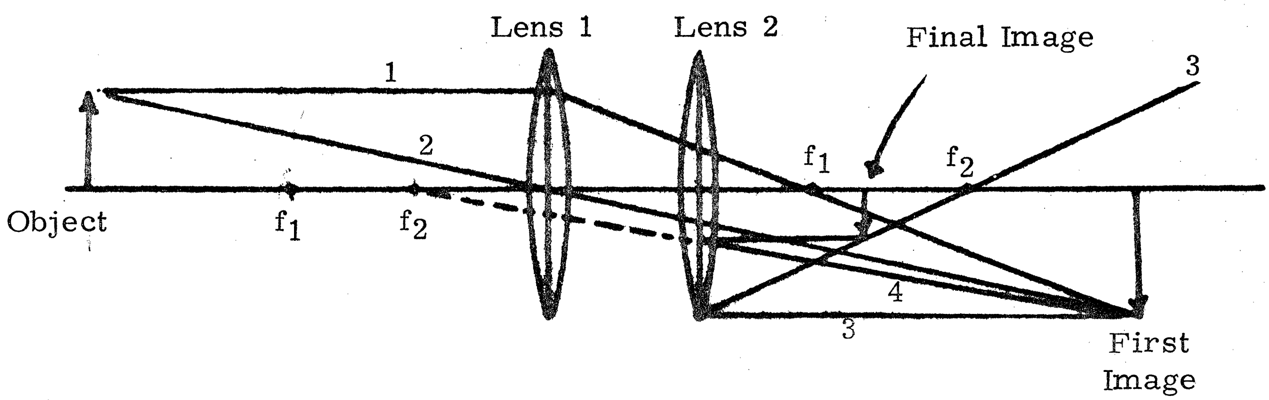
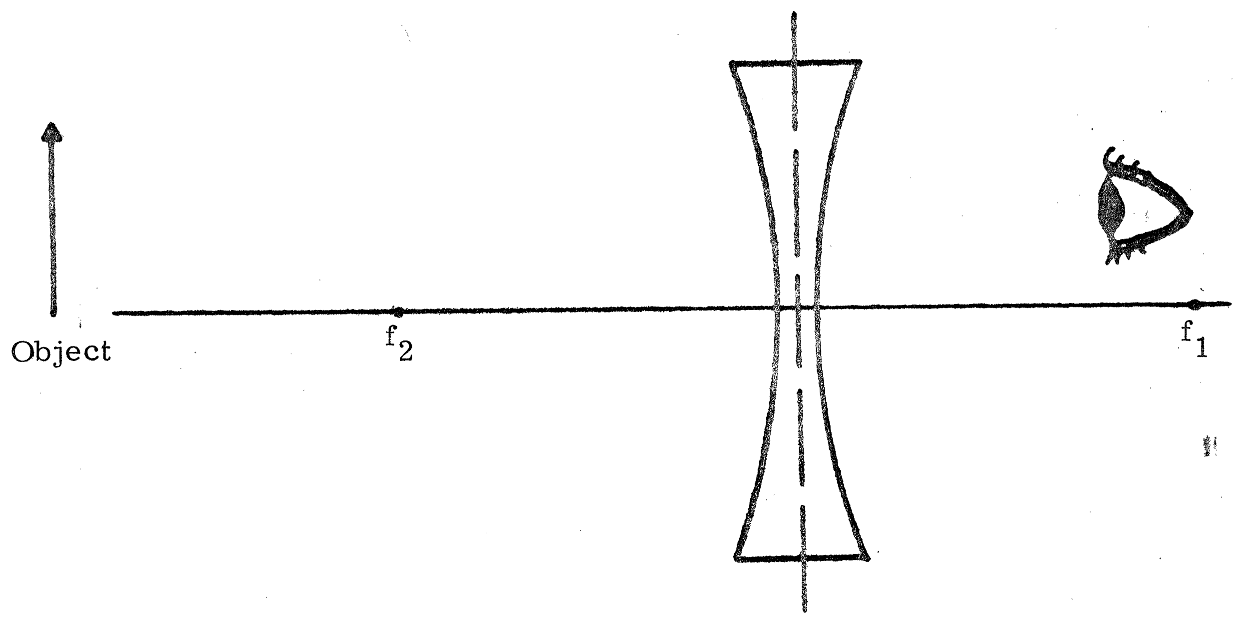


Figure 5-9. Two Lens Combination

At this point it is instructive to compute some of the image parameters. Problem #1 insert: Hint: Is this a converging lens? If not, should the image be the same as the converging lens? Notice the placement of the face.



Problem #1. Graphically locate the image.
How high is the image? Virtual or real? Inverted or right side up? What is lens magnification? Check all measurements by using formula.

The imaging for off axis rays causes a slight fuzzy appearance. For a spherical mirror this focus condition is known as spherical abberation. Figure 5-10 indicates the focus and circle of least confusion.

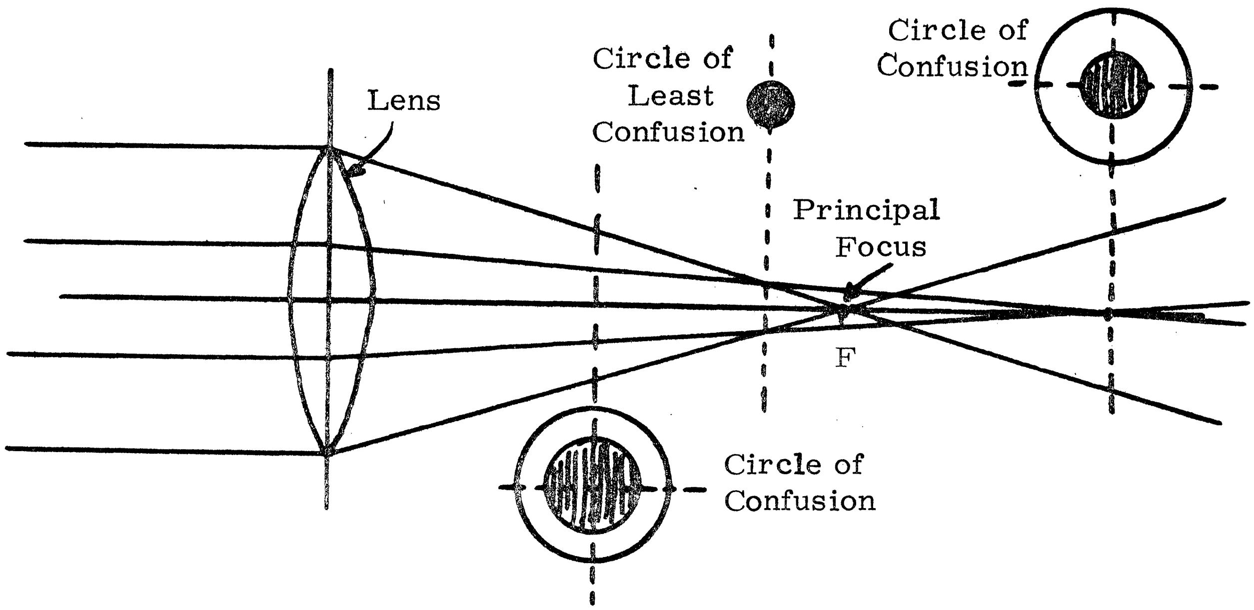
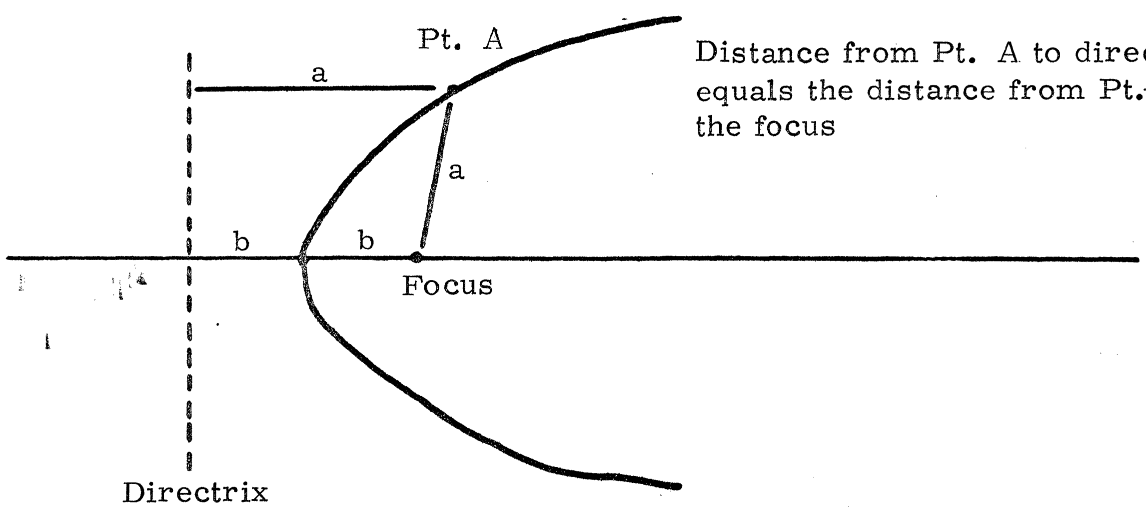


Figure 5-10. Circles of Confusion

When we study lenses we shall find a phenomena with spherical lenses.

The next conic surface to be considered is the parabola. A parabola is constructed as shown in Figure 5-11.



Distance from Pt. A to directrix equals the distance from Pt. A to the focus

Figure 5-11. The Parabola

A ray coming in parallel to the axis of a parabolic mirror will always pass through the focus unlike the sperical mirror. The most widely used mirrors in astronomy have parabolic surfaces.

The ellipse also has some interesting geometrical properties. Any ray originating at a focus, say a will pass through the other focus, b upon reflection. It is also a property of the ray that the distance is a constant: x + y = constant. If you had a light source at one focus it would focus and concentrate at the other focus. An elliptical reflector is used in the projection assembly of the DatagraphiX 3400.

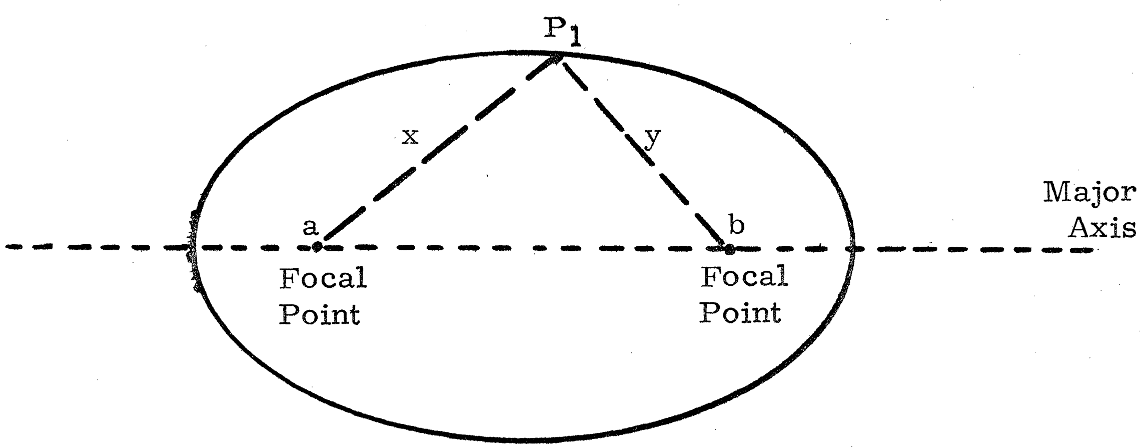


Figure 5-11b. The Ellipse

5-3. STOPS IN AN OPTIC SYSTEM

It is beyond the scope of this syllabus to detail the mathematical steps necessary to prove some of the following statements. In place of the proofs reference material is given if details of proofs are desirable.

The placing of stops in an optical system can have many effects. The two properties of the optical field that are of primary concern are the brightness and the field of view. Let's first discuss the brightness of a field.

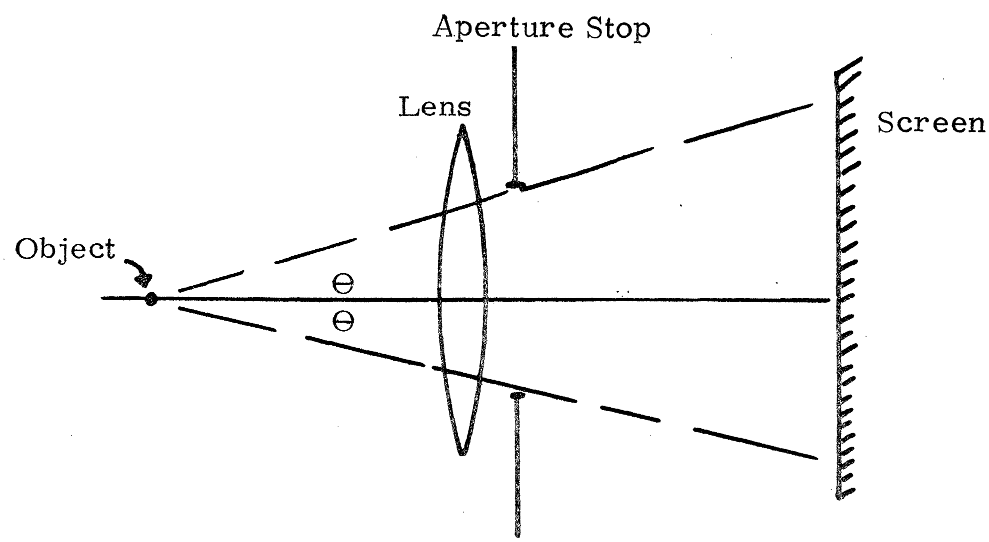


Figure 5-12. Aperture Stop

The half-field angle is usually measured in degrees, but sometimes one uses other angular measure. Listed in Table 3 are some angular measures:

1 degree	=	17.778 miles (Army)
	=	17.4533 milliradians
1 radian	=	57.296 degrees
1 Army mil	=	1/6400 of a circle (360^{o})
1 Navy mil	=	1 milliradian

TABLE 3

It is quite obvious that the half-field angle is determined by the position of the stop and the width of the aperture. When the stop is closer to the screen it is commonly called a field stop.

An often used term associated with the size of the aperture is the f/number or f/stop. The f/number of an optical system is given by the formula below.

<u>Equation 12</u> $$f\# = \frac{a}{f \text{ (focal length)}}$$

where a = aperture diameter, f is the focal length and the object is located at infinity. If the object is not at infinity, one calculates the effective f/number.

Equation 13 $$f_e = \frac{I}{f \text{ (focal length)}}$$

I = image distance and f = at infinite focus. Frequently used f/numbers are 2.8, 4.0, 5.6 for DatagraphiX lenses.

When an f/number change is made on a lens say from f/5.6 to f/4.0 the depth of field (tube face) and depth of focus (film plane) change. Using a ray diagram we can see the effect of a stop change.

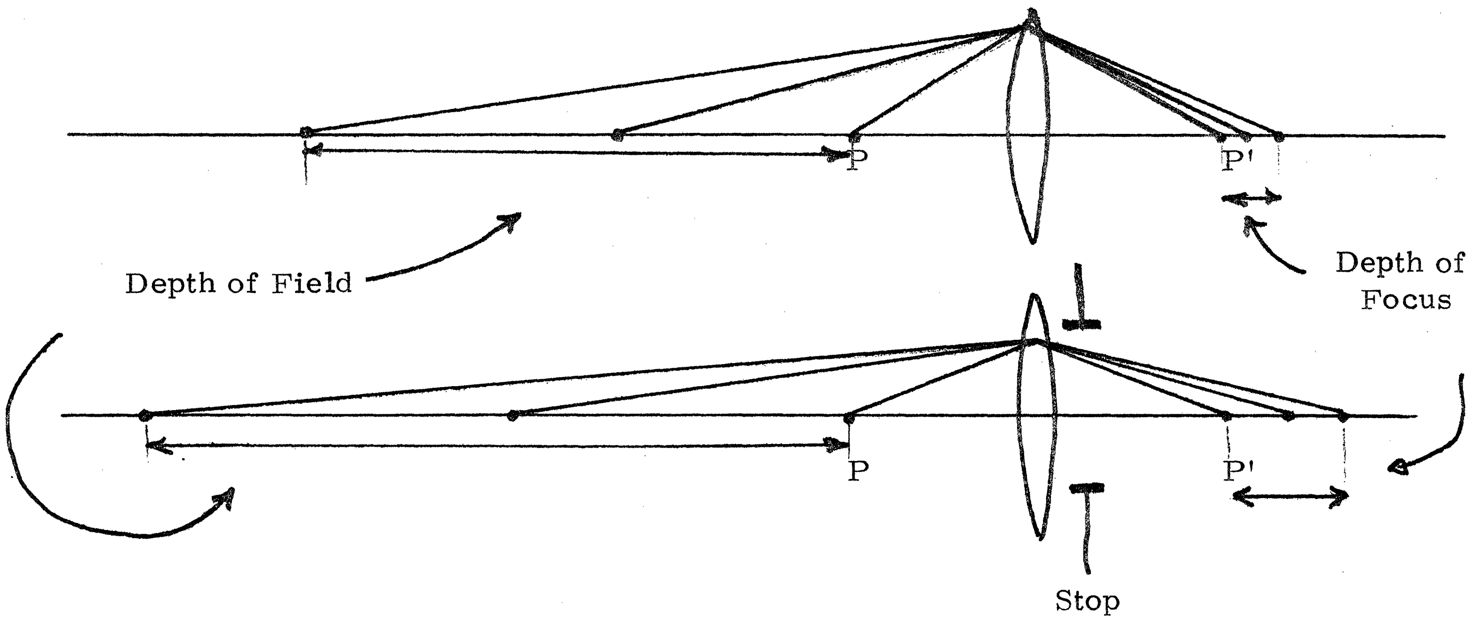


Figure 5-13. Depth of Field and Focus)

The importance of this phenomena is realized when a lens change or f/stop change is made and there is a loss of focus. A focus run must be made before mainframe is ready.

There is virtually no effect on the optical axis to the image illuminance other than normal field fall off. It is when the image is located off-axis, as shown in Figure 5-14, that the image illuminance is greatly affected.

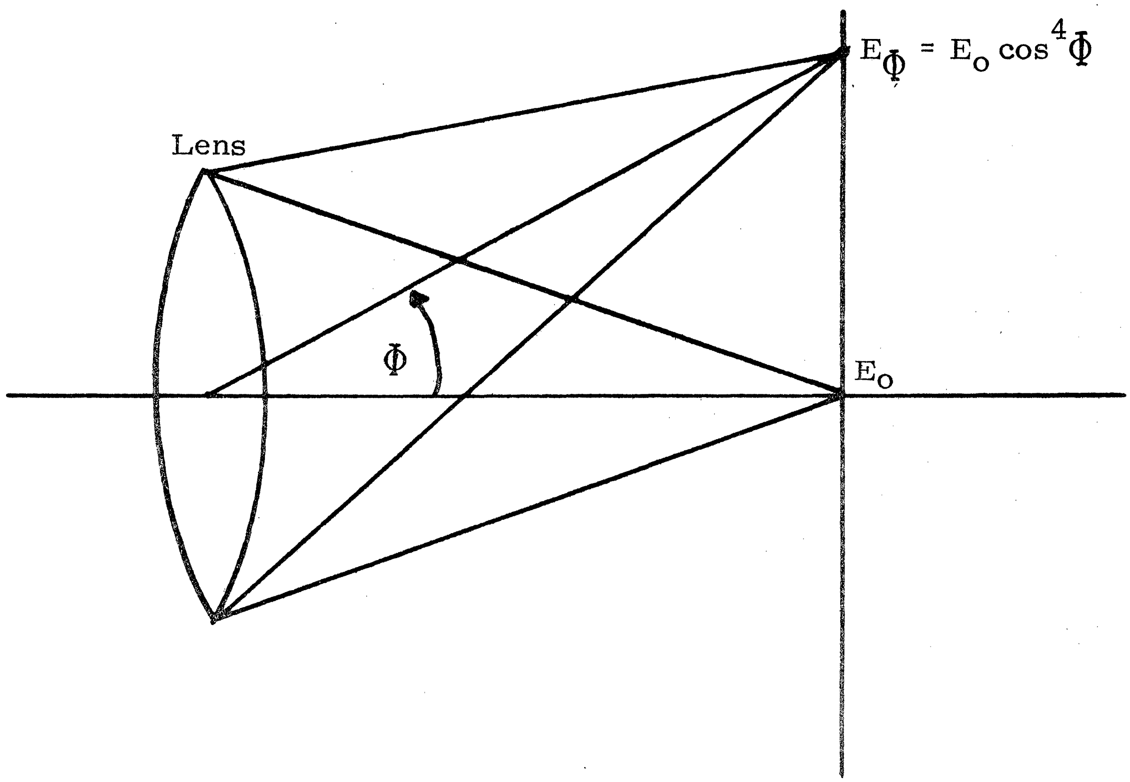


Figure 5-14. Illuminance Dependence on Field Angle

Let Ω be the solid angle subtended by the exit stop at the image on axis and Ω' be the solid angle at off-axis position I and it can be shown that the decrease in image illuminance decreases by $\Omega'/\Omega = \cos^2 \Theta$. In addition, the decrease in areas as seen from image point I is reduced by cos Θ factor and the non-normal incident light decreases the illuminance by another factor of cos Θ. The result of imaging too far off-axis is now seen to be a function of the $\cos^4 \Theta$ as indicated in Equation 14.

<u>Equation 14</u> $E = E_O \cos^4 \Theta$

where E_O is the axial image illuminance. The $\cos^4 \Theta$ loss is obviously something that can not be eliminated since not all the image can be put on axis. The illumination of an image is inversely proportional to the square of the f number. It was decided that exposure difference would change by factors of two, thereby changing the f-numbers by factors of $\sqrt{2}$. The illumination changes by 1/2 as given in Table 4.

f-number	1	1.4	2	2.8	4	5.6	8	11	16	22
Illumination	1	1/2	1/4	1/8	1/16	1/32	1/64	1/128	1/256	1/512
Relative Exposure	1	2	4	8	16	32	64	128	256	512

TABLE 4.

Under the topic of stops one last subject is of importance: Vignetting. This term is used for the light being incident at such an angle that the rays passing by the stop are allowed to go past the lens without touching it. A graphical representation is given in Figure 5-15.

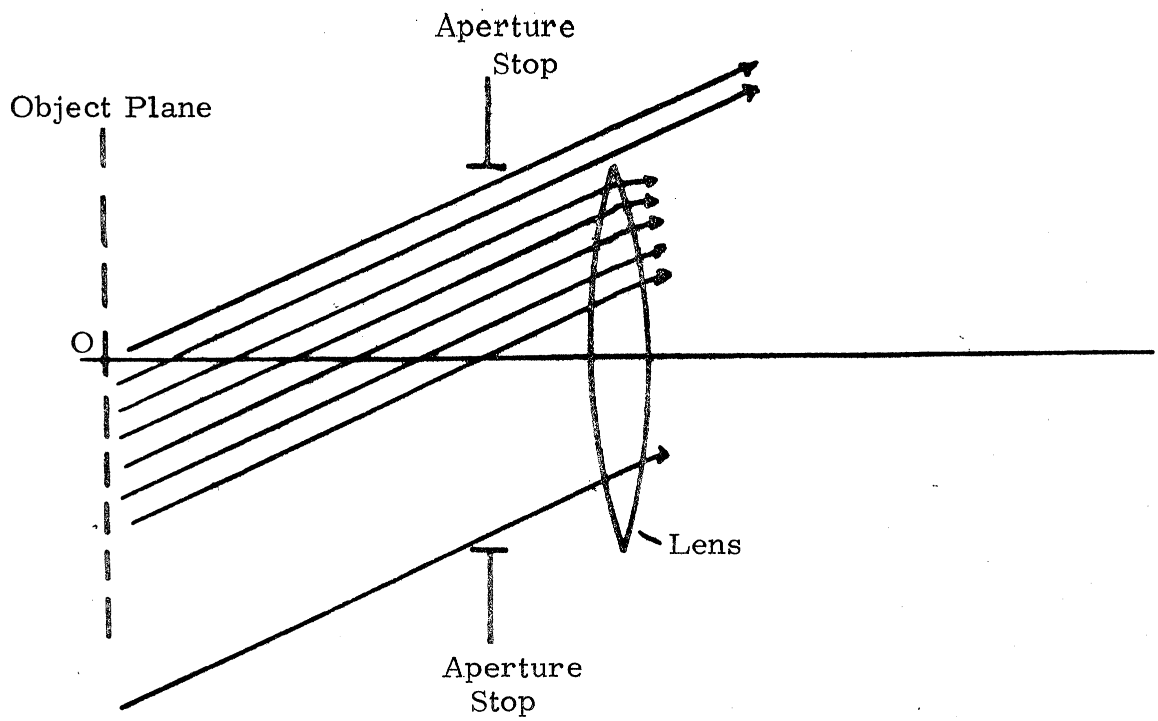


Figure 5-15. (Vignetting)

Vignetting is most commonly found in wide angle lens applications.

5-4. THIRD ORDER ABERRATIONS

Without involving ourselves with the mathematics of the theory of aberrations, we shall give some brief explanations and examples of all of the third order aberrations. Briefly the use of third order means that the variable has been cubed, (x^3 or O^3), in the mathematical approximation. All of the aberrations we shall discuss in this section shall be considered monochromatic aberrations.

There are five deviations from the Gaussian ray tracing in third order theory. They are: spherical aberration, coma, astigmatism, curvature of field, distortion. Spherical aberration has two components as shown in Figure 5-16.

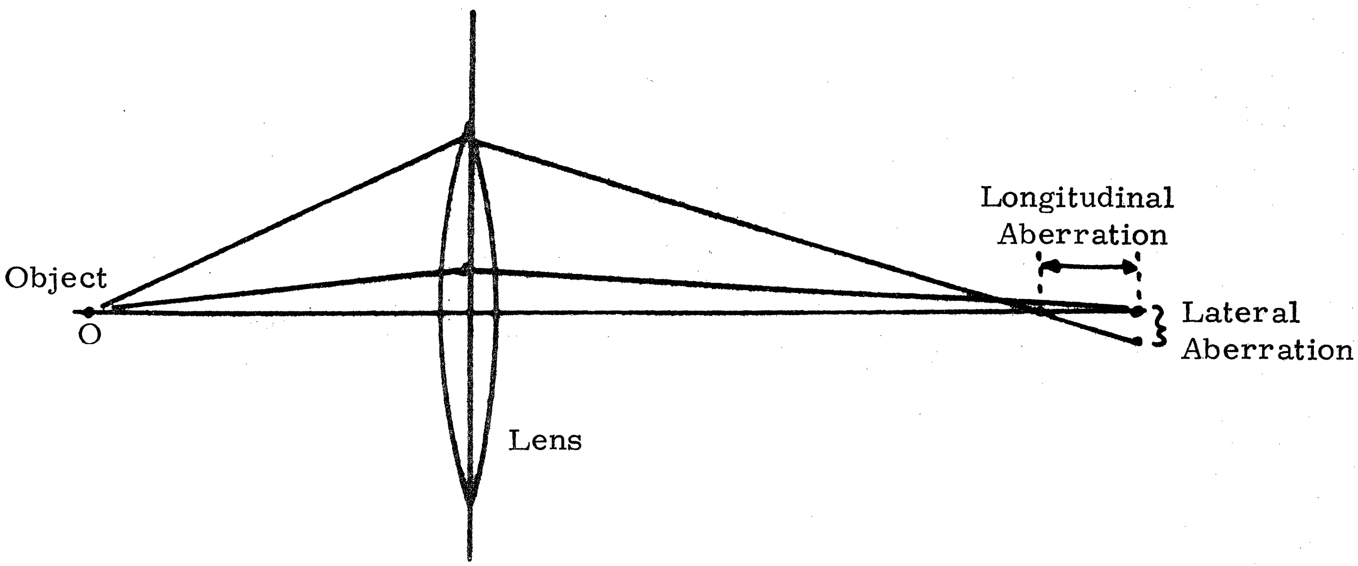


Figure 5-16. (Spherical Aberration)

The spherical aberration can not be eliminated completely, but can be reduced by proper choice of the radius of curvature.

The second aberration is called coma. Coma is seen when the incident ray has an angle of B with respect to the optical axis as shown in Figure 5-17.

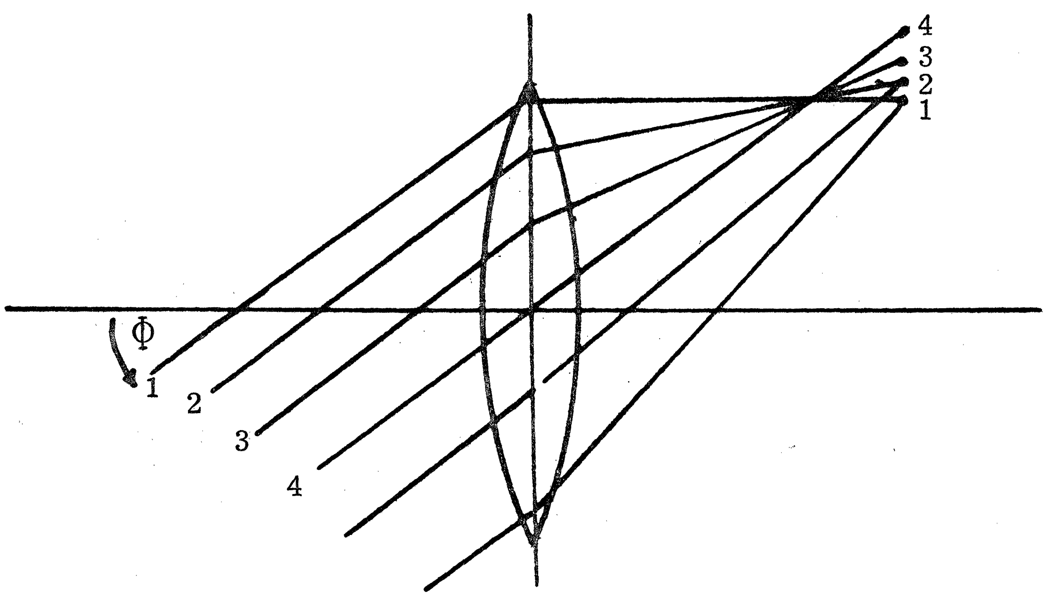


Figure 5-17. (Coma)

This aberration occurs for off-axis rays even though the lens has been corrected for spherical abberation.

Astigmatic lenses have still another abberation problem. It should be noted here that the first two aberrations must be corrected or minimized first. Figure 5-18 gives an example of aberration. It is good to note the tangential and sagittal planes which represent the image.

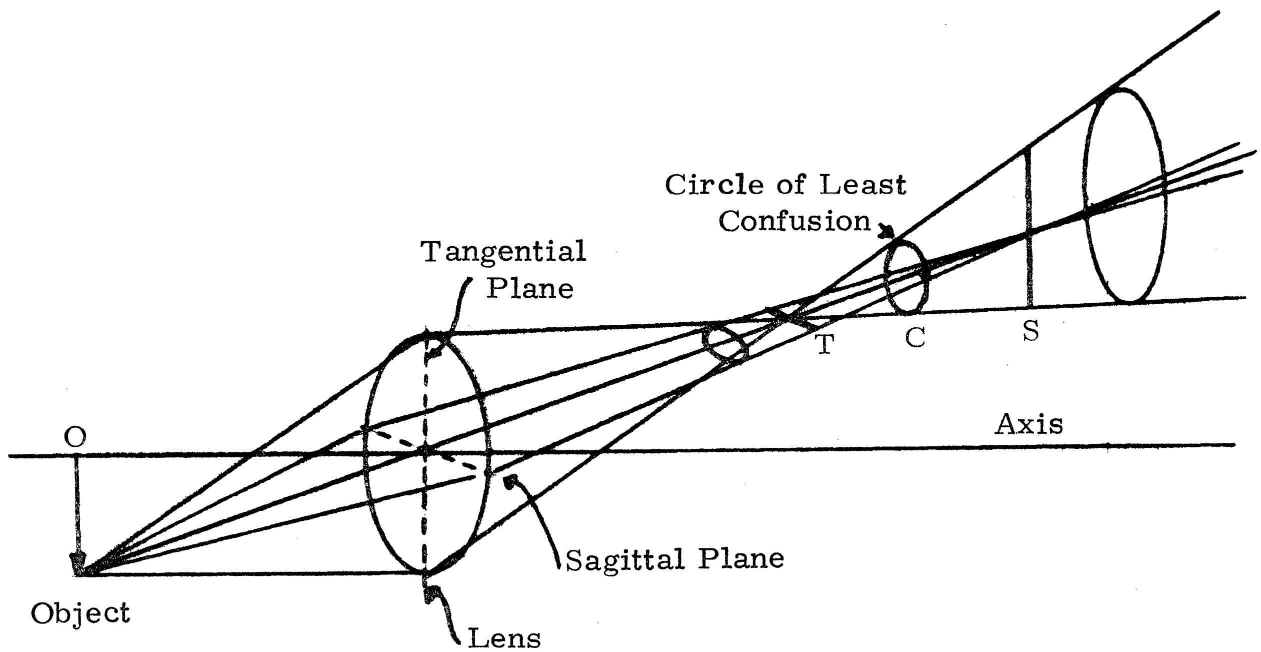
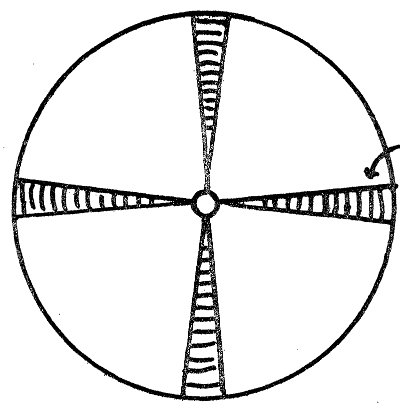


Figure 5-18. (Astigmatism)

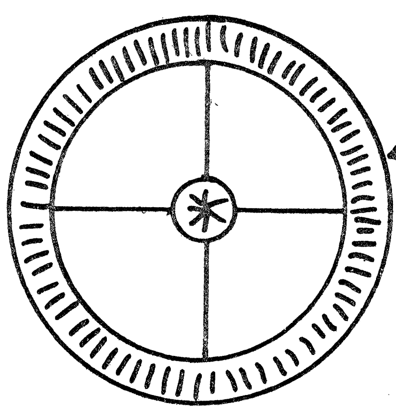
In between these two planes is the circle of least confustion, C. Astigmatism can occur in either the tangential plane or the sagittal plane. Shown in Figure 5-19 is a sample of both conditions.

Tangential Astigmatism



Spokes are spread more as distance from center is increased. Rim and hub are constant.

Sagittal Astigmatism



Outer rim and hub of wheel are widened. Spokes remain constant.

Figure 5-19. (Sagittal and Tangential Astigmatism)

Remembering the properties of the parabola we find that a paraboloid (surface generated by rotating a parabola) will eliminate the astigmatic condition. This surface is known as the Petzval surface.

Curvature of field is also a source of image degradation if the image surface is not curved the same as the Petzval surface for the optical system. Often times it is difficult to curve the image surface such as film. In these cases the field of view has to be minimized since the film or recording media cannot easily be regulated.

Last to be considered in third order aberrations is distortion. When an image is distorted the magnification throughout the image field is non-uniform. Two classic examples of distortion are illustrated in Figure 5-20. Equation 15 gives the mathematical relation for a distortion-free image field.

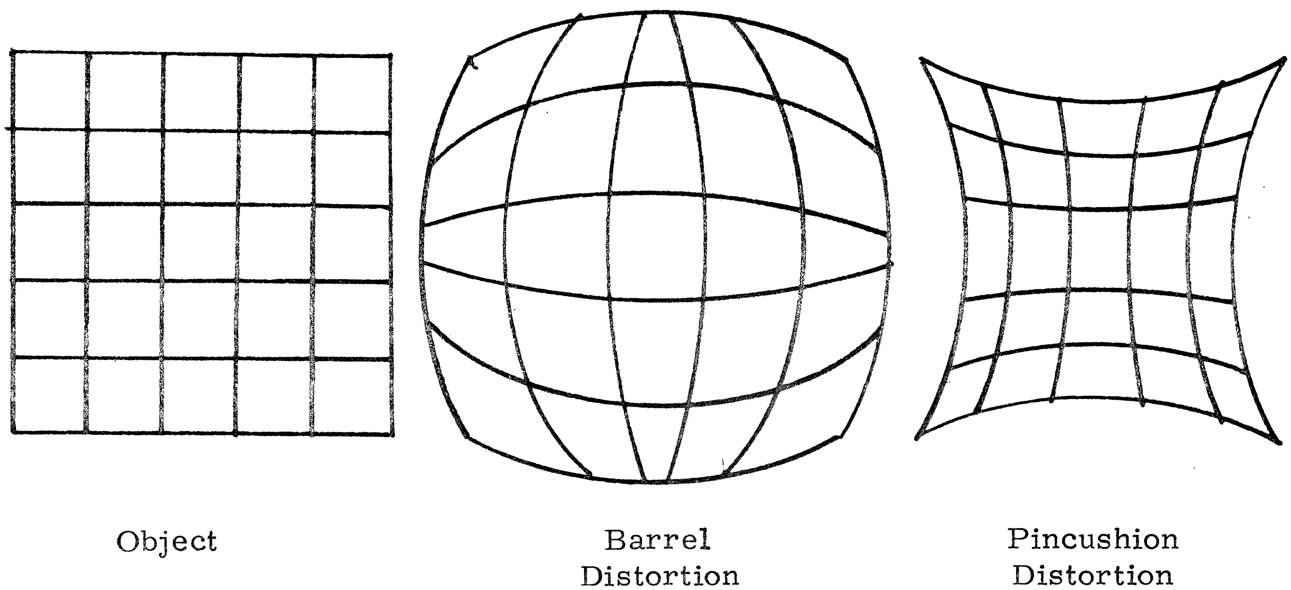


Figure 5-20 (Distortion)

Equation 15 $$\frac{\tan \Theta^1}{\tan \Theta} = \text{const}$$

where Θ is object ray angle and Θ^1 is image ray angle.

5-5. KEYSTONING

The phenomena of keystoning should not be confused with lens aberrations. When a square is projected into a trapazoid, Figure 5-20a, the effect is due to misalignment of the optical system, not the lens itself. This is not a third order aberration.

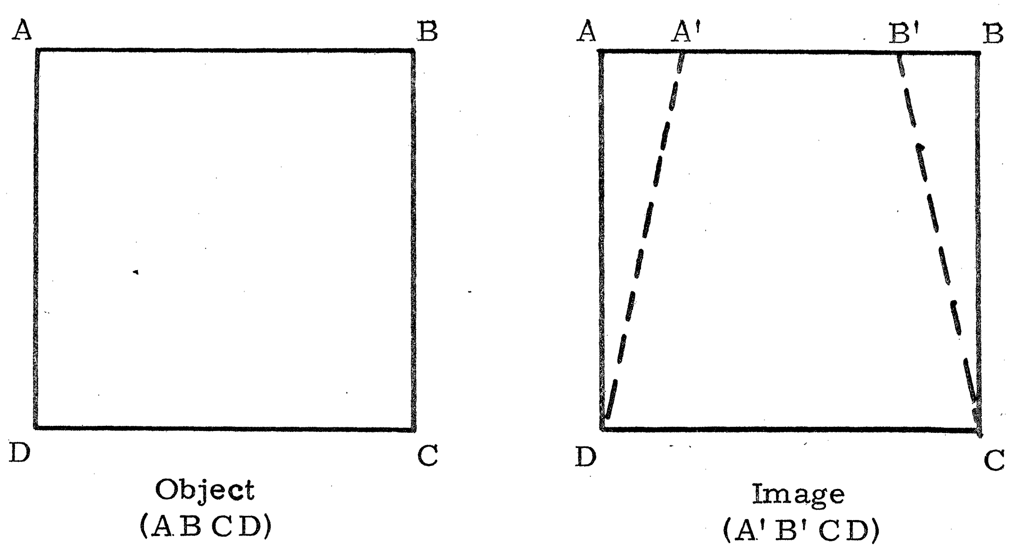


Figure 5-20a. Keystoning

5-6. DIFFRACTION, INTERFERENCE, AND RESOLVING POWER

Another property of light that has wave nature is interference and diffraction. Of primary interest to us is the diffraction due to edges of a stop in the camera or the lens itself. Let's look at the lens first. If we take a small distant object point in front of a condensing lens we find that around the image of this point is a "halo." This halo, shown in Figure 5-21, is called the Airys diffraction disc.

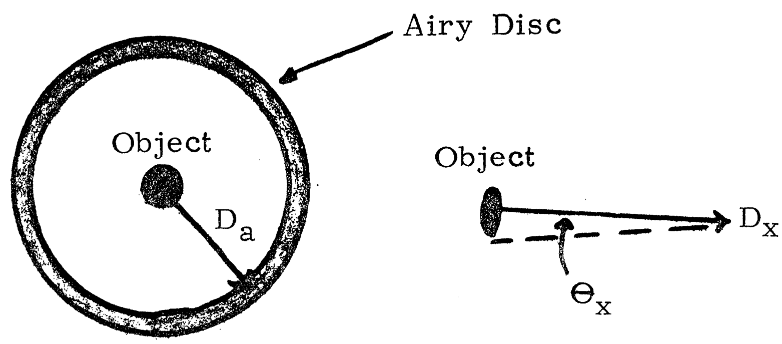


Figure 5-21. (Airy's Diffraction Disc)

To compute the diameter of the disc, D_a, you need to know the wave length λ (λ), index of refraction of image space medium (n) and the angle Θ_x between the extreme ray and the optical axis D_x.

Equation 16 $$D_a = \frac{1.22}{N \sin \Theta_x}$$

Even more useful is calculating the resolution limit of a lens due to diffraction. Here we are concerned with the diffraction of the lens plus the aperture setting. The diffraction will limit the resolution of a lens according to the following formula.

Equation 17 $$R_t = \frac{1600 \text{ lines/mm}}{(f/\#)}$$

R_t is the theoretical limit of resolution of the lens and f is the f-number of the lens. The resolving power in theory can be thought of in terms of wave length. If we use the lens system shown in Figure 5-22 -- has two point sources P1 and P2 -- the resolving power at I is a function of the frequency and separation of the object.

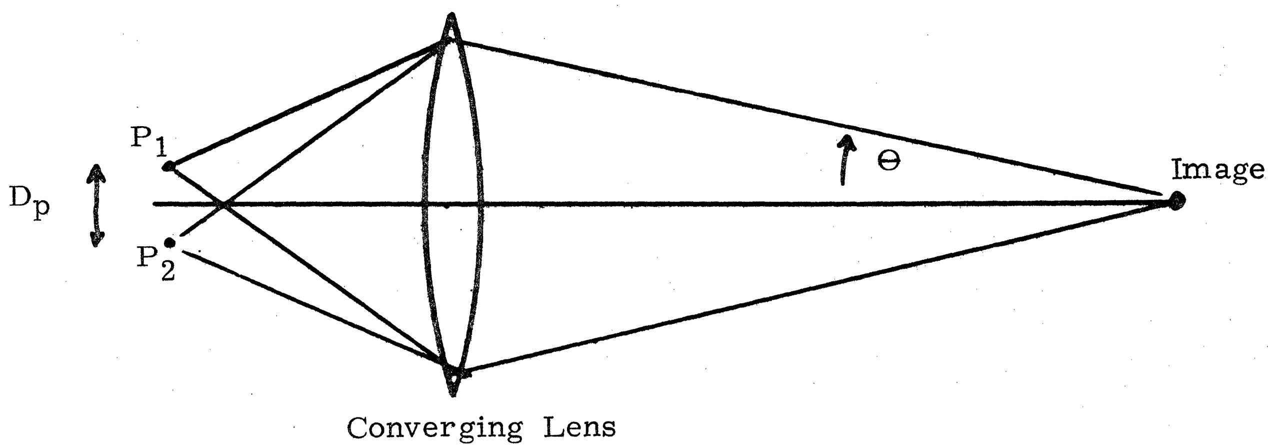


Figure 5-22. (Resolving Power)

One can resolve both points 1 and 2 if the time it takes for the light to reach point 1 differs from the time to point 2. Obviously, if the light takes the same time the points will coincide and will not be resolved. The minimum time difference required to resolve point 1 from point 2 is one period T of the light frequency ν. This corresponds to a path difference of λ, the wave length. With geometry it is easily shown that the distance between the points D_p must be larger than λ/n sin O.

5-7. CHROMATIC EFFECTS

The topic of different wave lengths of light could be a book by itself. We shall consider only a few topics as they relate to the DatagraphiX system.

Before we consider some of the results associated with different colors, different wave lengths (λ), it is instructive to consider the source of light in the DatagraphiX system. All film imaging devices use the P22B phosphor from the cathode-ray tube or a Xenon flash lamp for the form slide. Shown in Figures 5-23 and 5-24 is the emission spectrum for each source.

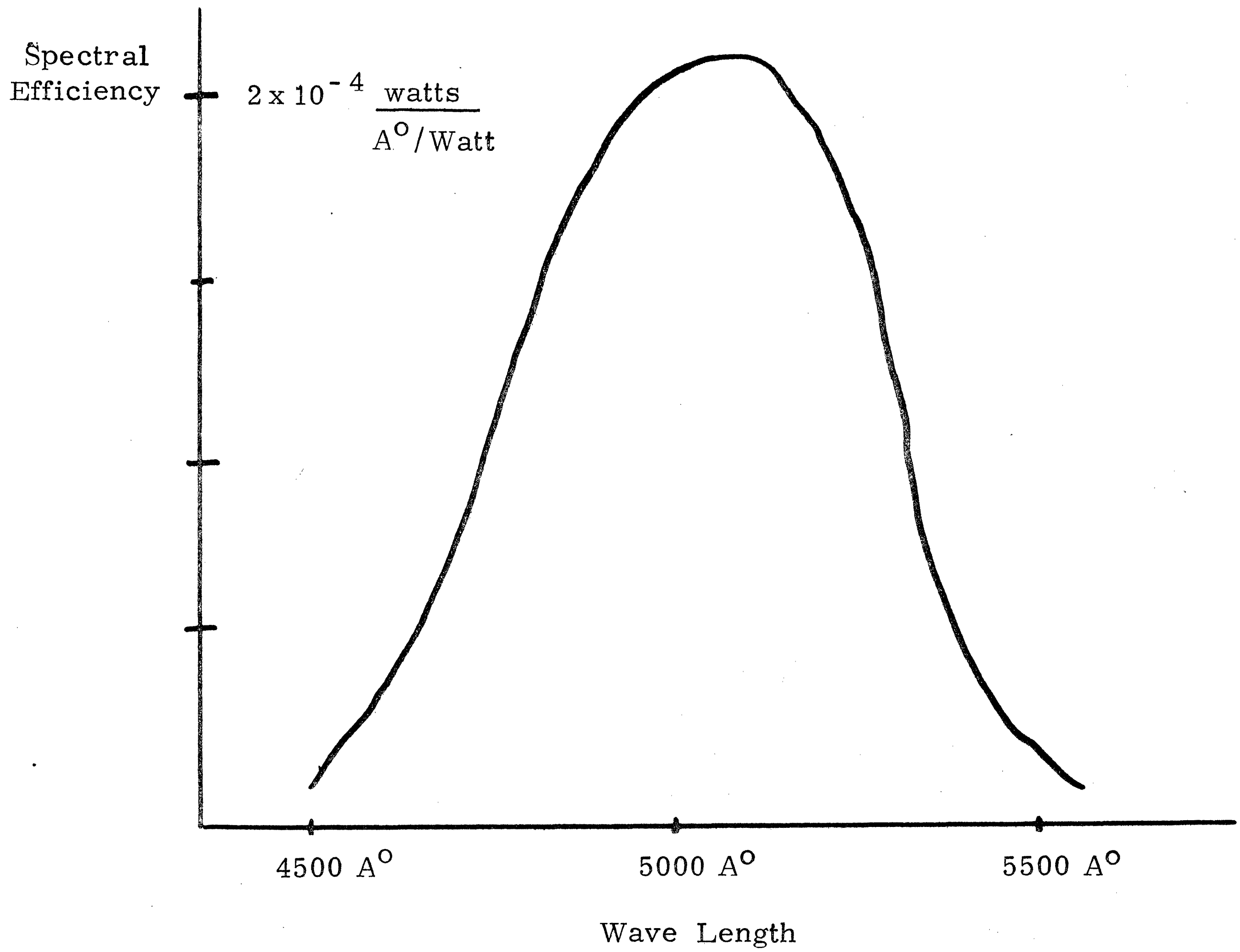


Figure 5-23. (Emission Spectrum for P22B Phosphor)

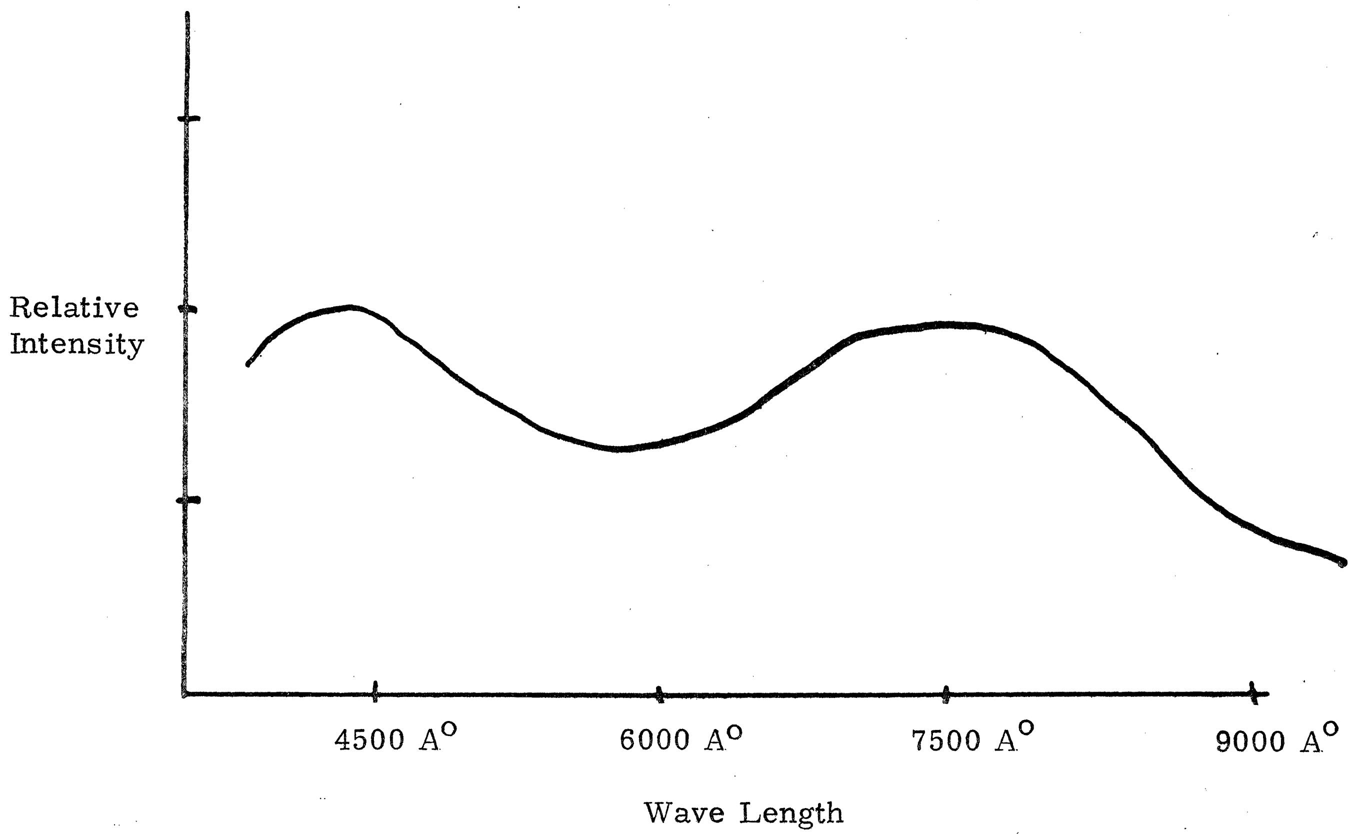


Figure 5-24. (Xenon **Flash** Spectrum)

Using the light from the tube we must have a lens system that focuses the λ = 4500 Å at the same point as the 5500 Å light. If we plot the index of refraction versus wave length for several types of glass, we notice a trend.

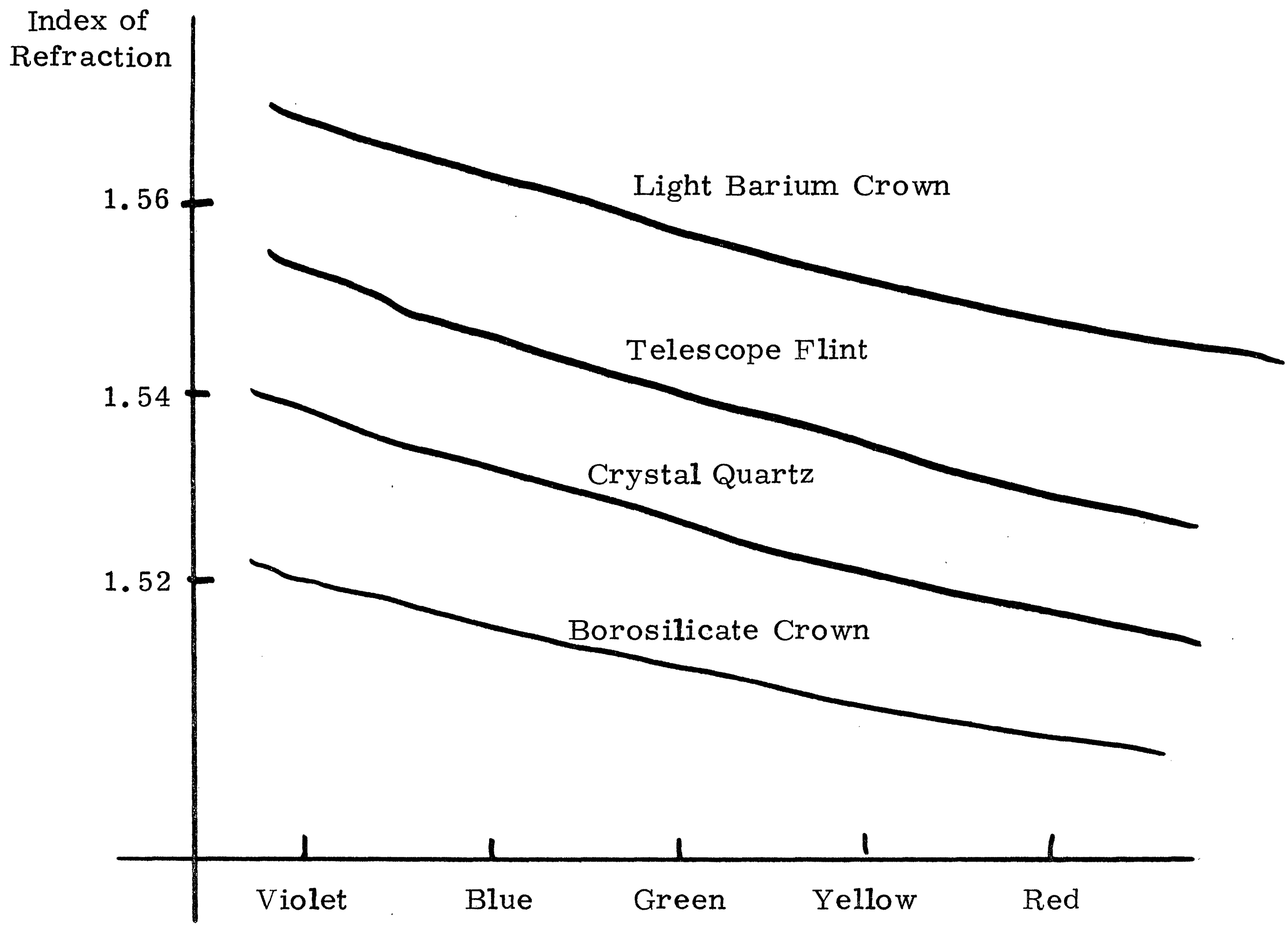


Figure 5-25. (Dispersion)

As the wave length increases from violet to "red" the index of refraction in that media decreases. When the index of refraction changes so does the speed of light for that media. The higher the index of refraction the slower the electromagnetic wave travels. The result is focusing at different points for each wave length of the spectrum. The chromatic aberration as it is called is very similar to spherical aberration in the sense that both have a lateral and longitudinal component. To have the image from the tube give a sharp image over the spectral range the lens must be corrected for chromatic aberrations. Chromatic aberration is also called dispersion.

The difference in the spectral output of the tube and the xenon flash has been used to aid the imaging system in the DatagraphiX 4060. Shown in Figure 5-26 is the configuration of the tube and form flash in the DatagraphiX 4060.

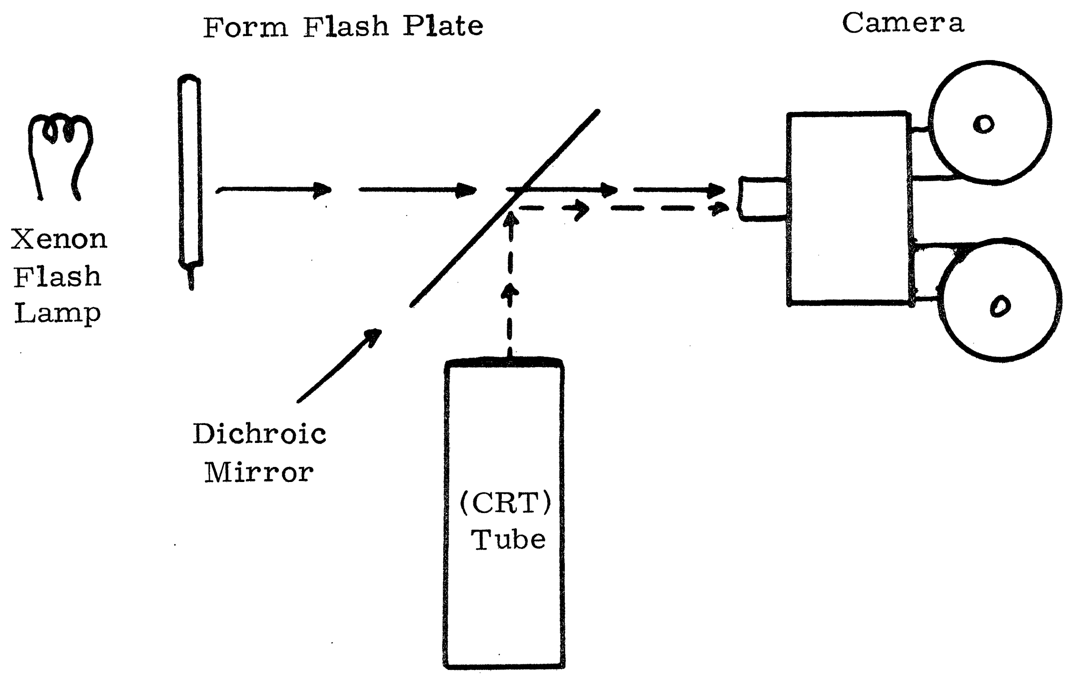


Figure 5-26. (DatagraphiX 4060)

The dichroic mirror is used to reflect the blue light from the tube and transmit the green light from the xenon flash unit. This allows the recorder to put the tube images and form flash image on the tube simultaneously.

5-8. OPTICAL ALIGNMENT PROCEDURES

A. Introduction

The D657 tooling autocollimator (Fig. 5-27) is designed to allow optical alignment of the surfaces used for data recording on microfilm by a DatagraphiX Service Representative.

The collimator light source sends a beam of light out of the objective in the form of parallel or infinite rays of light. When these rays of light are deflected by a tilted mirror, the angle thru which the reflected beam is turned is equal to twice the angle of mirror tilt. (Angle of incidence plus the angle of reflection.) However, the D657 has a built-in compensating factor that permits reading the exact angle of mirror tilt.

B. General Description

The standard D657 autocollimator is supplied with a cross-hair and a measuring reticle. Starting at the center of the measuring reticle, the values of the series of circles are one (1) minute each with each 5th circle numbered. The reticle supplied in this kit will read up to 30 minutes of error.

The values of the measuring reticle are accurate to 1% or 10 seconds. The instrument will repeat null readings to ± 1 second of arc. The total measuring range of the D657 is 1 degree of arc.

As the distance between the autocollimator and the external reflector increases, the measuring range decreases. The following table lists the measuring ranges at different distances using full aperture:

DISTANCE	MEASURING RANGE
3 feet	1 degree
10 feet	18 minutes
20 feet	9 minutes

C. Care and Maintenance

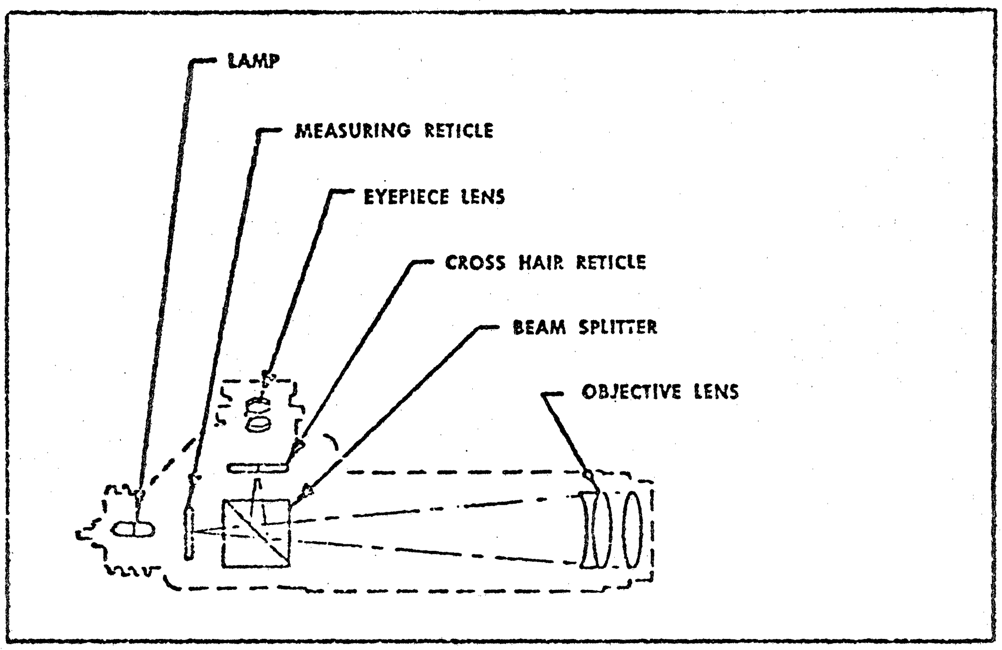
The D657 autocollimator is designed for a minimum of maintenance and should be treated as you would any fine optical instrument. Do not allow oil or water on the lens or interior optical elements. Keep clean, using only a soft brush or lint free material to remove dust from the optics. The D657 requires no lubrication and no parts should be lubricated.

D. General Procedures

This instruction package is written in three (3) sections, as listed below:

Section 1	4060 Printhead Optical Alignment
Section 2	4460 Printhead Optical Alignment
Section 3	Printer (4200, 4400, 4360, 4440) Optical Alignment

It is essential that all steps of each section be performed in order to assure proper alignment of optical paths.



OPTICAL SCHEMATIC

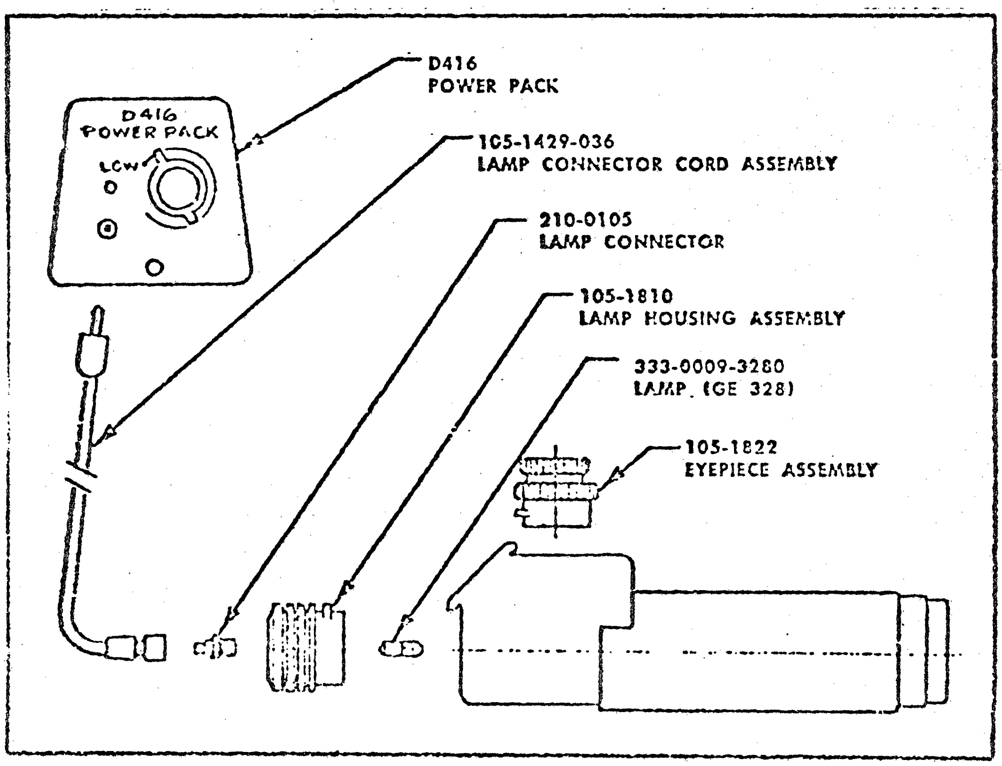


FIGURE 5-27

5-9. 4060 PRINTHEAD OPTICAL ALIGNMENT

A. Equipment Required

1. Davidson D657 Autocollimator w/power pack
2. Davidson D212 Adjustable Mount
3. Adjustable Stand Assembly
4. Form Slide Alignment Mirror
5. CSBT Alignment Mirror
6. Form Slide Holder Spacers, two required
7. Focus, Focus Paper Tape Program
8. 4060, 4460 Resolution Form Slide
9. Cam. Mirror

B. Alignment Procedure

Refer to Figures 5-28 thru 5-31 of this section.

1. Remove end cover from unit. (Fig. 5-28, Item 1)
2. Remove form slide lamp box. (Fig. 5-28, Item 2)
3. Remove form slide holder. (Fig. 5-28, Item 3)
4. Remove form slide corrector lens assembly. (Fig. 5-28, Item 4)
5. Replace form slide holder, using spacers between slide holder and optical system housing. (Fig. 5-29)
6. Remove window assembly nearest to camera lens. (Fig. 5-28, Item 5)
7. Insert form slide mirror in form slide holder with mirror surface toward camera.
8. Set up autocollimator and stand at camera end of unit. (Fig. 5-30)
   a. With Vought 16mm or 35mm camera installed, set height of collimator "line of sight" so as to allow alignment on film exposure station of camera. (Fig. 5-30, Item 1)
   b. Remove film guide roller. (Fig. 5-30, Item 2)
9. Remove camera, taking care not to disturb collimator height adjustment.
10. Adjust collimator in azimuth and pitch to place reflected ring image (yellow color) from the form slide mirror to zero minutes of error. Reflected ring image can be focused sharply by rotating collimator eyepiece assembly. Remove form slide mirror and cover opening to eliminate ambient light, or insert a black piece of paper in front of mirror. Collimator is now aligned to emulsion plane of form slide.

    <u>CAUTION</u>: Extreme care should be now taken not to move collimator <u>or</u> machine during following steps.

11. Install the 4060/4460 CSBT face mirror directly on the CSBT face with the reflective surface down. (Note: Remove corrector lens - "fish eye") the reflected rings (blue-white color) should be within 3 minutes of arc. If not, adjustment is required in <u>both</u> Comic and Cine rotation to bring the overall error to within 6 minutes of arc. (Fig. 5-31)

    <u>NOTE:</u> Correction adjustment in most cases will require movement of CSBT within tube shield <u>and</u> tube mount base. Record all readings of all steps to assure correction is in the right direction.

12. Install camera and secure. With camera mirror placed on film plane at exposure station, reflective surface facing optics housing, align camera mount in azimuth and pitch to within 1 minute of error.
13. If both 16mm and 35mm cameras are used, repeat Step 12 for each. If error between camera types is larger than 3 minutes, average the readings and re-adjust the mount to that average.
14. Replace corrector lens (fish eye), form slide corrector lens, form slide holder, lamp box and window assembly near camera lens.
15. Adjust camera lens for sharp focus of form slide on film. Use camera alignment telescope prior to filming.
16. Adjust tube display, "Matrix Test Pattern" for sharp focus on film. Use camera alignment telescope prior to filming.
17. Load "Focus, Focus" program into core.
18. Run focal tests by adjusting lens around setting found by using camera alignment telescope. Set to best output.
19. Install resolution form slide, and run approximately 20 frames in both Comic and Cine rotation for fall-off and resolution evaluation.

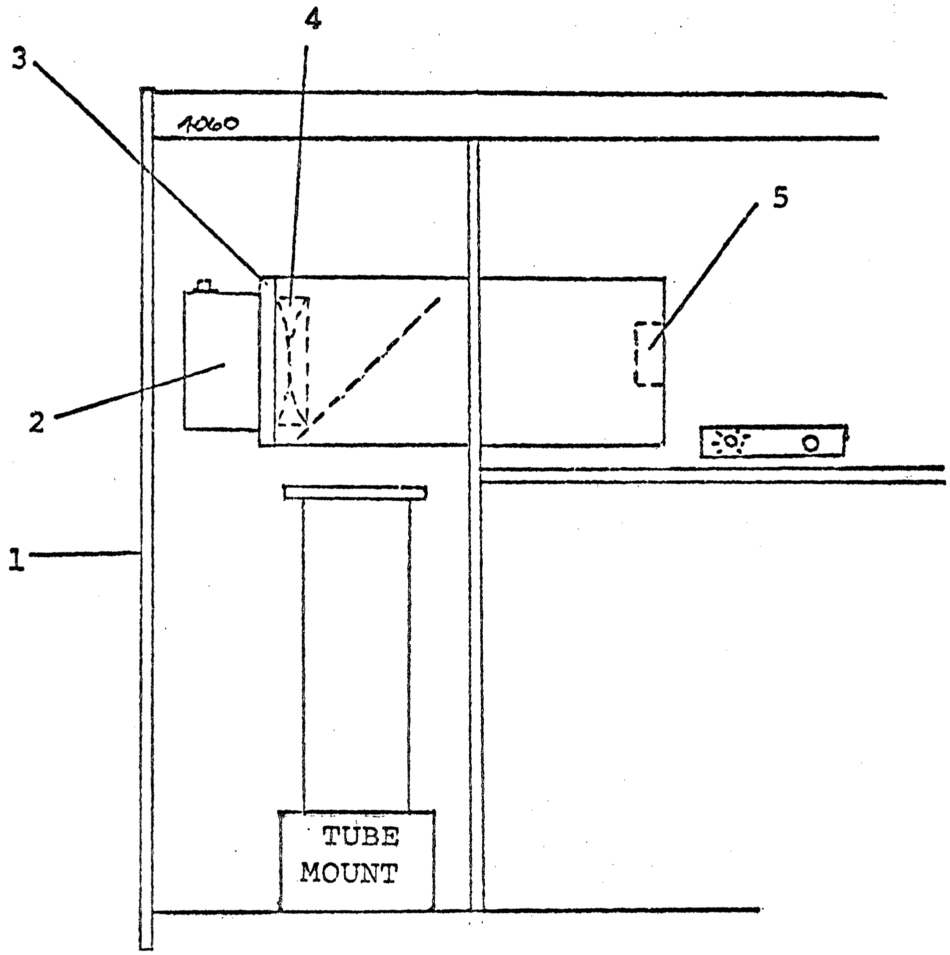


FIGURE 5-28 (D 4060)

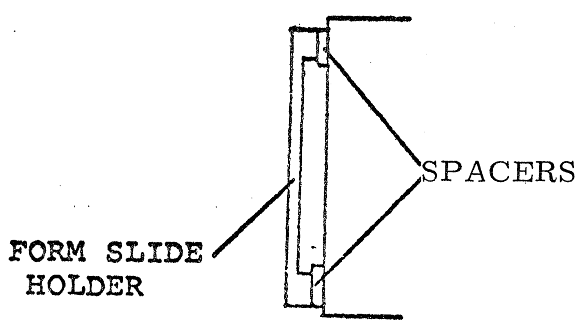


FIGURE 5-29

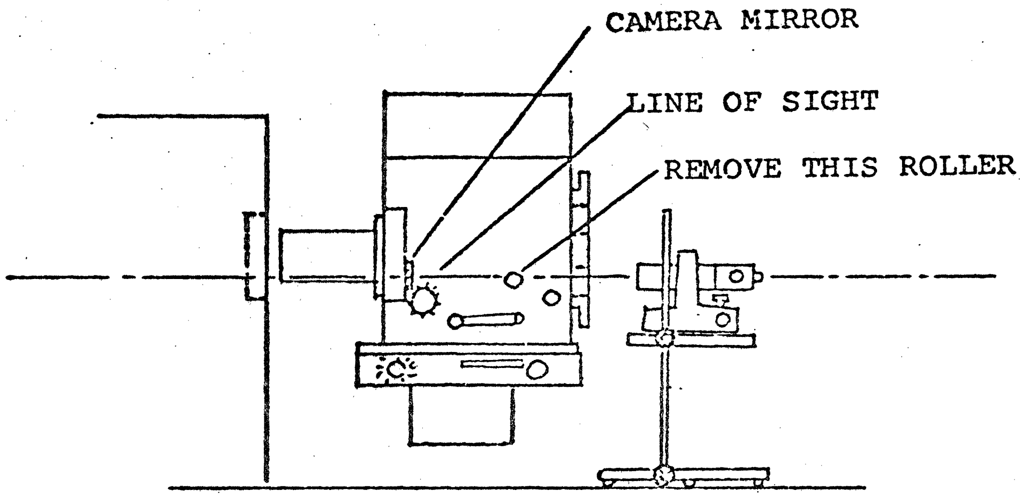


FIGURE 5-30

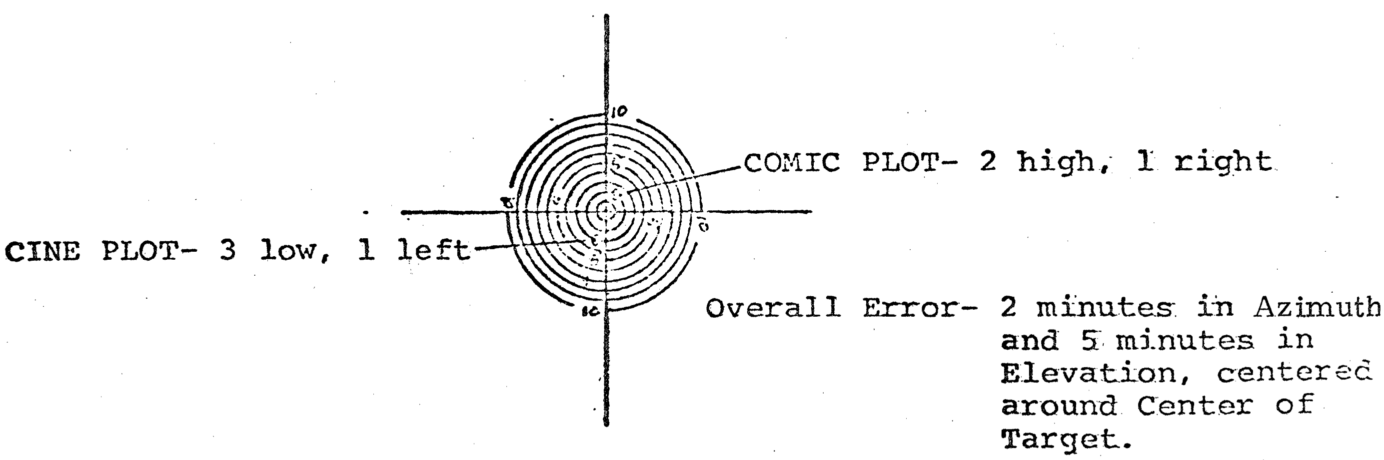


FIGURE 5-31

5-10. 4460 PRINTHEAD OPTICAL ALIGNMENT

A. Equipment Required

1. Davidson D657 Autocollimator w/power pack
2. Davidson D212 Adjustable Mount
3. Adjustable Stand Assembly
4. Form Slide Alignment Mirror
5. CSBT Alignment Mirror
6. Focus, Focus Paper Tape Program
7. 4060/4460 Resolution Form Slide
8. Cam. Mirror

B. Alignment Procedure

Refer to Figures 5-32 and 5-33 of this section.

1. Open right hand bay door. (Fig. 5-32, Item 1)
2. Remove U/C camera supply and take-up cannisters.
3. Remove U/C transport housing from camera.
   a. Remove 2 holding/hinge screws (Fig. 5-32, Item 2) to accomplish this step. Also, remove power cables!
4. Remove U/C camera lens and holder.
5. Position lens mount slide to center of camera.
6. Insert form slide mirror in form slide holder with mirror surface toward camera. (For details, see Steps 1 thru 6 of Section 5-7.
7. Set up autocollimator and stand at camera end of unit (Fig. 5-32).
8. Position autocollimator in height, azimuth and pitch to look thru camera lens opening to form slide mirror. Adjust collimator in azimuth and pitch to place reflected ring image (yellow color) from the form slide mirror to zero minutes of error. Reflected ring image can be focused sharply by rotating collimator eyepiece assembly. Remove form slide mirror and cover opening to eliminate ambient light, or insert a piece of black paper in front of mirror.

Collimator is now aligned to emulsion plane of form slide.

CAUTION: Extreme care should be now taken not to move collimator or machine during the following steps.

9. Install the 4060/4460 CSBT face mirror directly on the CSBT face with the reflective surface down. The reflected rings (blue-white color) should be within 3 minutes of arc. If not, adjustment is

required in both Comic and Cine rotation to bring the overall error to within 6 minutes of arc. (Refer to Section 5-7, Fig. 5-31)

NOTE: Correct adjustment in most cases will require movement of CSBT within tube shield and tube mount base. Record all readings of all steps to assure correction is in the right direction.

10. With camera mirror securely held against the U/C camera aperture rollers (Fig. 5-32, Item 3), reflective surface facing optics housing, align camera mount in azimuth and pitch to within 1 minute of error. Remove camera mirror and re-check collimation on form slide mirror.

11. If a Vought Camera is part of the 4460 system, perform the following additional steps:
    a. Remove U/C camera from camera mount.
    b. Secure "adapter" plate to camera mount (Fig. 5-33)
    c. Place Vought Camera on adapter mount. Do not secure at this time.
    d. Remove magazines, pressure plate assembly and guide roller (refer to Section 5-32, Fig. 3).
    e. Place camera mirror on aperture block with reflective surface facing optics housing.
    f. Set up autocollimator using Step 8.a and 8.b of Section 5-7 as guide.
    g. Remove camera and recheck for zero error from form slide mirror.
    h. Replace camera and camera mirror. Using the 4 allen set screws located at each corner of adapter plate, adjust camera for less than 1 minute of error. Now using thumb screws, secure camera to "adapter" plate and again check for no change in alignment.
12. Return 4460 system to original configuration for processing film. Load "Focus, Focus" program into core.

NOTE: The Universal Camera lens' DO NOT REQUIRE focusing because they are prefocused before shipment. Do not touch alignment.

13. Run focal tests by moving U/C camera forward or backward on mount until best output is achieve.
14. Install resolution form slide, and with 25X installed, run one fiche for fall-off and resolution evaluation.

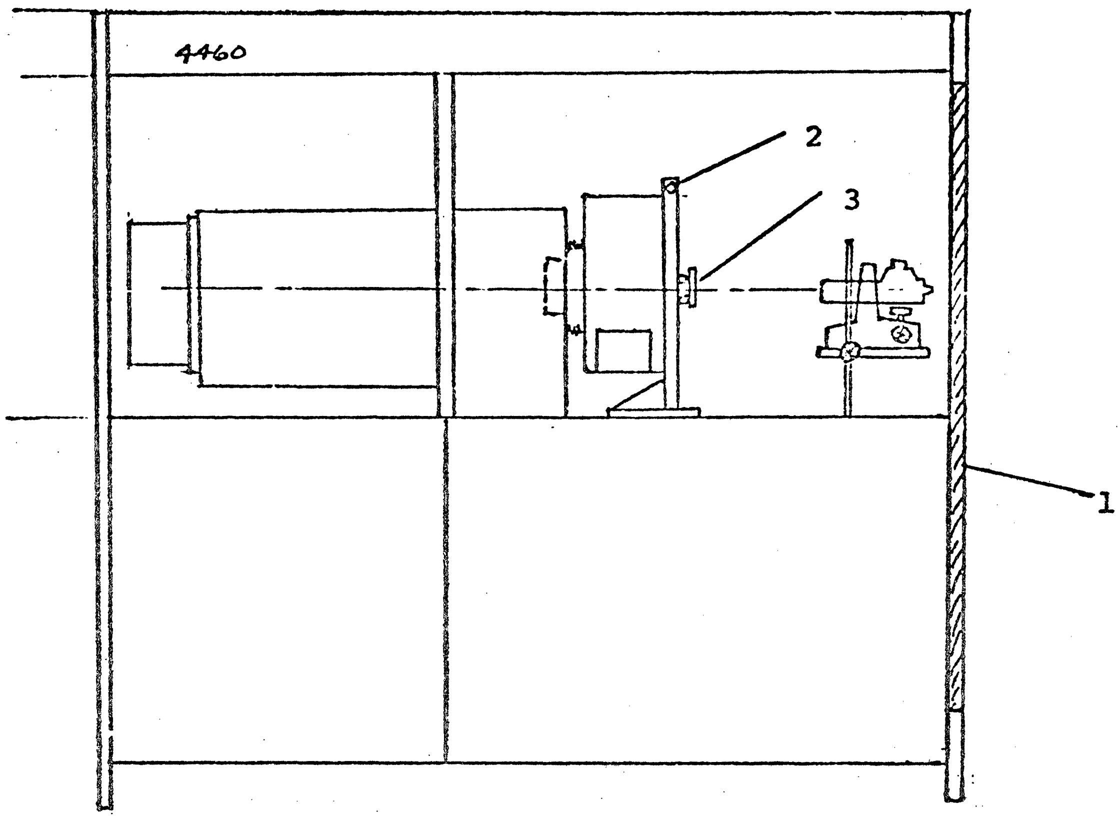


FIGURE 5-32 (D 4460)

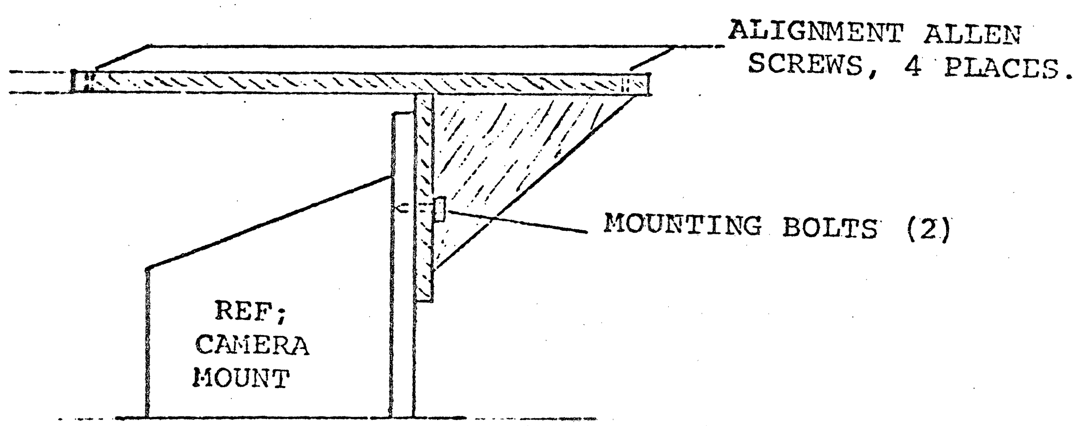


FIGURE 5-33

5-11. 4200, 4400, 4360 & 4440 OPTICAL ALIGNMENT

A. Equipment Required

1. Davidson D657 Autocollimator w/power pack
2. Davidson D212 Adjustable Mount
3. Adjustable Stand Assembly
4. 4200, 4400, 4360 & 4440 Form Slide Mirror
5. 4200, 4400, 4360 & 4440 Resolution Slide
6. Camera Mirror
7. CSBT Mirror
8. Spring Clips

B. Alignment Procedure - w/Universal Camera

Refer to Figure 5-34 of this section.

1. Remove outer and inner end panels if 4360 or 4440. (Fig. 5-34, Items 1 & 2)
2. Remove supply and take-up cannisters.
3. Hinge the transport assembly down, a s shown in Fig. 5-34.
4. Install printer form slide mirror.
5. Place collimator and adjustable stand assembly at end of lowered transport, as shown in Fig. 5-34.
6. Remove lens assembly. Position lens mount slide to center of camera.
7. Adjust autocollimator for zero error in azimuth and pitch from form slide mirror.

NOTE: Multiple sets of reflected ring images may be observed, one from each pellicle housing window and a bright one from the form slide mirror (yellow in color).

Collimator is now aligned to the same plane as the form slide. Removal of the form slide mirror causes the loss of the centered ring images from the form slide.

8. Using spring clips and associated mounting hardware (Item 20) attach the CSBT mirror (Item 19) to face of tube in the center. Reflective surface toward tube. Place in operating position and adjust tube mount assembly for less than 3 minutes of error in all three rotational positions.

Tube face is now aligned to form slide.

9. Place the camera mirror securely against the U/C camera aperture rollers (Fig. 5-34, Item 3), reflective surface facing optics housing, and align camera mount in azimuth and pitch to within 1 minute of error. Remove camera mirror and recheck collimation on form slide mirror.
10. Return system to operational status and set-up for focus runs. Select best run and "lock" camera down. Re-check camera collimation against form slide and re-adjust camera mount if collimation has moved.
11. Install printer resolution form slide and film 1 full fiche for fall-off and resolution evaluation.

NOTE: For resolution evaluation, (using a 42X lens) the resolved target group should be approximately 3.1.

C. Alignment Procedure - w/Vought Camera

1. Remove cannisters, film pressure plate assembly, and film guide roller. (Fig. 5-35, Item 1)
2. Install the printer form slide mirror.
3. Place collimator and adjustable stand assembly at end of camera bay (left of camera).
4. Position collimator so as to be able to look into the cameras take-up output opening. (Note Fig. 5-35)
5. Remove camera and adjust autocollimator for zero error in azimuth and pitch from form slide.

NOTE: Multiple sets of ring images may be observed, one from each pellicle housing window and a bright one from the form slide mirror (yellow in color).

6. Place a piece of black paper over form slide mirror for the next step.
7. Using spring clips and associated mounting hardware (Item 20) attach the CSBT mirror (Item 19) to face of tube in the center. Reflective surface toward tube. Place in operating position and adjust tube mount assembly for less than 3 minutes of error in all three rotational positions. Tube face is now aligned to form slide.
8. Re-install camera, taking care not to disturb collimator setting.
9. With camera mirror placed on film aperture plane at exposure station, reflective surface facing optics housing, align camera mount in azmuth and pitch to within 1 minute of error. (Fig. 5-35, Item 2)

10. Return camera and system to operational status and run a focal spread to find best focus. Lock lens down.
11. Install printer resolution form slide and run approximately 20 frames of F/F data for fall-off and resolution evaluation.

NOTE: For resolution evaluation, (using the 45 M/M lens) the resolved target group should be approximately 3.6.

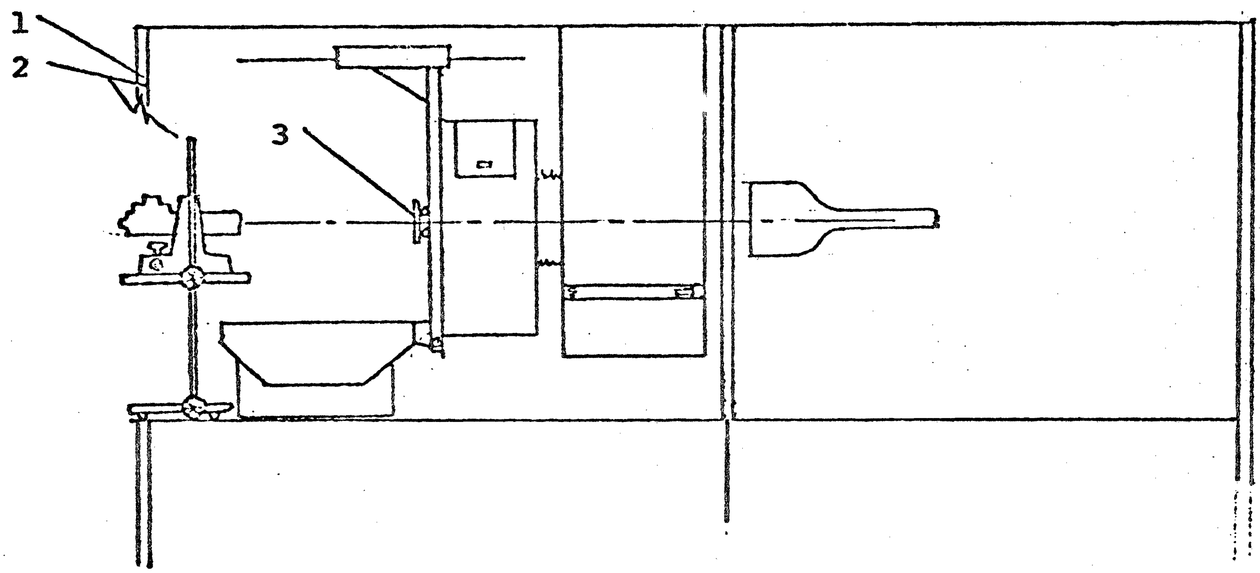


FIGURE 5-34
(4360/4440 w/U.C.)

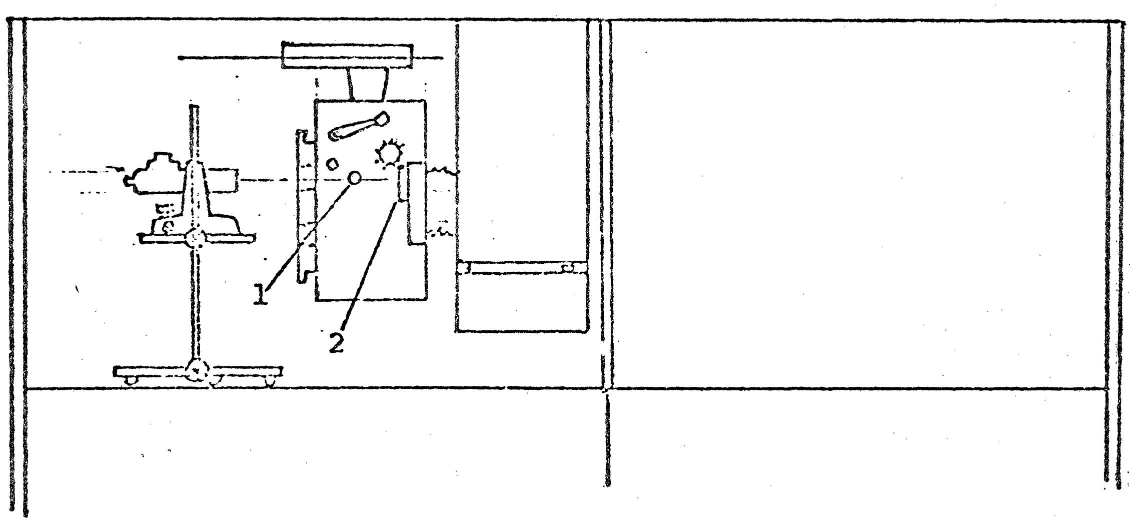
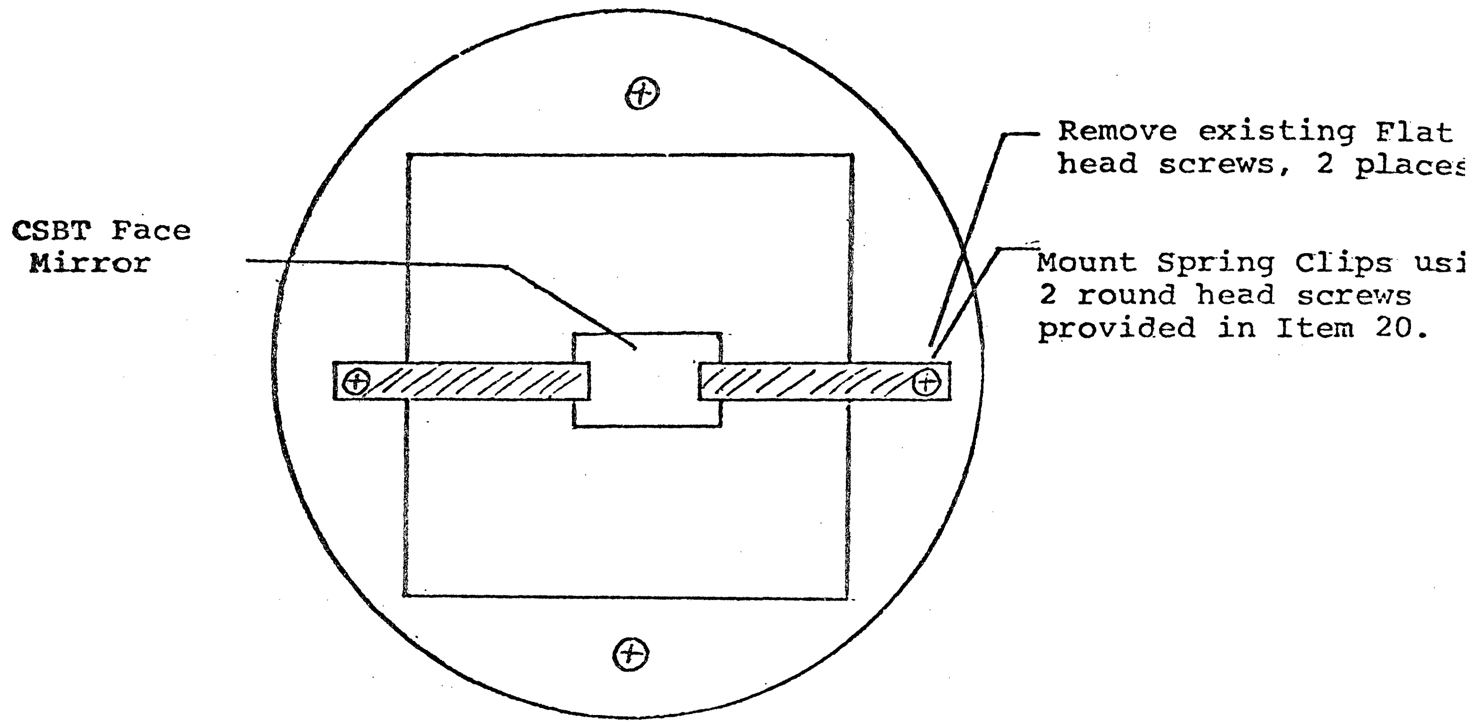
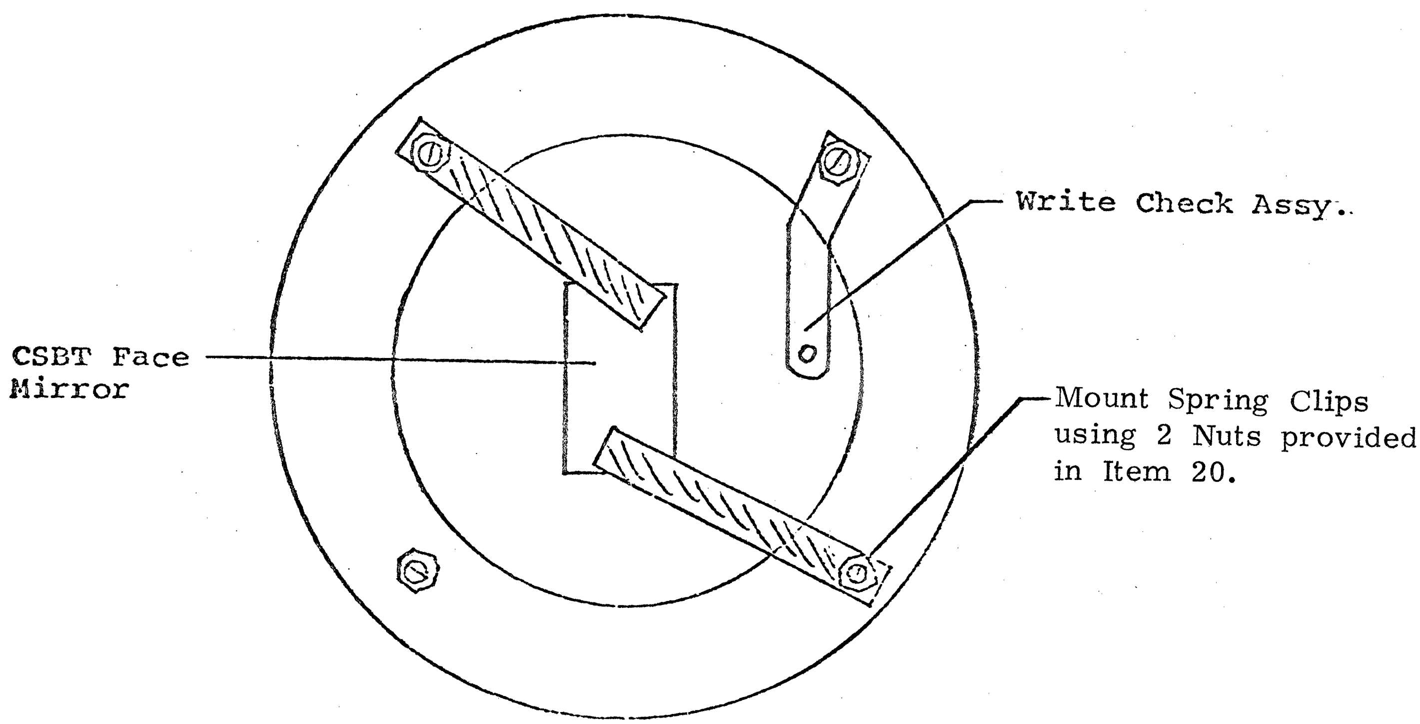


FIGURE 5-35



4200,4400,4360 CSBT FACE VIEW

FIGURE 5-36



4440 CSBT FACE VIEW

FIGURE 5-37

SECTION VI

IMAGE ANALYSIS

6-1. 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 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.

6-2. 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.

6-3 LIGHT SOURCES FOR PHOTOGRAPHY

A. Daylight

Daylight is 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. 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, photo-mechanical 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 ultraviolet. 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 wave length range. The nature of the energy finally emitted can be controlled by an appropriate choice of coatings, e.g., Calcium Tungstate 3100 A^o Peaks @ 4400 A^o to 7000 A^o; Cadmium Borate 3200 A^o Peaks @ 6000 A^o to 7500 A^o.

6-4. FILM SENSITIVITY

The emulsion is sensitized to certain wave lengths of light, namely for the imaging of excited P22B phosphor. The phosphor has a spectral emission curve as shown in Figure 6-1.

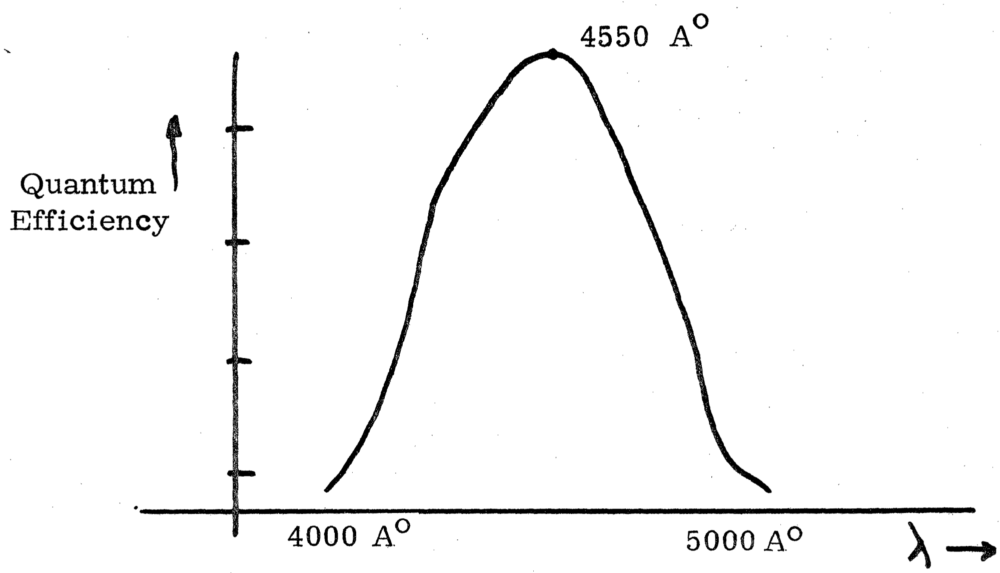


Figure 6-1. (Emission Spectrum of P22B)

The emulsion obviously must be capable of reasonable response in the 4000 Å to 5500 Å region of the visible spectrum. Looking at the Stromberg DatagraphiX film response in Figure 6-2 indicates the regions of peak response.

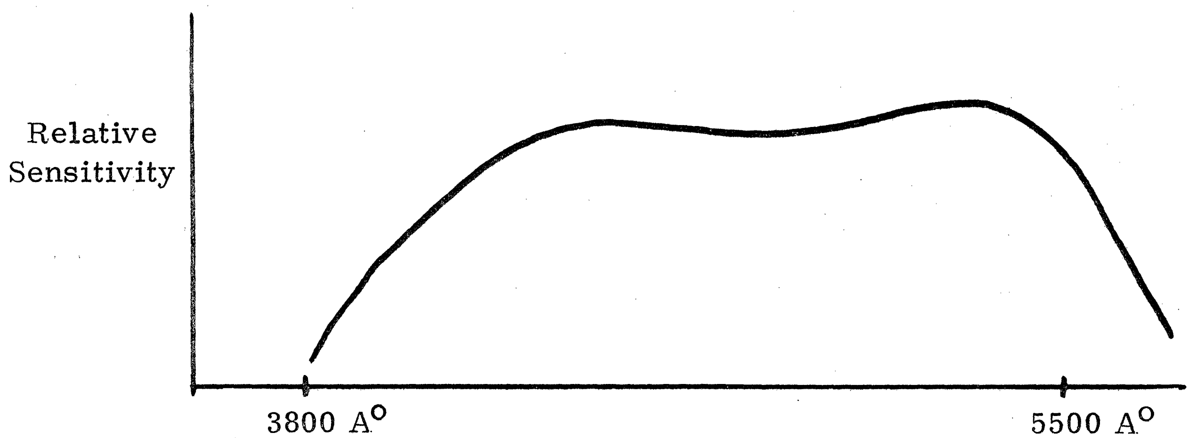


Figure 6-2. (Spectral Response of DatagraphiX film)

6-5. SENSITOMETRIC MEASUREMENTS

We now come to the discussion of the film images and how they are measured. To date no method is generally accepted by which one can give a quantitative measure of image quality. Many parameters, however, are quite frequently used to describe the image or the capability of the photo-optical system. It is these commonly used terms that we shall discuss here.

Our first interest is how does the film respond to light? The film, when given lots of light, turns very dark when negatively processed. If given more light the film doesn't get any darker. At this level of exposure, one has saturated the film and the opaqueness or density of the metallic silver has reached the maximum. This means that more exposure doesn't yield more film density. In an analogus manner if we start with a very weak source of light, it might not yield any appreciable density on film until a certain threshold value is reached.

The response of a typical silver film is shown below in Figure 6-3.

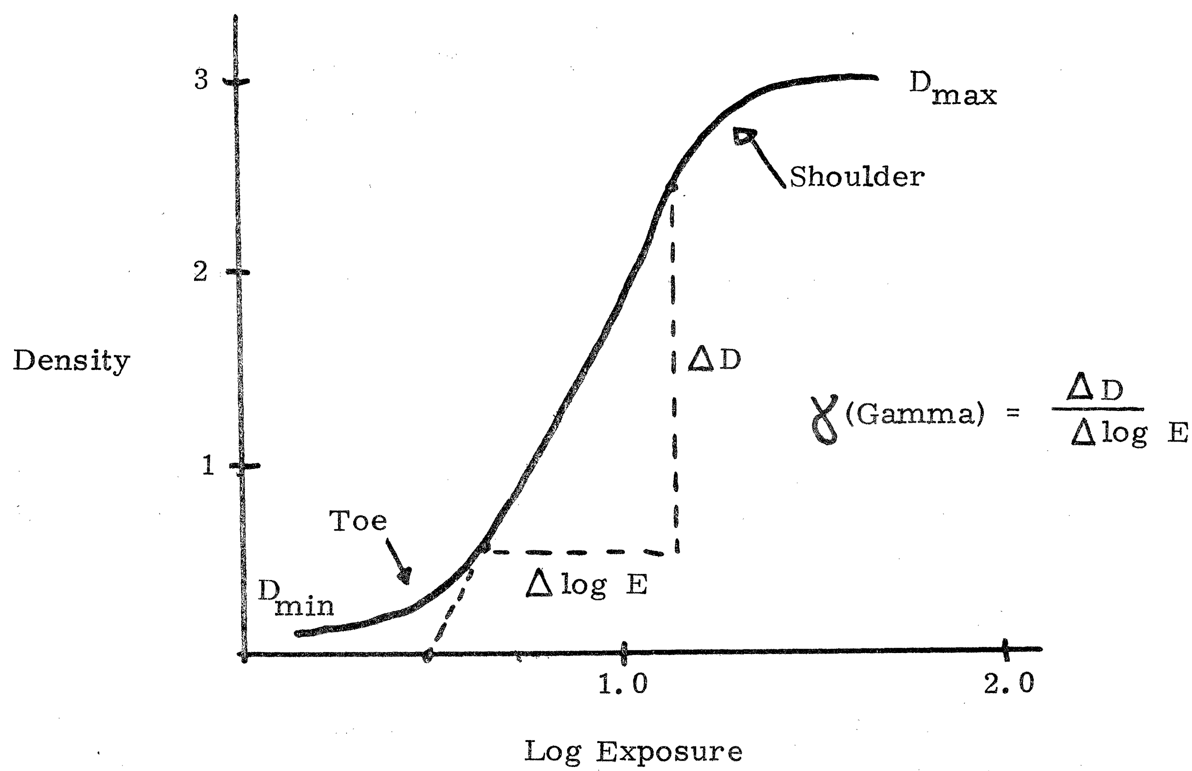


Figure 6-3. (D-Log E Curve)

The reason for using D-Log E for the parameters is found in the 1890 paper by Hunter and Driffield. The opaqueness of a silver film is a measure of how transparent the film is. If we let T be the transparency, then I/T is the opacity and log (I/T) represents the mass of silver per unit area in the developed area, commonly referred to as density, D. When plotting the density, D, versus exposure, E, which is the product of the source, intensity, I, and duration of the source, t, the curve generated is not as useful as the one plotted with D and Log E. One portion of the curve in the D-Log E plot is a straight line which is easy to work with. Also in practice the difference in relative intensity is better measured in terms of Log I than I. The curve D-Log E is frequently referred to as the H and D curve for the original researchers.

This curve, Figure 6-3, really describes the behavior of the film, and studying the different portions, yields insight into the behavior of the film. Figure 6-4 indicates one of the factors which must be taken into account before discussing Figure 6-5.

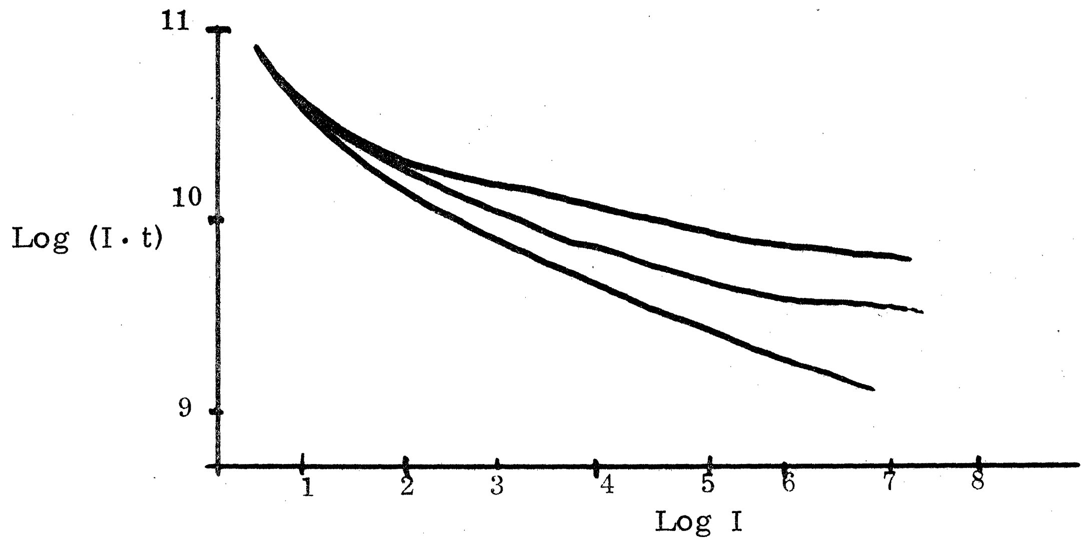


Figure 6-4. (Log I)

If we look at the equation for exposure in terms of intensity, it would appear that an intensity of 5 and time of 2 is the same as an intensity of 2 and a time of 5, since both yield E=10.

Equation 6-1 $\quad E = I \cdot t$

Figure 6-4 says that this is not so. One finds that an exposure necessary to give a certain density on film doesn't vary linearly with the intensity. If it did, then the exposure would remain constant and the curve in Figure 6-4 would be a straight horizontal line. The curved line represents the reciprocity failure in exposure. Although not discussed here, reciprocity failure occurs as a function of temperature and development time.

Now let's look at Figure 6-5. The straight line portion between the toe and shoulder is where most exposure takes place. This straight line segment has a slope called gamma. Gamma is a measure of how much silver density can be developed with increasing exposure. The horizontal component of the straight line portion is called the latitude, shown in Figure 6-5.

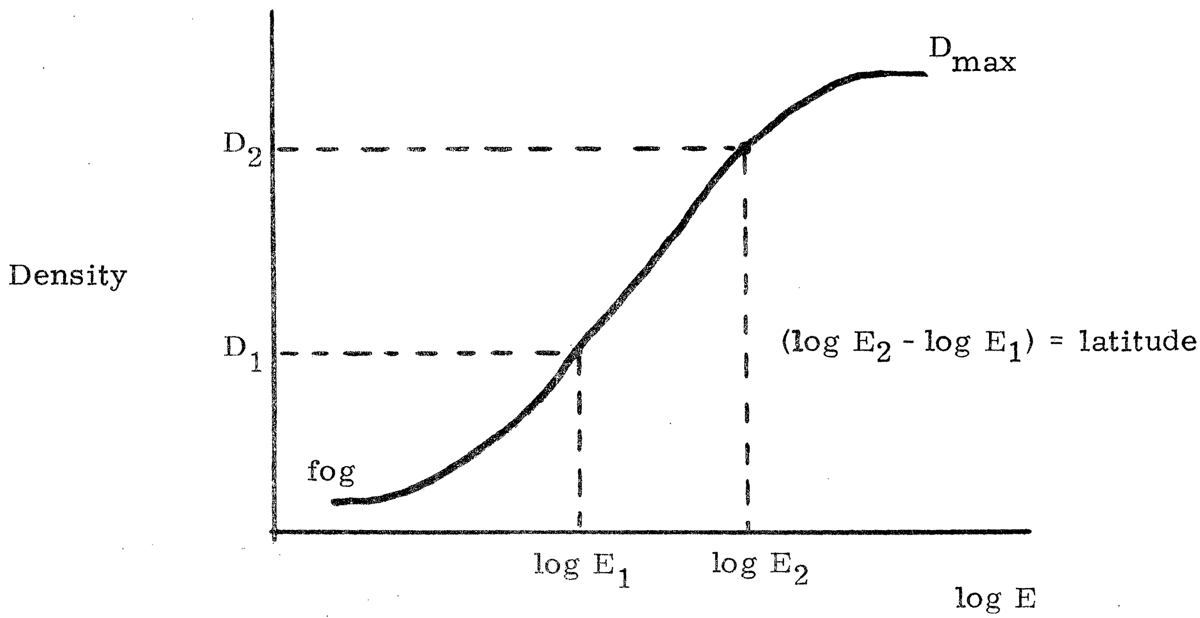


Figure 6-5. (D-Log E)

The photographic latitude of a film determines how much density difference there is between various exposures. For example, take the Character I on the DatagraphiX 4060 matrix. The intensity of the heavy line portion is greater than that of the thin line portion as shown in Figure 6-6.

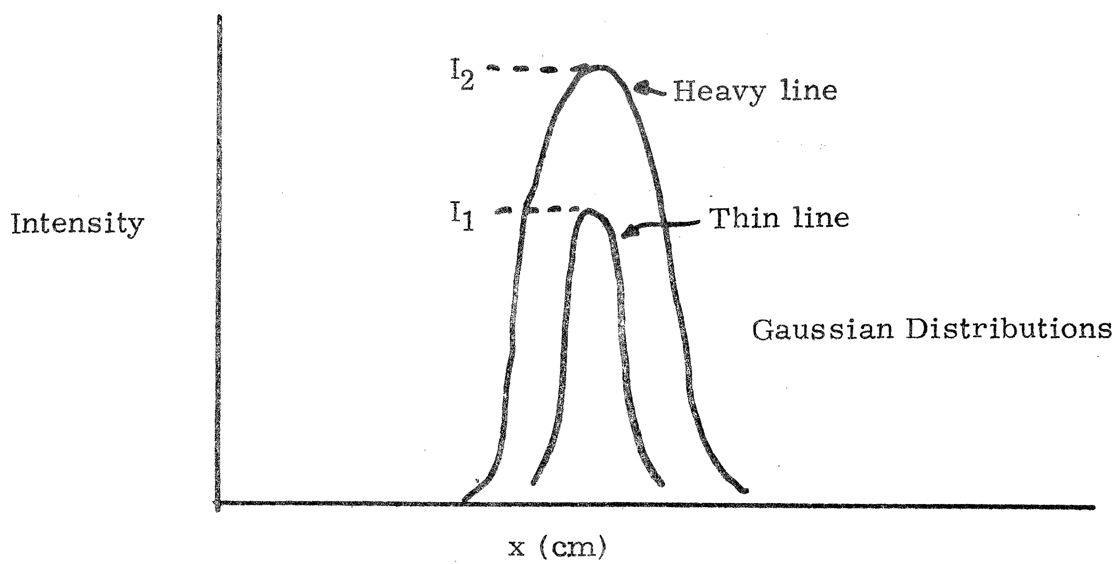


Figure 6-6. (Intensity Distributions)

Since the exposure is equal to I $\cdot$ t and t is the same for both lines, $E_2 > E_1$ since $I_2 > I_1$. E_2 and E_1 are shown in Figure 6-6 and the corresponding developed densities D_2 and D_1.

If the exposure difference is really large it is possible that the character will look like an L since the thin line doesn't give as much exposure above fog as does the thick line.

Further latitude requirements are necessary when one considers the $\cos^4$ loss from center to edge when imaging the film and another $\cos^4$ loss when making hardcopy.

To optimize the film one has to take the maximum and minimum energy within a single frame and make sure the minimum energy results in an exposure yielding a usable density. Figure 6-7 illustrates.

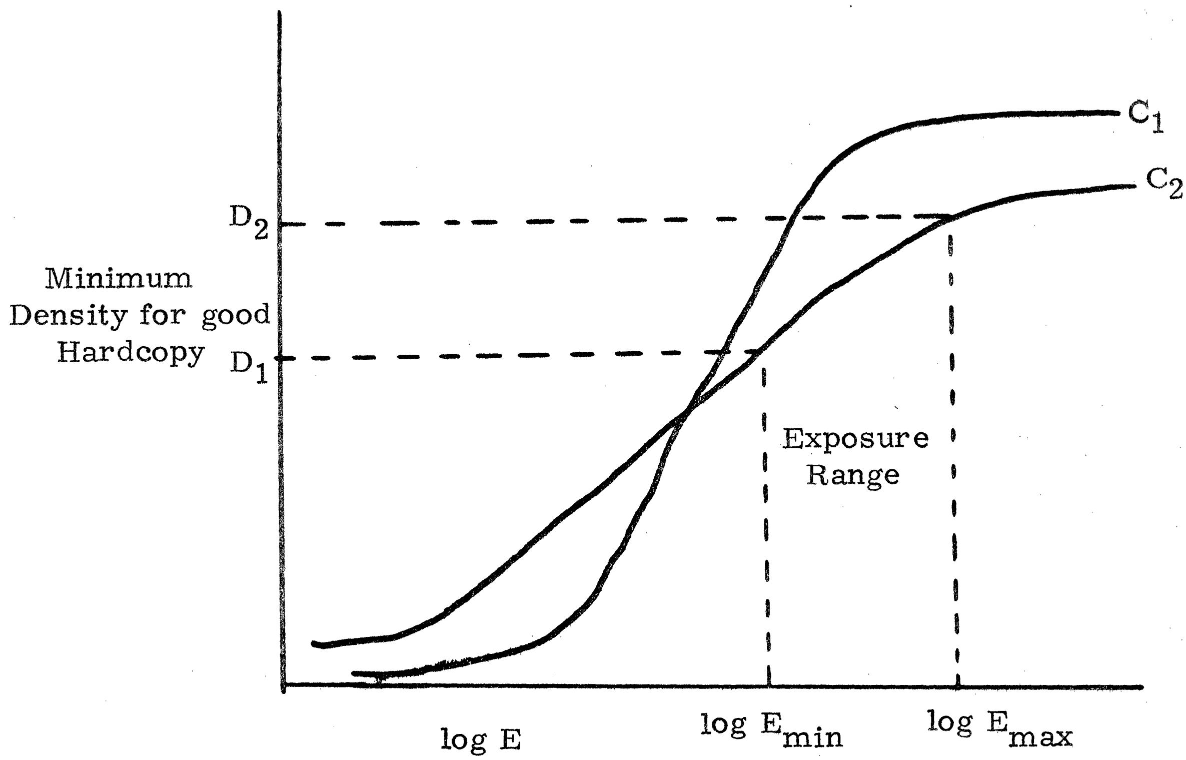


Figure 6-7. (Exposed Requirements)

The requirement for latitude should be clear by now, however, one must not think that a large latitude will solve all the problems.

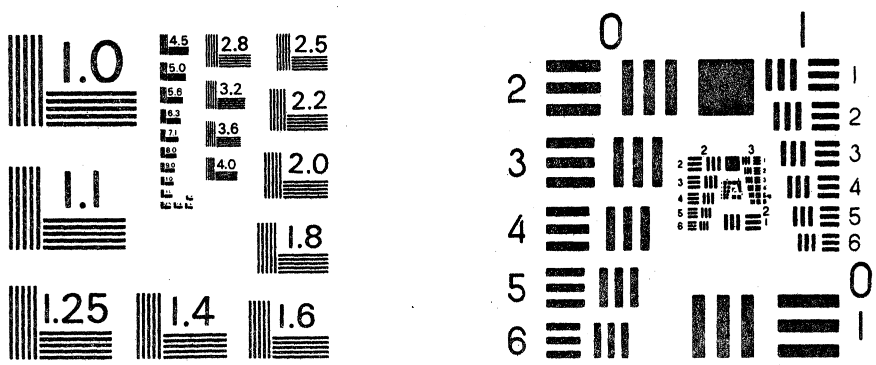
In addition to latitude, one must have enough contrast difference in density between the background and the character to make an acceptable image for viewing, copying and printing. A character density on film of 1.3 with a fog of 0.1 yields acceptable copy. Achieving the proper minimum density across the page requires just enough latitude with an adequate contrast ratio. Obviously the gamma becomes fairly well-defined. For the present Stromberg DatagraphiX film a $\gamma = 1.6$ is best.

Another physical parameter that is very important when looking at film images is the grain size. The silver grains of the raw, unexposed film determine the speed of the film or where the toe is on the D-log E curve. The finer the grain the slower the film. The developed film now is a function of the type of processing. For example, taking a fine grain film and processing it carefully at 68° F for five minutes in fine grain developer will yield a much sharper character than taking the same film and processing it for 9 seconds at 110° F. The graininess increases with temperature. A quantitative measure of the graininess of an image is called the granularity. Most often the Selwyn granularity is used which is completed by Equation 6-2.

Equation 6-2 $$G_s = (2a)^{1/2} \sum_n \frac{(D_n - D_o)^2}{N-1}$$

where a is the area of the scanning aperture, D_o the mean density, N the number of values and D_n the individual density measurements. The larger G_s, the larger the density fluctuations as measured by a microdensitometer. The characters graininess is then a function of both the grain size of the raw film and the type of processing that is used. One usually makes the distinction between granularity and graininess: Graininess is a subjective impression whereas granularity is the measured root mean square (r.m.s.) value determined by Equation 6-2.

Very closely tied in with the grain size of the raw film is the resolution. The film resolution is governed by how fine an image can be generated. A typical target that is used to measure resolution is shown in Figure 6-8.



FIVE BAR

National Bureau
of Standards

THREE BAR

Figure 6-8. (Resolution Test Targets)

The three bar configuration is commonly used. There are several ways of determining the maximum resolution of a film for a given set of exposure and processing conditions. Without lenses a contact print can be made by the experimental set up shown below:

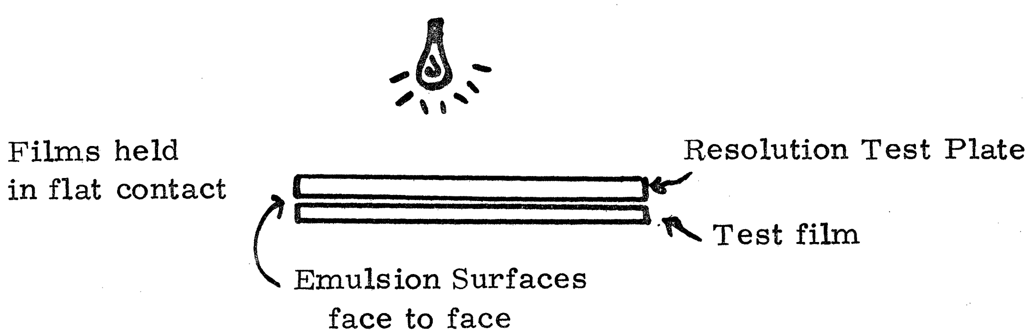


Figure 6-9. (Contact Printing)

After the contact print is made, then sensitometric development should follow. A suitable sensitometric development is outlined below in Table 6-1.

	Solution (68° F)	Time
1.	Fine grain developer	5 to 8 minutes
2.	Stop bath	15 to 30 seconds
3.	Fine grain fixer	2 to 4 minutes
4.	Wash	10 to 20 minutes

TABLE 6-1

Now to determine the resolution in lines/mm or line pair/mm, one uses a microdensitometer trace or a microscope. Briefly, a microdensitometer is an optical device that scans very small areas of a film and gives a graphic representation of the density variation. For simplicity we shall schematically represent a microdensitometer in Figure 6-10.

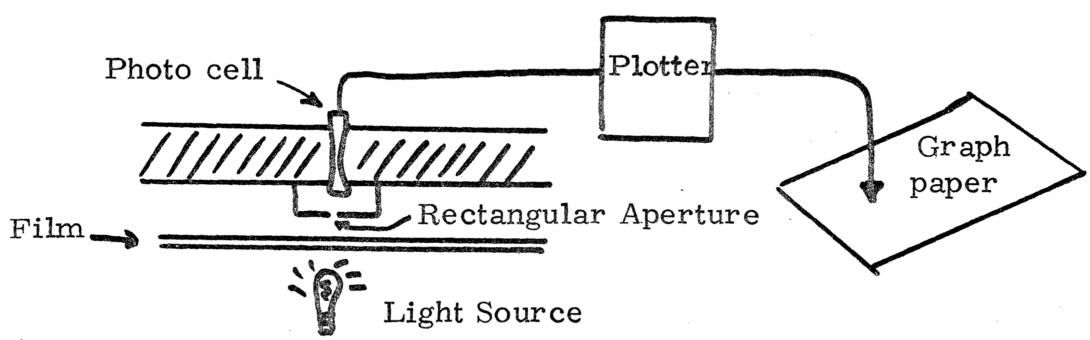


Figure 6-10. (Microdensitometer)

Film image passed by rectangular slit and the transmitted light is measured by a photocell. This optical signal is converted to a mechanical signal and a graph is drawn by the ink pen.

For example, the letter I could be scanned across the line width of the character and the graph would resemble Figure 6-11.

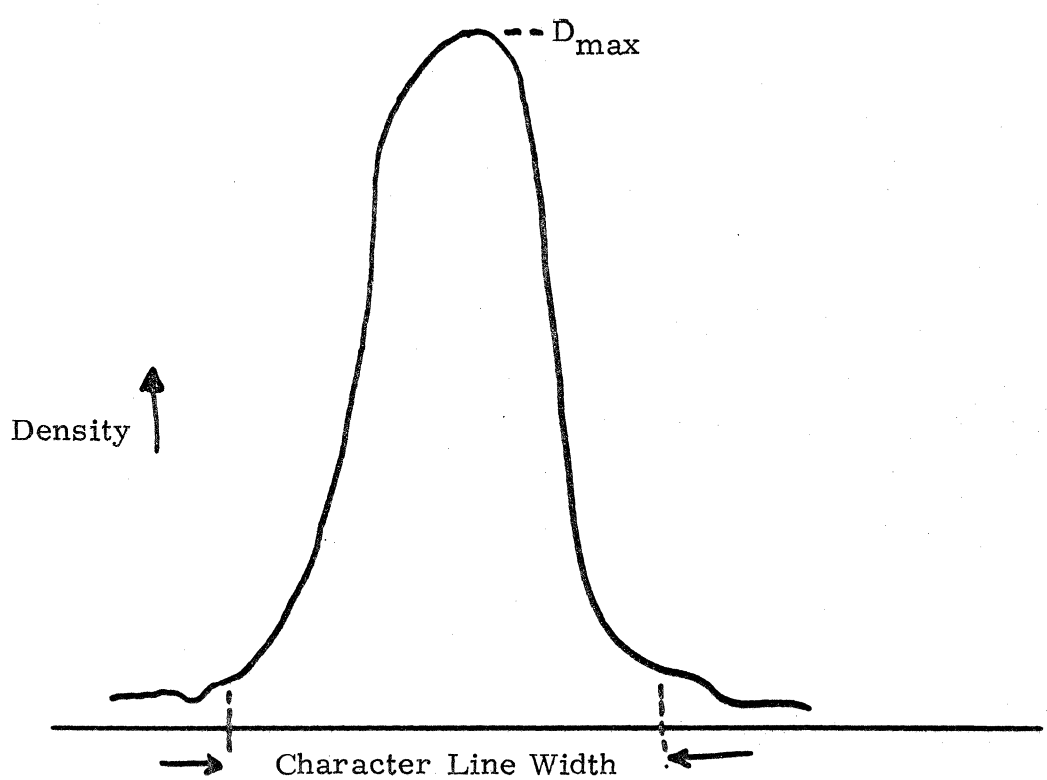


Figure 6-11. (Microdensitometer Trace)

If we wanted to see how much resolution was transferred during the contact printing, scan the smallest three bar target with a microdensitometer. The scan would look similar to Figure 6-12.

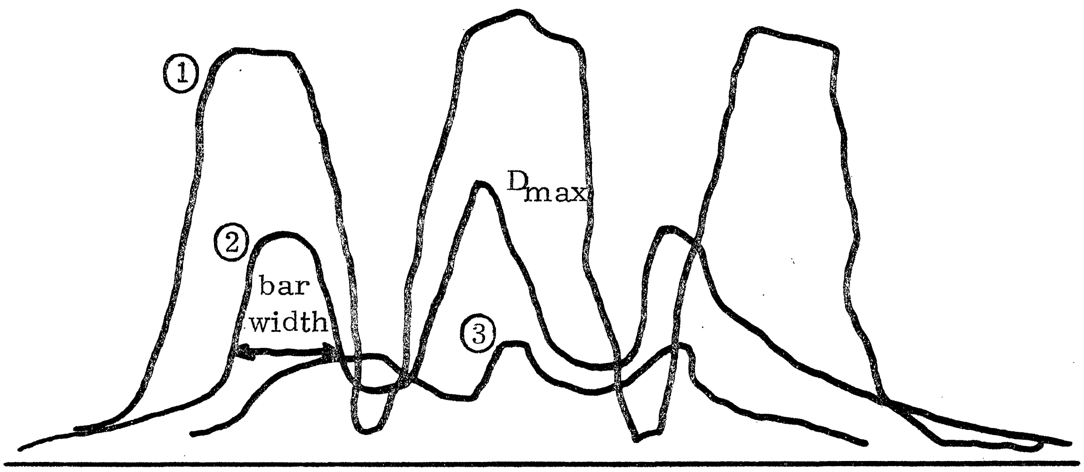


Figure 6-12. (Microdensitometer Trace of 3-Bar Target)

The amplitude of this scan appears to be smaller than the single line traces in Figure 6-12. If we superimposed several scans from the 3-bar targets, different size bars, we see that the difference between the big bar and small bar scans is one of amplitude and bar width. It is here we begin to see that specification of the resolution is somewhat ambiguous since the density is not taken into consideration. The two films shown in Figure 6-13 give the same resolution reading, but the microdensitometer trace indicates a higher contrast on one film. One with satisfactory density for viewing and one with unsatisfactory density.

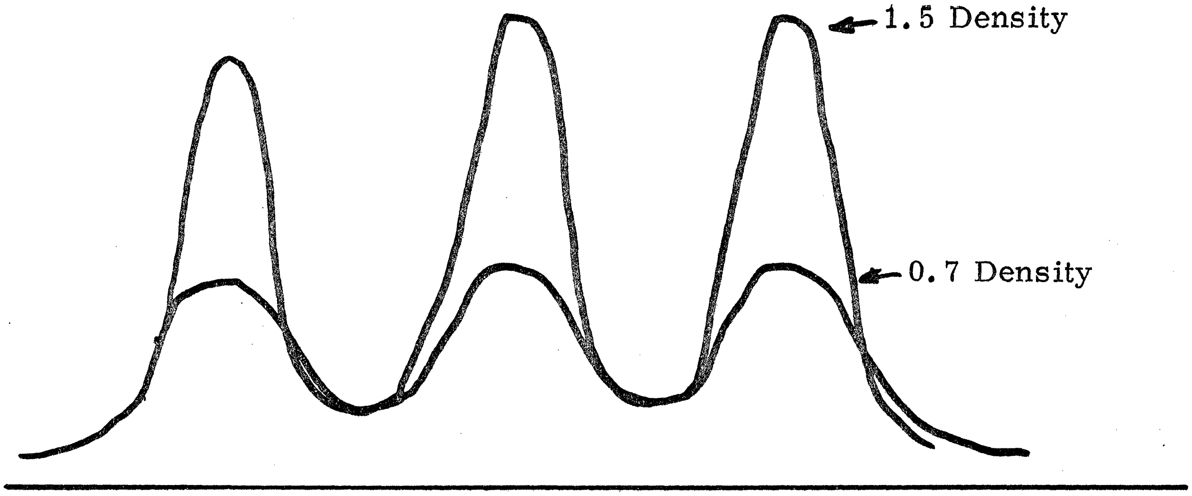


Figure 6-13. (3-Bar Trace)

The way to take this fact into account is to compute a modulation transfer function (MTF). The details of this calculation are not of immediate interest here, but a brief discussion of the graph of the MTF is educational.

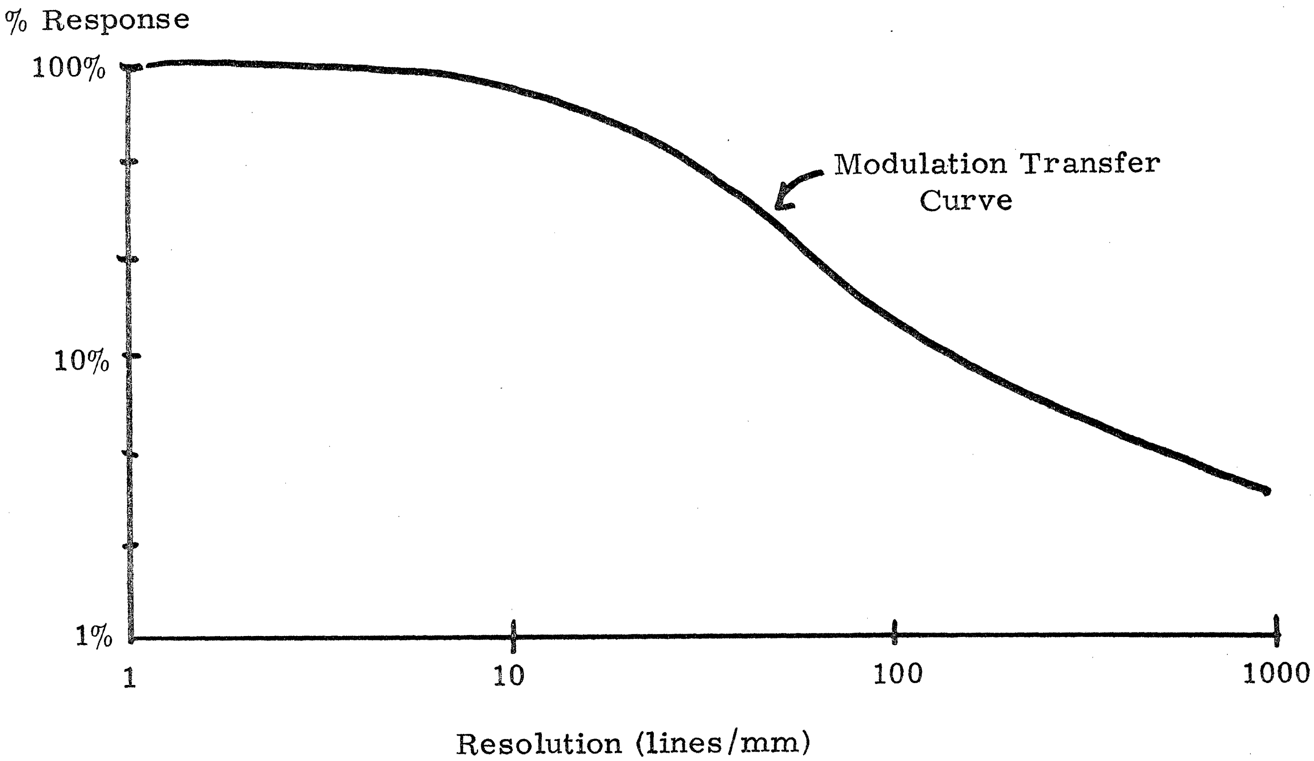


Figure 6-14. (M.T.F.)

The MTF is a measure of the amount of line density at a given resolution. The greater the difference between the maximum density at the peak and the minimum density in the trough, the more modulation exists. If we compare the modulation of the image with the modulation of the target, then a percentage response can easily be calculated. As the resolution gets higher, the modulation becomes smaller and until finally the modulation is imperceptable. When the modulation falls below 10% the image is usually not very legible.

Examining Figure 6-14, one sees 100% response for the film at low frequencies and a decrease in response as the number of lines/mm increases. Note that both scales are logarithmic.

A measure of character sharpness is called the acutance. Equation 6-3 gives the formula for the acutance, A_c, computed from an edge trace.

Equation 6-3
$$A_c = \frac{1}{n} \cdot \frac{\sum \left(\frac{\Delta D}{\Delta X}\right)^2}{D_{max} - D_{min}}$$

The acutance is measured from the microdensitometer trace of an edge exposure. It is found in practice that the acutance is highly correlated with edge sharpness. Edge sharpness is a measure of the slope from a microdensitometer trace. Given below are two traces -- one with high edge sharpness and one with a low edge sharpness.

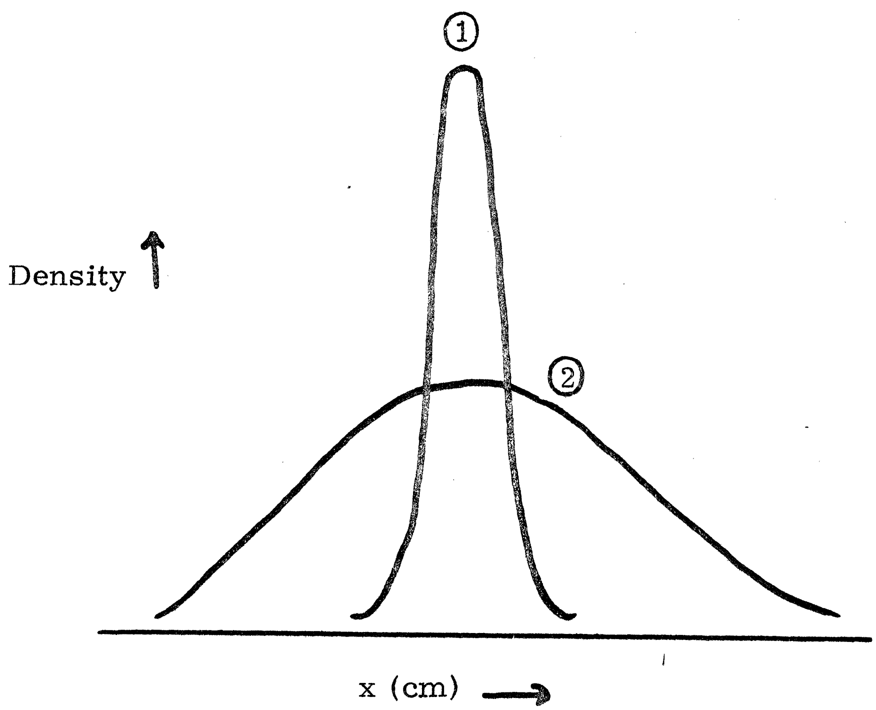


FIGURE 6-15. (Edge Sharpness)

To make a visual comparison of this difference, one uses a microscope and a camera to take a picture of the edge. Trace (1) would indicate a crisp well-defined edge, whereas Trace (2) would yield a slightly fuzzy area between the image and the background. The pictures taken through a microscope are commonly called photomicrographs.

6-6. USE OF THE D-LOG E CURVE

Let us turn our attention to the D-log E curves and some of the film parameters that vary with processing. Temperature has a pronounced effect upon the D-log E curve. Suppose we take some raw film and expose it on a sensitometer (a type of contact printer) to calibrated step wedge. A calibrated step wedge is represented below.

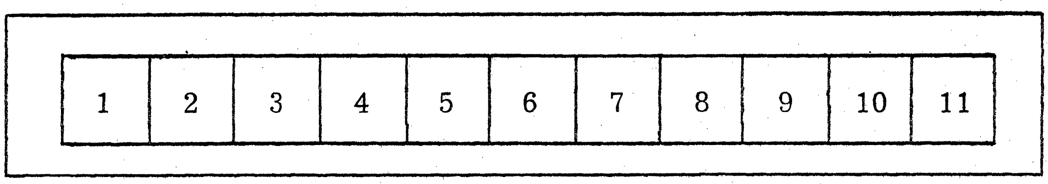


Figure 6-16. (Step Wedge)

Starting at Step 1, the density becomes greater according to the D-log E curve. When this wedge is contact printed onto the raw film, naturally the step density on the film is reversed since the denser steps from the target lets less light through to the image film.

Now take the exposed wedges and process them in the DatagraphiX 156 at 5 feet/minute and temperatures of 90° F, 100° F and 120° F. Shown below are the various wedges as processed at different temperatures.

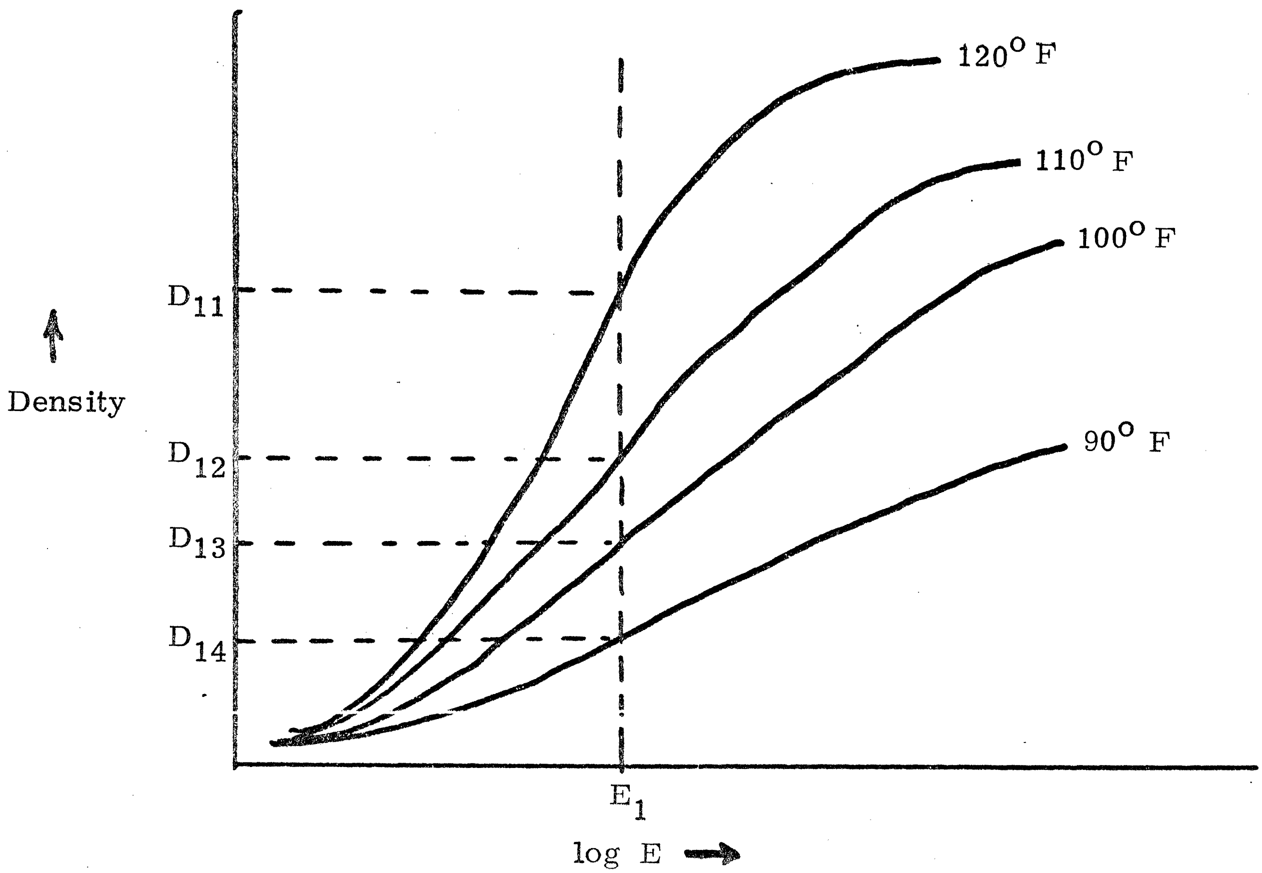


Figure 6-17. (D-Log E Curve Temperature Variation)

Clearly the curves have different gammas, latitudes, D_{max}'s, D_{min}'s, acutances, and speeds; in fact, the film shows an entirely different curve for each temperature of processing.

Compare the difference in densities between the curves. If the exposure El represented maximum exposure from the tube then the 90° process would not develop some of the minimum exposures because the corresponding density would be too small. When the same strip of film is processed at 120° F the developed density of the character is good, but the fog level or D-min starts increasing.

When making hardcopy, the ratio of the character density to fog, called the contrast ratio, must be as high as possible. This statement at first seemingly contradicts the remarks about latitude made earlier, but in fact does not. This requirement must be satisfied within the latitude requirement. So, since we are really limited by the latitude and therefore the D-max, any increase in fog decreases the contrast ratio and therefore the hardcopy quality. The next set of parameters we want to look at result from changing the processor speed. Without changing any other variables we can draw the family of D-log E curve, for speed changes. As we would guess,

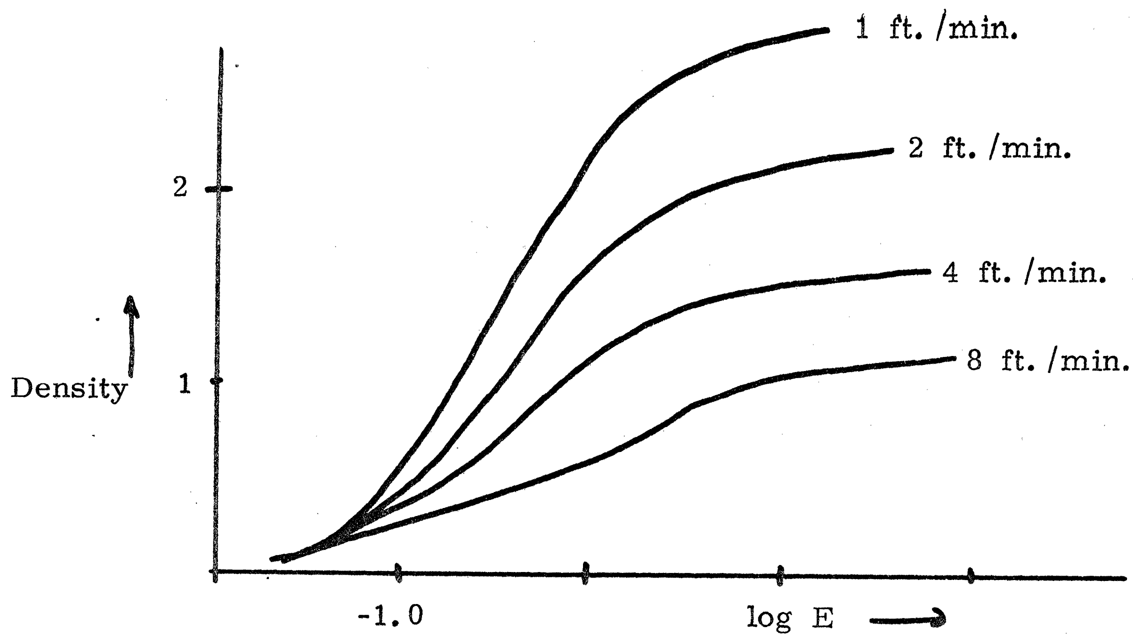


Figure 6-18. (D-Log E)

the amount of developed density increases as the temperature increases. We have now a family of curves that have the same restrictions as do the curves for temperature. The higher speeds naturally mean less time for the developer, fixer and wash solutions to diffuse into the emulsion. It is becoming clear that the film can not be developed at any temperature or speed. The accuracy with which one sets the machines determines which curve you are on and what type of quality you'll get. We shall draw one more family of curves to further illustrate the photographic requirements for quality film images. If one carelessly mixes the processing chemicals so that the solutions are not 3:1 as recommended, the family of curves shown in Figure 6-14 clearly indicates the problem. The same latitude, D-max, D-min, gamma and contrast ratio parameters will vary here as when you vary the temperature.

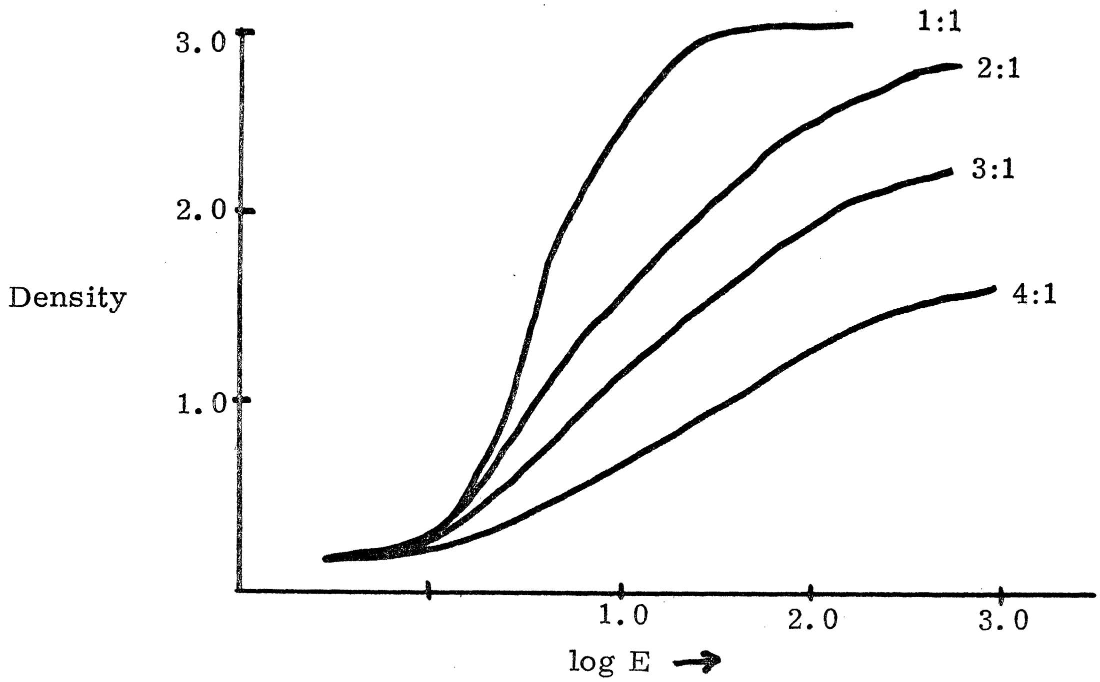


Figure 6-19. (D-Log E)

All photo-optical parameters must be set accurately to attain consistency and best image quality. Mentioned here are just the basic ideas behind the total system. The interpretation and use of these ideas is up to you.

Chart of Resolving Power Values for Individual Targets

USAF 1951

Group #	Target #	Resolving Power (lines per mm)	Group #	Target #	Resolving Power (lines per mm)
0	1	1.00	4	1	16.0
	2	1.12		2	17.9
	3	1.26		3	20.2
	4	1.41		4	22.6
	5	1.59		5	25.4
	6	1.78		6	28.5
1	1	2.00	5	1	32.0
	2	2.25		2	35.9
	3	2.52		3	40.3
	4	2.83		4	45.3
	5	3.18		5	50.8
	6	3.56		6	57.0
2	1	4.00	6	1	64.0
	2	4.49		2	71.8
	3	5.04		3	80.6
	4	5.66		4	90.5
	5	6.35		5	102
	6	7.13		6	114
3	1	8.00	7	1	128
Best quality	2	8.98		2	144
	3	10.1		3	161
	4	11.3		4	181
	5	12.7		5	203
	6	14.3		6	228

SECTION VII

FINAL EXAM

1. What is the primary reason that silver halide films are the only suitable type of films for generating a master from a COM unit?

2. What does the word halide refer to? Give an example.

3. A silver halide film can be on polyester or triacetate base. True or False?

4. What does halation mean?

5. The electrographic process utilizes:
   a. Wet toner
   b. Dry toner

6. Tinted base, AHU and dye back are all examples of halation protection. True or False?

7. Halation protection can occur between:
   a. Emulsion and base
   b. On back of film
   c. (a) and (b)

8. MMF has halation protection. True or False?

9. In addition to the base and emulsion, a silver film can have an anti-static layer and protective layer over the emulsion. True or False?

10. What is the base stock thickness of DatagraphiX silver film (MMF)?

11. A grounded equipment roller touching the paper surface:
    a. Decreases the positive and negative charge.
    b. Increases the net negative potential.
    c. Does not affect the charge.

12. What is the base material in MMF?

13. Exposure = ______ x _________. Briefly explain these two parameters in terms of the forms flash and the CRT.

14. What is the spectral range of an ortho chromatic film? Panchromatic film? Datacomatic film?

15. What is the spectral range of the P22B phosphor? Draw curve and label axis carefully.

16. Is it important that the spectral output of the P22B phosphor be matched to the spectral absorbance of the MMF film? Explain.

17. What is the spectral output of the light-emitting diode?

18. What mark does the light emitting diode put on film?

19. What is the spectral range of the Xenon on flash tube? Draw curve, label axis carefully.

20. Explain the beam-splitter (pellicule, membrane) in the 4360 and 4440 in terms of wavelengths transmitted and wavelengths reflected. Draw diagram.

21. The loss of the positive corona charge:
    a. Will affect the print image.
    b. Will not affect the print image.

22. Explain beam-splitter on 4060. Draw diagram.

23. Humidity (relative) affects the charge potential. True - False? Explain.

24. If one changed a lens setting from 4.0 to 5.6, what would be the intensity of the light at 5.6 relative to 4.0?

    In terms of Log E, what is the corresponding change in exposure? Give a number!

25. Which lens opening would yield more light to the film, 2.8 or 4.0?

26. What is the optimum setting of the aperture for a U.C. lens considering only the manufacturing specifications?

27. Using a diagram show the effect of aperture change on the depth of focus.

28. Any paper may be used in the electrographic process used in the 3500. True - False (explain)

29. What does AHU mean?

30. The print image can be changed from a positive image sign to a negative image sign by reversing the corona charge wires. True - False? (Explain)

31. What does Rem-jet mean?

32. What is the purpose of collimating a mainframe? Use diagrams to explain.

33. Lenses should be repaired in the field? True or False?

34. A 25X lens marking means 25X reduction in image size from the tube face to the silver film. True or False?

35. If a character was .025" high on the tube face, what would be its height on film for a 9.46X lens? A 5.86 lens? Show calculation in detail.

36. For a 10X lens, if the distance from the lens to the film is 1", what is the distance from the lens to the tube face? To the form slide? Assume tube and forms flash in good focus. Show calculation.

37. Using the USAF 3-bar target and a 9.46X lens, what is the resolution on film if you can see the 3.6 set of lines? Show calculations.

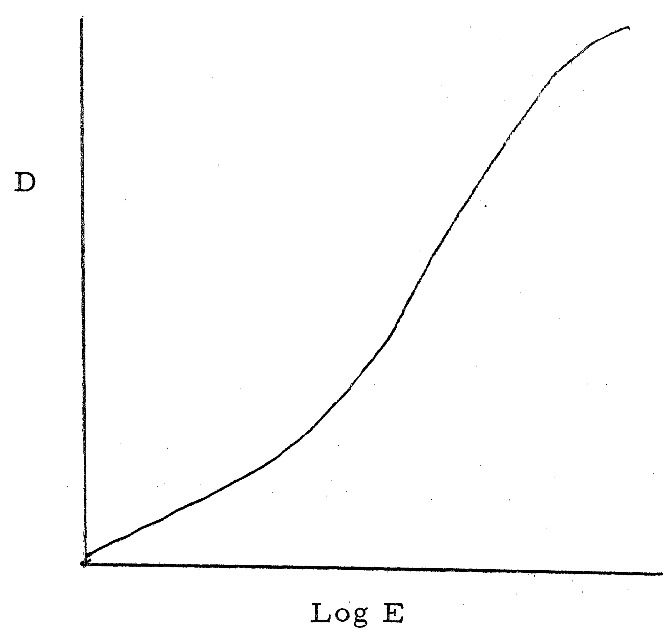
38. Nodes (deposits on corona wire) cause print data to be obliterated. True - False?

39. What is minimum specification for film resolution on the 4360?

40. Would you expect the same resolution in the corners of the frame as in the center? Explain.

41. Would you expect the same density on film from a character in the center of a frame compared to a character in one of the corners? Explain.

42. Using the D-log E curve drawn below, indicate the exposure latitude for a density range of 0.8 to 1.2



43. What is the value of gamma in the above curve? Show calculation.

44. If answer to 38 is true, explain phenomenon by graph. If answer to 38 is false, explain.

45. Draw an H&D (D-Log E, characteristics curve) and clearly indicate the following parameters:

    (1) Fog
    (2) D-Max
    (3) Speed at 1.0 above fog
    (4) Total exposure latitude
    (5) Gamma
    (6) Toe
    (7) Shoulder

46. In terms of a D-Log E curve, what would over development do to the shape of the curve? What would the film ima ge look like for negative processing?

47. Give the processing steps required for the following types of processing. Indicate DX processor.

    a. Standard or negative
    b. Partial reversal
    c. Full reversal
    d. Stabilization

48. Give five reasons why replenishment is necessary in the 156 processor.

49. Ghosting of the image is caused by:

    a. Double exposure
    b. Wet prints
    c. Dirty rollers
    d. Weak corona charger
    e. A&C, B&C, A&D, A, B & C, none of them

50. There is replenishment in the stabilization process in the DatagraphiX True or False? If true, what is rate for 35 mm film?

51. What process should be used for 16mm film if one desires a silver film with a clear line and black background?

52. What duplication process should be used if one wanted to retain the image polarity in question 51? Which one if reversing the polarity is required?

53. Image fall-off - weak date in a corner or one side is caused by:

 a. Improper illumination
 b. Improper charge
 c. Poor original
 d. None of these
 e. All of these

54. If a white stain is observed in the background of a negative processed COM silver film, what would be the problem?

55. If you had a 5 quart bottle of chemical concentrate and someone asked you to mix it 7:1, how much working solution would you have? Show calculations in detail.

56. How many chemical changes are allowed on the 156 before a recommended cleaning of processor?

57. Add acid to water when mixing. True or False?

58. The fixer has a PH (greater, less than) 7.0. The developer has a PH (greater, less than 7.0). An acid has a PH (greater, less than 7.0)?

59. Bleach is a very strong acid and rubber gloves and apron should be used when mixing. True or False?

60. Draw a diagram of the cross section of a vesicular film. Label the layers.

61. Using the type of drawing in answer 60, show a sequence of steps for exposure, development, clearing. Provide brief description of the process in each case.

62. The toner is comprised of:

    a. A carrier and carbon particles
    b. A carrier and plastic particles
    c. A colored solution

63. It is desirable to develop a vesicular film as soon after exposure as possible. True or False?

64. Draw the D-log E curve for a typical silver step wedge. If this wedge is exposed on to a vesicular film, draw the corresponding curve on the same graph indicating how each silver density corresponds to a vesicular density.

65. If the toner particles are negatively charged, the paper surface must be positively charged to obtain a print. True or False?

66. How does one process diazo film? What is the mechanism of image formation?

67. What does archival film mean? Does the 156 produce archival film when it is running properly?

68. In the direct image process, the toner particles are:

    a. Repelled by the near Zero potential charge
    b. Attracted by the near Zero potential charge

69. Is there a difference between the method used to measure vesicular density and silver density? If yes, what is the basic difference?

70. What color is HS Xidex film?

71. What color is type 16 Kalvar film?

72. What color is HD Xidex film?

73. What color is type 10 Kalvar film?

74. If a vesicular film is not completely fixed, what would have to be done to complete the fixing?

75. Previously processed paper can be recharged and reprocessed. True or False?

76. If a poorly cleared vesicular film is put in a hot viewer, could the image be degraded? If yes, explain.

77. Draw a picture of a static discharge exposure on a strip of film.

78. Is there disadvantage in using polyester base film to acetate base when there are static problems in the camera? Explain.

79. Excessive film curl can result from too high a temperature in the dryer. True or False?

80. If a character had a density of .85 and a fog or background density of .095, what is the contrast ratio? Show calculations.

81. In silver films the developed silver image absorbs light and heat. In vesicular films is this true? Explain.

82. The coated paper used in the 3500 must not be exposed to any light before processing. True or False?

83. Hypo is often substituted for thiosulfate. True or False?

84. A standard microfilm image polarity will be opposite to a COM image if both are processed in the same way. True or False?

85. If the diameter of the development drum on a DatagraphiX 94 is 4" and the development time required is .25 or 1/4 of a second, what is the maximum speed that can be run for proper development? Show all work.

86. If the shutter is set at 5 for run 1 and for run 2, it has been determined that twice as much light is needed, what is the new shutter setting?

87. What is the optimum background density for vesicular film?

88. What is the relationship between vesicular film density and development temperature? Draw graph and label axes.

89. A processed print must be subject to heat to fuse the image. True or False?

90. What is the spectral output of the mercury vapor lamp? __________ Å

91. What is the ratio of 1 millimicron to 1 nanometer?

$$1\ \mathrm{M} = 10^{-4}\ \mathrm{cm}$$
$$1\ \text{nanometer} = 10^{-9}\ \text{meters}$$
$$1\ \mathrm{cm} = 10^{-2}\ \text{meters}$$

92. Is vesicular film sensitive to normal room light? If yes, explain.

92. The black pressure marks made by the feed rollers are caused by:

a. Removal of the zinc oxide, causing a very low negative charge.
b. By grounding prior to charging.
c. By causing a static charge prior to charging in the corona.

93. Is development time critical on diazo. If no, explain.

94. What is the upper temperature limitation when developing vesicular film for one second?

95. Silver film can be used as a duplicate film. True or False?

96. In your own words describe sharpness using the D-log E curve to illustrate the density differences. Use other graphs if necessary.

97. The negative charge should be at least:

a. 400 volts more than the positive.
b. 180 volts more than the positive.
c. 500 volts more than the positive.
d. 300 volts more than the positive.
e. None of these. Should be _______ volts more.

98. At 5 ft./min. transport speed what is the actual time in developer in the 156 processor? __________ seconds.

99. A sensitometer is used to measure image density. True or False?

100. Reversal processing doesn't give as much resolution as negative processing. True or False?

101. Where is a high gamma film useful. Give good example.

102. Where is a low gamma film useful?

103. The silver master has a focused light leak on every frame of a fiche. In what general area would you look for the problem?

104. The customer is complaining about uneven density on the silver master, where would you first look for the cause?

105. Toner concentrate is:

a. A special mixture.
b. A concentrated solution of the starter kit toner.

106. Every fifteen frames of a 16 mm duplicate copy a frame is found to have a blacked out portion of data. What is the probable cause if the silver master is good?

107. The customer is complaining about loss of density during the entire day of operation. Where would you look first for the answer?

108. An out of focus condition is reported on the DatagraphiX 92. Upon examination you find the silver master to be good. What two items would you check first?

109. What surface of a first surface mirror do you place against the film rollers during a collimation alignment?

110. Starter toner can be made by adding a quantity of diluent to a bottle of concentrate. True or False?

111. What is collimation?

112. What effect, if any, will processor speed have on D-max?

113. What is the allowable distance of misalignment for the camera mount after collimation? ________ Degrees, ____ _ Minutes, _______ Seconds.

114. If a customer complains about light leaks that look like lightening bolts, what is normally the cause?

115. On a fiche the image from the tube will not match the form flash image across the fiche. Both edges will not match and the center is good. What is the probable cause?

116. If answer to 110 is true, state ratio to be used.

117. A light leak on the edge of the film could have been caused by? Name three different causes.

118. The resolution figure has been determined to be 60 line pairs using good test methods and test equipment. What could you adjust to help increase this reading?

119. Will the numerical factor from resolution chart table for a 10X lens be higher or lower than a 6X lens if resolution on both is 86 line pairs?

120. Toner shelf life is:

a. Two months
b. One year
c. Six months
d. None of these. It is ___________

121. What handling and storage precautions should be taken with silver film prior to exposure?

122. How do you correct keystoning?

123. The system should be cleared and flushed with diluent:

a. Every month
b. Once a week
c. Every three months
d. Never
d. None of these. Every ___________

124. Give the legibility ratings and explain the relationship to resolution.

125. What does the ISO character look like? How is it commonly used?

126. A microdensitometer measures small images and a typical trace of a letter, say I, would look like:
(indicate character width and maximum character density)

127. Light photo-activates the zinc oxide coating on the paper, converting the surface charge to the opposite potential. True or False?