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TASK ORDER NO. 03(100,762)65-R

# ELECTROPHOTOGRAPHIC PROCESSING TECHNIQUES

FIRST INTERIM TECHNICAL REPORT

Prepared for

THE U.S. GOVERNMENT

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Issued: December 16, 1965

Approved For Release 2004/08/25 : CIA-RDP78B04770A000600010015-0

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# PREFACE

This is the first of a series of interim technical reports on a study of electrophotographic processing techniques. This twelve-month study comprises the investigation and development of photographic and electronic techniques for processing photographic images. This report covers the work performed by the [redacted] during the period from June 22 to October 22, 1965.

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The principal authors of this report are: [redacted]

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# SECTION I

# INTRODUCTION

The current investigation of Electrophotographic Processing Techniques (EPT) is one of three related Programs to Improve Photographic Image Perceptibility in which the [redacted] is engaged. The other two are:



(1) A Prototype Modulated-Light Film Viewing Tables development program, which covers the development and delivery of two viewing tables. With this equipment, photographic transparencies will be illuminated by a fast-moving spot of light whose intensity will be automatically varied to effect large-area contrast compression. The design of these tables is based upon a breadboard modulated-light film viewer which was built under a previous contract. The feasibility of various modulated-light source and pickup techniques was demonstrated in this prior program.

(2) A Spatial Frequency Analyzer study which covers the breadboard development and feasibility demonstration of a photographic image spatial frequency analyzer. The high-resolution electronic image processing equipment being developed for the EPT investigation will be modified for use with an electronic frequency spectrum analyzer to provide records of the spatial frequency contents of photographic images. Feasibility demonstrations, technique evaluations, and equipment development recommendations are included in the program tasks.

The EPT program covers the investigation, development, and evaluation of electrical-chemical and electronic techniques for processing photographic images to improve their perceptibility to human observers. The key to electrical-chemical processing will be the control of acutance and granularity in processed transparencies by (1) adjustment of density thresholds, (2) expansion and contraction of density variations, and (3) variation of the illuminating spot from a modulated-light (cathode-ray tube) printing source. The key to electronic processing, analogous to electrical-chemical processing, will be separate and simultaneous operation on the high- and low-frequency information in photographic images and the employment of a high-resolution kinescope as a modulated-light printing source.



Prior to the start of this EPT investigation, preliminary study and experimentation under [redacted] sponsorship had resulted in the demonstrated feasibility of certain electrical-chemical image processing or correcting (deblurring) techniques. Improved Ranger, Nimbus, TIROS, and lunar telescopic photographs had been obtained by careful and selective modification of image densities and by programmed operation of a commercial modulated-light (cathode-ray tube) printing source.

Additional study had shown that the development of electronic techniques could lead to a significant reduction in the number of image processing steps required in electrical-chemical processing and therefore correspondingly reduce the time for final improved image perception. Electronic equipment constructed by [redacted] and other activities had successfully utilized flying-spot scanners and specially designed circuits (e.g., filters, thresholders, limiters, and amplifiers) to enhance the properties of photographic images. Immediate and variable edge enhancement is an example of what has been achieved with electronic image processing. STAT

An important element common to both the proposed electrical-chemical and electronic image processing systems was a modulated-light printing source. Although the performance specifications (and therefore the actual components) of the source would differ from system to system, each set of techniques would include the final exposure of a transparency by modulated-light from a cathode-ray tube. The feasibility of various modulated-light techniques, including isotropic beam scan, remote photomultiplier pickup, and negative feedback operation, had been demonstrated for the previously cited Government-sponsored study of modulated-light film viewing systems.

The objective of the EPT program is to further the development of both electrical-chemical and electronic techniques for processing photographic images to improve their perceptibility to human observers. These techniques are expected to be compatible with the additional goal of eventually developing high-speed high-capacity processing equipment. Although the program is principally experimental in nature, an orderly schedule of study, testing, and analysis is being pursued to achieve the stated objective.

The program plan is divided into and discussed under two sub-headings: Electrical-Chemical Processing Techniques, emphasizing chemical manipulations of image densities, and Electronic Processing Techniques, stressing electronic operations on photographic images. These two areas are interrelated and a constant interchange of analytical and experimental results is maintained between the two approaches. By way of emphasizing this point, Section II of this report discusses electrophotographic image processing techniques in the context of a common, simplified theory of image processing. Sections III and IV discuss Electrical-Chemical and Electronic Processing Techniques, respectively.

# SECTION II

# TECHNICAL DISCUSSION OF IMAGE PROCESSING TECHNIQUES

The purpose of this section is to discuss electrophotographic image processing techniques in the context of a simplified theory of image processing. A conceptual model of processed imagery systems serves as a base for the discussion.

## A. PROCESSED IMAGERY SYSTEMS

A general representation of processed imagery systems is given by Figure 1. The model incorporates six basic transducers: a sensor, a processor, a human, a translator, a processor controller, and a sensor controller. The purpose of the sensor is to detect (observe) and record the object to be imaged. The output of the sensor is the original image, e.g., a photographic transparency. The sensor may be a photographic or electronic camera.

The purpose of the processor is to convert the original image (transparency) into a processed image for display to a human interpreter. The processor is generally a multi-process device employing combinations of chemical, electronic, and optical techniques. Typical processors are contact printers, electronic viewers, and rear-view projectors.

The human who constitutes the final element in the image system, converts the processed image into a perceived image. The inputs to the human are the original image, the processed image, and psychophysiological factors that include the environmental conditions affecting the photo-interpreter.

A preliminary function of the human is the generation of image criteria, i.e., criteria leading to improved processor and sensor operation and/or design. For example, a photo-interpreter may view an initially processed image and decide that edge-sharpness will improve his ability to perceive some detail in the transparency. This information would then be fed back to the processor to produce a more desirable display.

Since the image criteria generated by the human are often not expressed in conventional technological terms, a translator is included in the model to convert these criteria into image data that, in turn, serve as inputs to the processor and sensor controllers, respectively. The function of each controller is to supply control, as required, for the respective transducer.

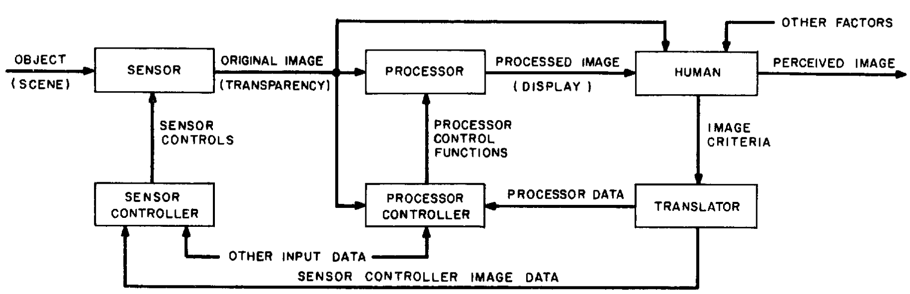



Figure 1. General Representation of Processed Imagery Systems

## B. IMAGE PROCESSING TECHNIQUES

The information content in any given photograph cannot be increased by any operation in which only the information in that photograph is available. However, this information can be processed in viewing or in reproduction to make it more accessible to the interpreter, so that he can work more accurately and more rapidly. For example, the contrast steps in detail may be too small for perception by the eye, but may have sufficient signal-to-noise content so that a stretch in constrast permits perception.

Certain basic principles underlie systems of useful processing, including the electrical-chemical system and the electronic system which are being developed in this program. These principles can be incorporated into an analytic model which is being developed, and which should provide guidance for the direction of the experimental programs.

The model is at present in a preliminary state. It will become more complete and refined as the work progresses. It is clear, however, even at this early stage, that a system for improving the visibility of detail, as shown in Figure 2, includes the following operations:

(1) An image signal is generated that yields a point-by-point measure of the density content of the original image.

(2) Background brightness information, i.e., low (spatial) frequency contrast, is suppressed in this signal.

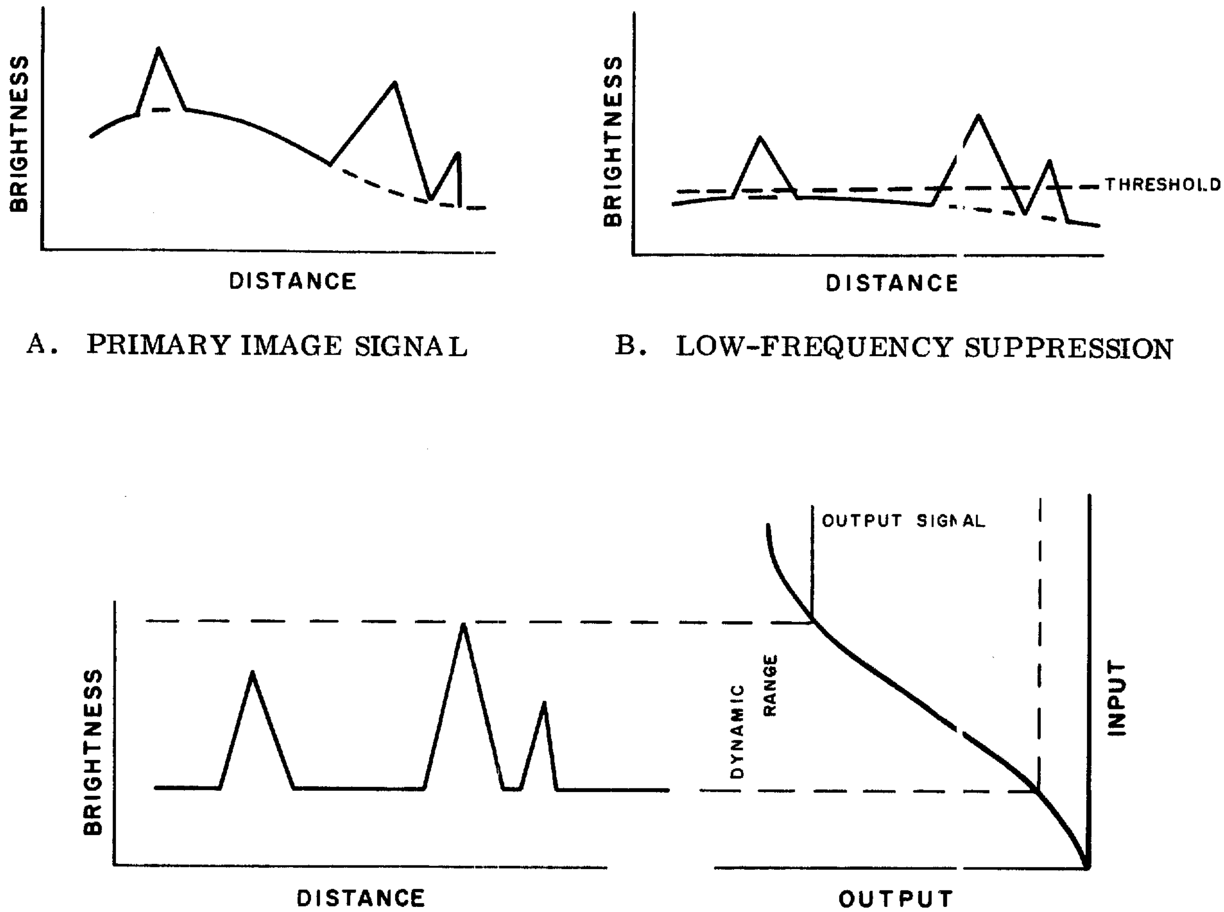
(3) A brightness threshold is applied to the modified signal. (This brightness threshold may be the toe in the D-LogE curve of the reproducing film.)

(4) The new signal is amplified.

(5) A bias level is applied.

(6) The resulting signal is amplified and reproduced or displayed (as a processed image).

In electrical-chemical processing systems, many of the above functions are not performed in real time; delays may be excessive. Electronic processing techniques, however, may ultimately lead to the expected improved image output, in what may approach real time. A brief description of the electronic techniques for providing the above functions is given in the paragraphs that follow.




A. PRIMARY IMAGE SIGNAL

B. LOW-FREQUENCY SUPPRESSION

C. PRE-AMPLIFICATION AND BIAS

D. FINAL AMPLIFIER

Figure 2. Image Processing Steps

Assume that the image to be processed is given by a photographic transparency. A common technique for generating the image signal involves photocell detection of light transmitted by the transparency. The light source may be a cathode-ray tube. The photocell output is a voltage analog of the brightness distribution in the original image.

Suppression of background brightness information or low (spatial) frequency contrast is achieved by unsharp negative masking (also called automatic dodging) techniques. A combination of modulation transfer curves can be used to illustrate how negative masking operates to reduce low-frequency contrast. Figure 3 shows the modulation transfer curve* of the original transparency and the modulation

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* Contrast as a function of image size or spatial frequency.

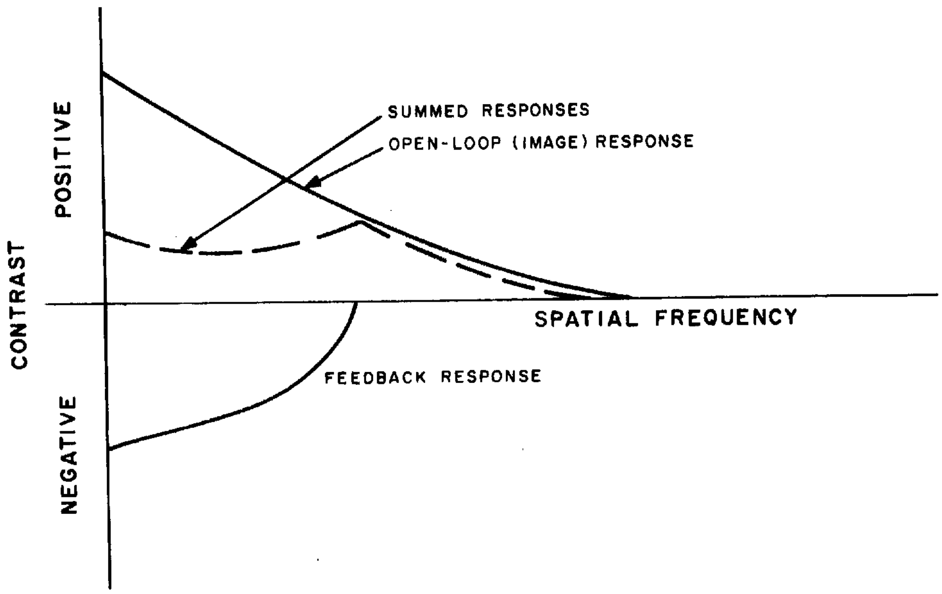


Figure 3. Modulation Transfer Function as it Applies to Low-Frequency Suppression

transfer curve of the masking image, which is subtracted (fed-back negatively) in the reproduction (or display) process. The masking signal may, for example, be implemented by a defocussed cathode-ray tube beam. Unsharp negative masking signals have less contrast and lower cut-off frequencies than do their original image signals.

By cascading the masking modulation transfer function with that of the original image, low-frequency contrast is reduced without affecting the high frequencies. Thus, low-frequency suppression yields a flatter response with a relative increase of high-frequency information. Obviously great operating flexibility can be achieved with a feedback response whose amplitude and cutoff frequency can be varied. These properties can, for example, be exhibited by a cathode-ray tube beam with variable spot size. Figure 3 actually illustrates a case in which the modulation transfer function has been modified across a substantial part of the spatial frequency spectrum.

Following the suppression of low-frequency contrast, a brightness threshold may be applied to the signal. As can be seen in Figure 2, detail information which had been "riding" above various background brightness levels (View A) now "sits" on top of a nearly constant brightness level (View B). Thresholding (View B) then acts to pass only this detail information through the rest of the system. It should be apparent (from View A) that thresholding cannot precede suppression of the low frequencies.

In a proper system design, the brightness threshold, preamplifier, and bias level cooperate to make full use of the dynamic range of the final amplifier. The transfer characteristic of the final amplifier, which influences the design and operation of the other processing system elements, provides the output signal or processed image. When the final amplifier is photographic copy film, the transfer characteristic of the final amplifier is the film's D-LogE curve.



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## SECTION III

## ELECTRICAL-CHEMICAL PROCESSING TECHNIQUES

### A. GENERAL

The Electrical-Chemical Processing Techniques portion of this program is directed toward the further development of essentially photographic techniques for processing photographic images that will lead to improved perceptibility by human observers. Some of these techniques were applied in a limited way to specific images; the current efforts are concerned with a more general approach to processing photographic images.

The Electrical-Chemical Processing Techniques portion of the EPT program comprises the following tasks, some of which have been performed during this reporting period:

#### 1. Equipment Procurement and Calibration (Task 1)

Special test equipment required to perform the electrical-chemical processing experiments has been specified and ordered. Following delivery and installation, these items were calibrated to ensure consistency of experimental results and to relate properly the findings to other efforts.

#### 2. Film Evaluation and Selection (Task 2)

Materials required to perform the electrical-chemical processing experiments have been specified and ordered. Photographic films of many types have been evaluated for their properties, in order to select films which are compatible with the system requirements.

#### 3. Breadboard Modulated-Light Contact Printer Development (Task 3)

A high performance modulated-light contact printer has been designed for use in the electrical-chemical processing experiments. The design objective for the (light) spot size at the front surface of the transparency is one millimeter. Based upon this design, printer components (cathode-ray tube, lenses, etc.) were specified and breadboard construction was accomplished. Checkout and calibration of the experimental printer will be completed in the electrical-chemical processing laboratory.

4. Transparency Investigation (Task 4)

Government-supplied transparencies (scenes) will be analyzed in terms of density distribution, image shape and structure, resolution, and detail spacing. This data will then aid in the design and operation of the processing controls. In addition, the fabrication of experimental samples and the utilization of controlled test samples (GEMS, Edge-GEMS, etc.) will be investigated for application to the current efforts.

5. Processing Experiments (Task 5)

Upon completion of system checkout and calibration, film evaluation and selection, and the preliminary transparency investigation, processing experiments will begin. The general effectiveness and utility of the proposed photographic techniques will be determined. Modifications of the test procedures and/or equipment will be based upon the results of initial tests with simple transparencies. Further study and evaluation of these and other electrical-chemical processing techniques will be reflected in continuing experiments.

6. Techniques Study and Evaluation (Task 6)

The state-of-the-art of electrical-chemical processing techniques will be reviewed in light of the current program objectives. The breadboard equipment and proposed modifications thereto will be analyzed to predict expected performance and future capabilities. The results of processing experiments, as evaluated

STAT by [redacted] and Government personnel, will be reviewed for agreement with theoretical predictions. Finally, recommendations for future efforts in this area will be made.

B. TECHNICAL APPROACH

1. Statement of the Problem

In this branch of the program, the objectives of enhancing image perceptibility by increasing contrast where it is required and improving acuteness are to be implemented by manipulation of the density relationships in the copy transparency. Part of the density manipulation will be accomplished by copying with the modulated-light contact printer, with which negative masking at spatial frequencies to about one cycle per millimeter will be achieved. Further operations involve the resetting of increments in the density scale in copying and processing procedures which do not rely on the use of modulated light.

The transformation of the density scale will critically depend on the properties of the materials which are to be used. Calibration is therefore required for the film materials, with respect to the spectral content of the light sources used in measuring and replication equipment, chemicals, processing time, and processing temperature.

## 2. Program Plan

The program plan therefore includes a preliminary phase dealing with the systematic calibration of equipment and materials, so that reproducibility and repeatability of density ratios and density ranges may be achieved. When this phase is completed, the processing of transparencies will be undertaken. The program plan is detailed below.

### a. Calibration Plan

The calibration plan is diagrammed in Figure 4. The step standards will be measured for density and transmittance characteristics and will be copied onto various types of film. Each of the copies will then, in turn, be measured for density and transmittance characteristics. Since the light source in each piece of replication equipment varies in spectral response, each copy film will be measured along with each step standard against each piece of replication equipment.

Each copy film and each step standard will be calibrated in terms of illumination intensity and time in exposure. Chemical processing will be investigated in terms of various chemicals, processing times, and processing temperatures, exercising one variable at a time.

### b. Processing Program Plan

The processing program plan is diagrammed in Figure 5. The input transparency will be measured for film-response characteristics by means of a microdensitometer. Then on the isodensitracer, density distribution will be mapped. This film will next be placed on a transparency viewer, and transmittance measurements will be obtained by means of a microscope photometer. The characteristics of the input image will thus have been determined.

Prior to the replication cycle, standard density/resolution targets will be reproduced on various types of film and modified as required. Both the standards and the modified copies of the standards will be measured for density and transmittance characteristics in the same manner that the input transparencies are measured.

Following analysis of both the input film and the modified copies of the standards, the replication program will be undertaken. This part of the program is intended to provide a range of transparencies at different density ratios at several density levels as a function of image characteristics. The output of the replication cycle will be measured for density and transmittance characteristics. The results of these measurements will be compared with the results of the initial measurements to ascertain what physical improvement has been achieved. Further the output transparencies will be compared by skilled interpreters with the input transparencies for their operational value.

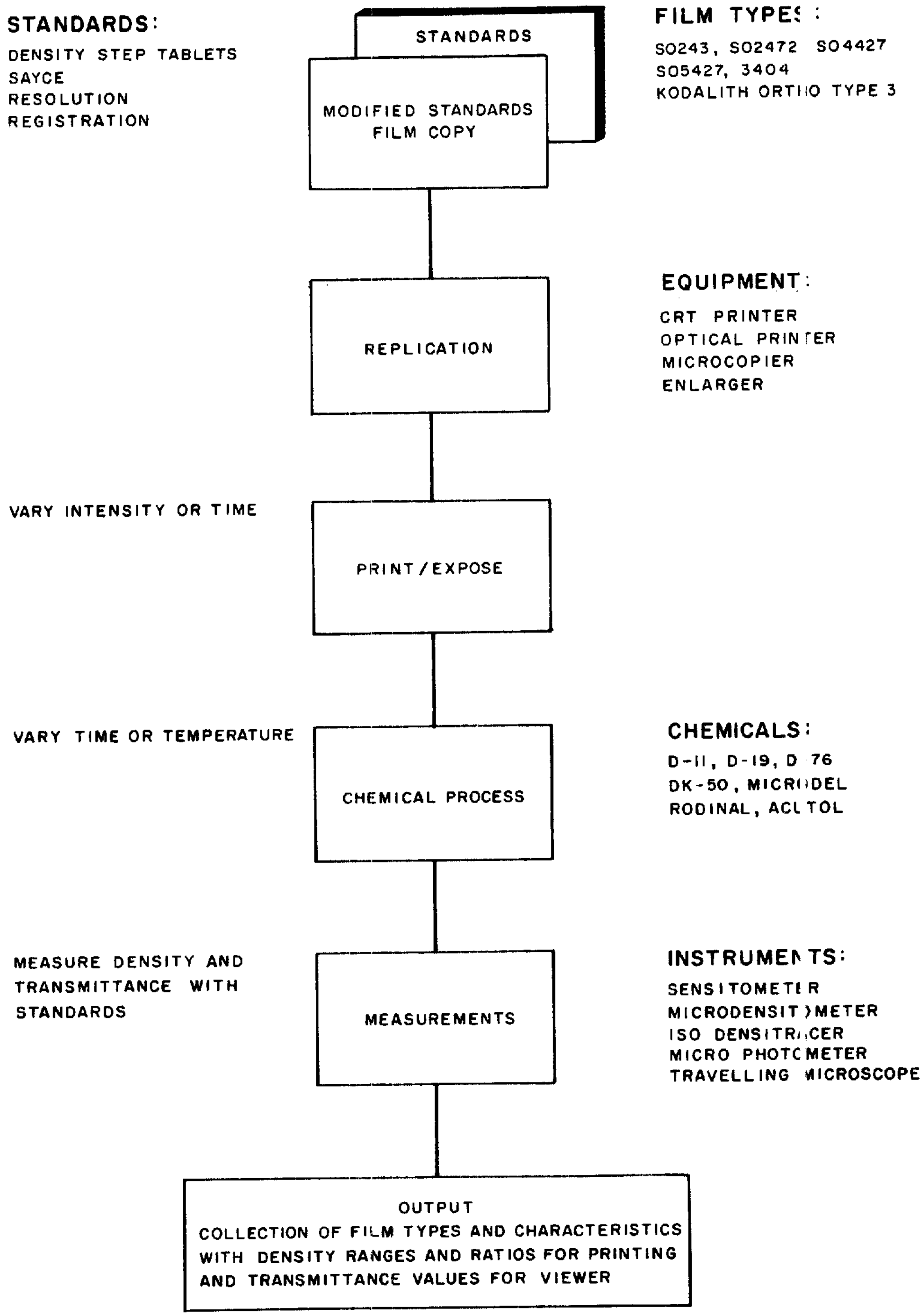


Figure 4. Experiments Measurements Plan



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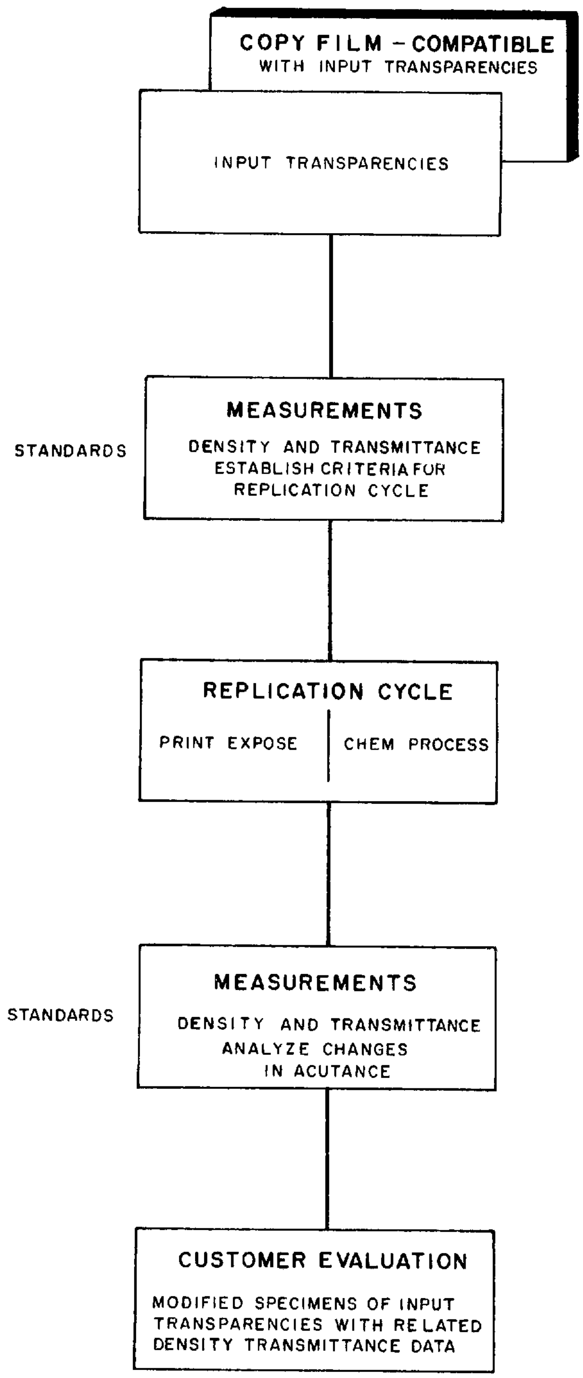


Figure 5. Acutance Experiment Plan

## C. MATERIALS AND EQUIPMENT

The working area of about 760 square feet is divided into two rooms, each with provisions for light tightness and ventilation. It is a complete self-contained photo techniques laboratory.

In one room, shown in Figure 6, the controlled film processing experiments are performed using nitrogen-burst agitation and time-temperature controls. A micron retention water filtration system is used to preclude the deposit of contaminants on the photographic films.

The second room, shown in Figure 7, is used for photo-replication and physical measurements. The photo-replication equipment consists of an [redacted] breadboard intensity modulated cathode-ray tube printer, [redacted] optical printer, [redacted] microprinter, and a modified [redacted] enlarger. Measurement instruments include a [redacted] microdensitometer, which can be used with a Tech/Ops isodensitracer; traveling microscope; and a Gamma scientific photometric microscope, to be used with a [redacted] transparency viewer. By the reporting date it is expected that all equipment processed will be in use with the exception of the modulated-light contact printer. The design and development effort on this piece of equipment is described in Paragraph E of this section.

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Individual equipments have been calibrated and the capability for repeatability has been established. A measurements program is beginning to build up in that procedures and modes of operation are being developed with non-imaging type standards. Step tablets are being converted to relative standards for use in the measurements program. Consequently, the photo-techniques laboratory has reached the stage of making meaningful measurements and determining how to effectively use the precise measuring equipments to verify the procedures laid out in the plan. The capability for applying precisely all the equipments and instruments to the measurements and acutance experiments program is in the order of 85 percent complete.

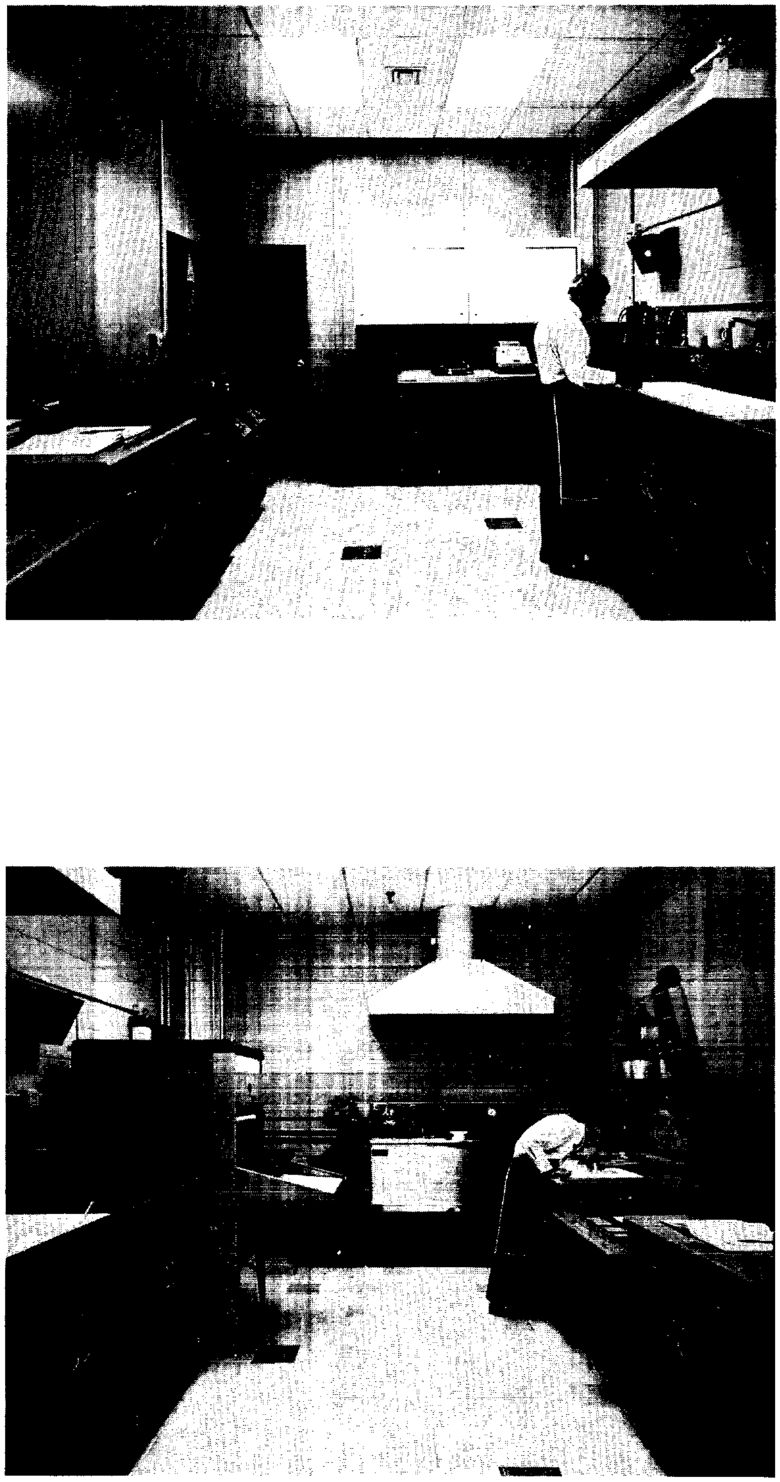

Figure 6. Controlled Film-Processing Room

Figure 7. Measurements Room

## D. EVALUATION OF MATERIALS

### 1. Photographic Film

Thirty-two types of film were reviewed by studying manufacturer-furnished film-characteristics curves. These curves were examined in terms of density range/ratio response to the specific light sources used in the replication equipment. Six film types have been selected with which to begin preliminary measurements.

### 2. Film Processing Chemicals

The selection of chemicals was based on grain-size development capability and density ratio control contribution. After analysis, eight types of chemicals were selected for experimentation.

## E. MODULATED-LIGHT CONTACT PRINTER

### 1. General

The design and construction of the modulated-light contact printer is nearly complete. A special feature of this equipment is the provision, through electronic means, of a negative light mask with which the contact print will be made. The equivalent density of the negative mask, the resolution of the mask, and the exposure time are all variable.

It is expected this equipment will be operational by November, following electrical checkout.

### 2. Design and Mode of Operation

A photograph of the modulated-light contact printer is shown in Figure 8, a schematic diagram of the mechanical and optical layout is shown in Figure 9, and a block diagram of the electrical components is shown in Figure 10.

The equipment is mounted on a massive drill-press base and column, which stands approximately seven feet high. The raster of light from a flying-spot scanner tube* passes through an enlarging lens** to the negative to be copied, which is held in contact with the positive copy film by a film press, as shown in Figure 11.

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* Developmental [redacted] Kinescope Model No. C74325, which is a 5ZP16 tube with P11 phophor.

** Focal length 8 inches; f/2.8, with iris.

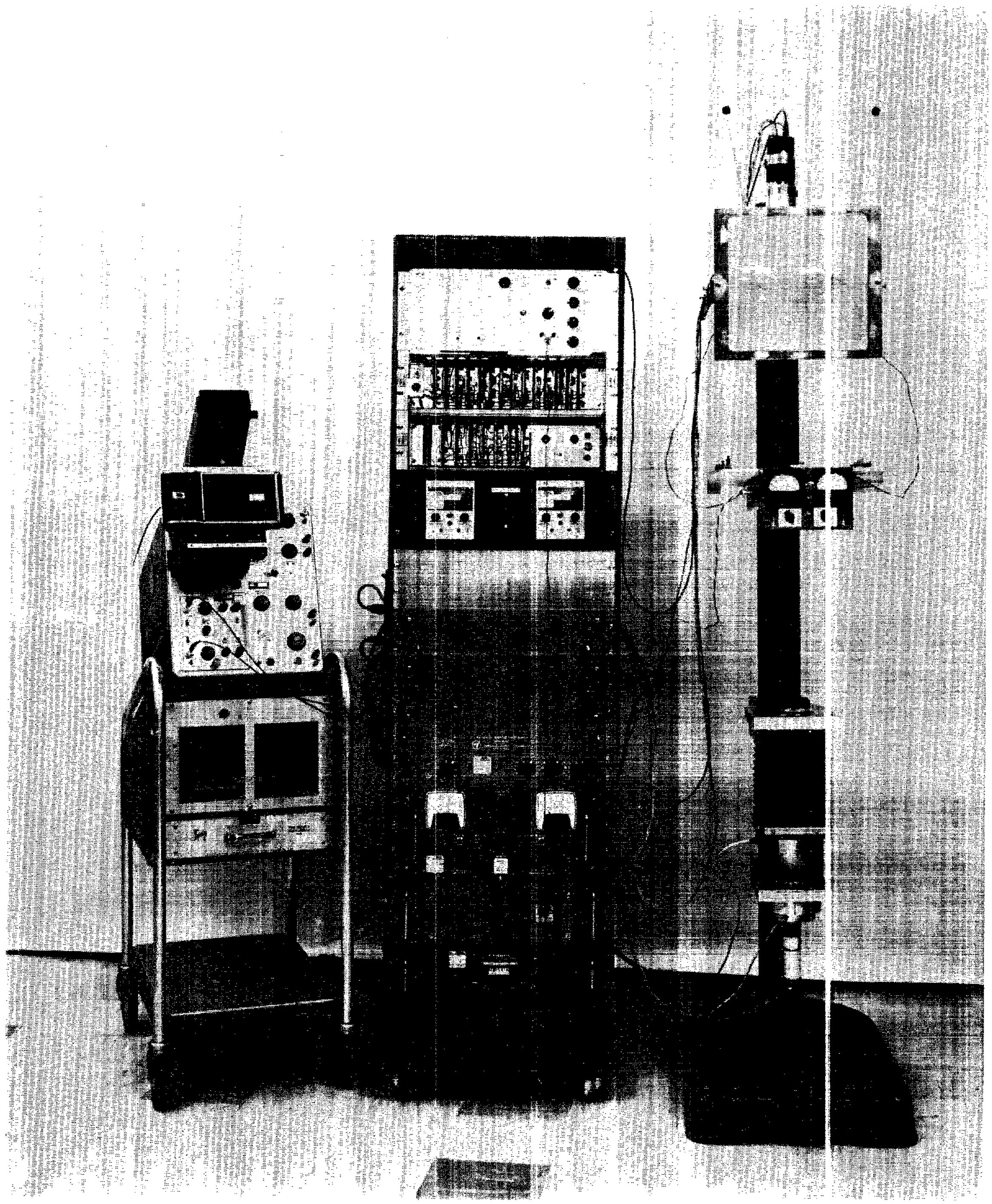

Figure 8. Modulated-Light Contact Printer



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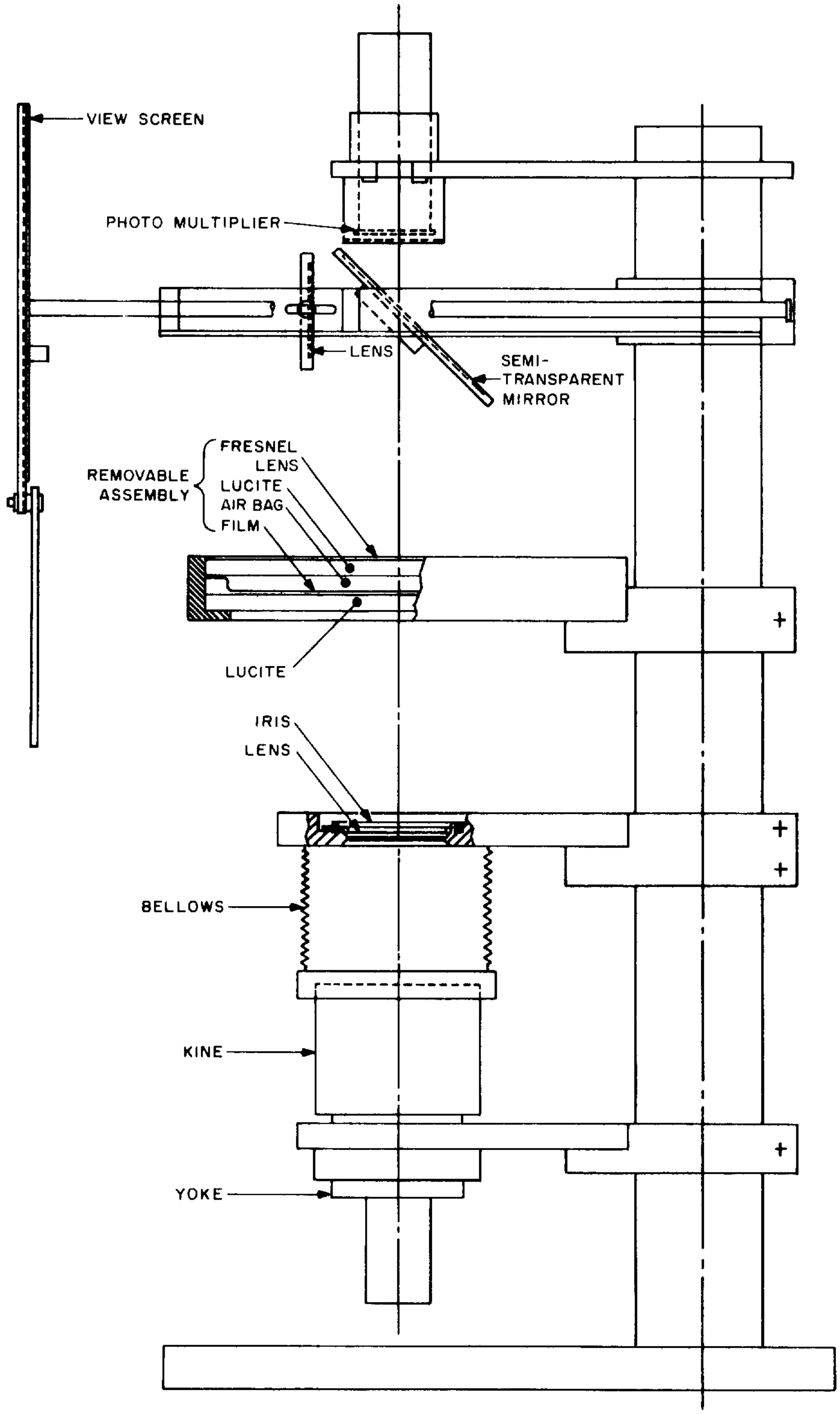


Figure 9. Modulated-Light Contact Printer, Mechanical and Optical Layout

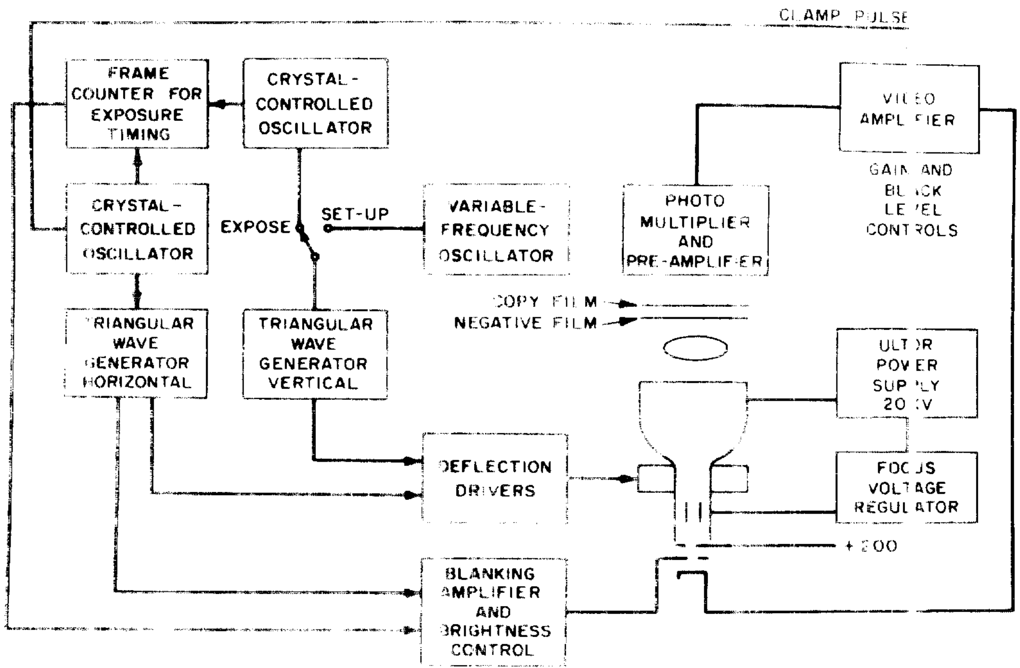


Figure 10. Modulated-Light Contact Printer Block Diagram

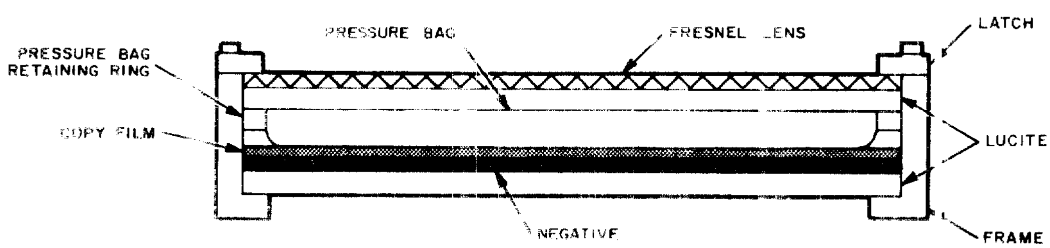


Figure 11. Film Press

The illumination passes through the negative to the copy film in intensities that vary with the densities in the negative. A Fresnel field lens condenses the illumination passed through the copy film. This condensed illumination is then transmitted to the photocathode of a photomultiplier tube for feedback pickup. The electrical signal so produced is fed back to the grid of the flying spot tube so as to modulate the exposure of the copy film.

Thus, in the areas where the density of the negative film is light, the illumination intensity of the flying spot is reduced or in areas where the densities are heavy, the illumination is increased. In this manner the exposure contrast in the copy film is reduced. This contrast compression is not effective in detail smaller than the diameter of the flying spot at the film; the contrast in fine detail is thereby enhanced relative to contrast in broad areas. The minimum size of the flying spot will be one millimeter; the size can be increased by optical or electron optical defocussing.

Before the copy film is actually exposed, a "set-up" operation is required. In this case there is no copy film in the film holder. Instead, a copy-film chip is placed in front of the photomultiplier which serves to produce the same optical attenuation that would occur under exposure conditions. The electrical signal so produced is fed to the grid of the flying-spot scanner thereby modulating the light passing through the film holder. A half-silvered mirror between the condensing lens and the photomultiplier reflects part of the transmitted light so that it may be imaged onto a ground-glass screen at eye-level for viewing. This screen is provided with two small photocells, so that the transmitted contrast range may be measured.

The raster scans in an isotropic pattern; each element is scanned in two orthogonal directions during each frame of exposure. The crystal-controlled scanning frequencies are 1023 and 1024 cycles per second, so that a frame of exposure is accomplished in one second. This scan pattern produces a line density equivalent to that of a 1450-line picture using unidirectional scan. With a one-millimeter spot at the negative, there is more than a six-fold overlap of lines, and no scanning structure should be visible in the copy.

The exposure raster, with a one-second cycle, is inconvenient for viewing and set-up. Provision has therefore been made for a faster coverage of the field during the set-up period, at a rate of up to at least 30 frames per second, with correspondingly fewer lines.

The exposure can be controlled in several ways. Duration of exposure can be preselected to be one, two, three, or four frames (always in an integral number of seconds). Intensity of exposure can be controlled by the bias of the grid of the electron gun in the flying-spot tube, and by the iris of the enlarging lens.

The equivalent density of the negative mask (the modulation of the flying spot) is controlled by the gain in the feedback loop. The attainable equivalent density will be evaluated during the checkout of this equipment.

3. Relationship of Contact Printer to Other Efforts

This equipment is functionally similar to equipment which is being developed for Electronic Film Processing, but has a more limited range of capability.

The contact printer will provide a negative mask with a resolution of up to one cycle per millimeter. One stage of processing is obtained; further processing to enhance image perceptibility will be accomplished by electrical-chemical photographic techniques.

The resolution capability of the breadboard Electronic Film Processor in forming a mask is substantially higher, 10 cycles per millimeter, and with the high-resolution Ferranti kinescopes should reach 60 cycles per millimeter. Within this resolution range, either negative or positive masking may be applied, or the mask may be negative in one part of the resolution range and positive in another, or the mask may be otherwise shaped. The processing to achieve improved image perceptibility in the copy film is to be achieved primarily by manipulation of the shape and equivalent density of the mask.

# SECTION IV

# ELECTRONIC PROCESSING TECHNIQUES

The objective of the Electronic Processing Techniques portion of this program is the development of electronic image-processing techniques that will lead to photographic records with improved image perceptibility. The current effort is concerned with utilizing the flexibility of electronic circuits and components in combination with high-resolution photographic copying methods to achieve in one step the results obtained previously in many steps. The investigations in this area will, for the most part, be performed on a breadboard high-resolution electronic image-processing system.

## A. PROGRAM PLAN

The Electronic Processing Techniques portion of the EPT program comprises the following tasks:

### 1. Feasibility Investigation (Task I)

A preliminary electronic image-processing system analysis will be performed to identify critical aspects of the proposed two-kinescope system. Breadboard equipment will then be designed, constructed, and assembled to test hypotheses and demonstrate operating principles. Experiments with this equipment will lead to the design of a preliminary breadboard system.

### 2. Preliminary Breadboard System Construction (Task II)

The characteristics of various electronic components and circuits will be investigated and reviewed in terms of system requirements and overall program objectives. A preliminary breadboard electronic image-processing system, incorporating standard kinescopes, conventional beam scan, and broadband negative and positive "feedback",* will be designed, constructed, and assembled to provide valuable data on system stability, signal-to-noise ratio, and light characteristics. Experiments with this preliminary system will lead to the design of a final breadboard system.

### 3. Final Breadboard System Construction (Task III)

The results of Tasks I and II will be applied to the design, construction, and assembly of a final breadboard electronic image-processing system incorporating a high-resolution modulating kinescope, isotropic beam scan, and variable-band

*As is discussed later, this will not be a true feedback system, because it operates open-loop.

(filtered) negative and positive feedback combinations. Experiments with this high-resolution processing system will establish operating characteristics and control parameters for the processing experiments.

4. Processing Experiments (Task IV)

Processing experiments, beginning with simple test transparencies, will be performed with both the preliminary and final breadboard systems. The general effectiveness and utility of the proposed electronic techniques will be determined. As with the electrical-chemical processing experiments, modifications of the test procedures and/or equipment will be based upon results of initial tests. Further study and evaluation of electronic processing techniques will be reflected in continuing experiments with the breadboard system.

5. Techniques Study and Evaluation (Task V)

The state-of-the-art of electronic processing techniques will be reviewed in light of the current program objectives. The breadboard system and modifications thereto will be analyzed to predict performance and growth capabilities. The results of processing experiments, to be expressed in terms of actual and subjective evaluations of the processed images by [redacted] and Government personnel, STAT will be reviewed for agreement with theoretical expectations. A mathematical model of the electronic processing system, similar if not identical to the electrical-chemical system model, will be developed. Finally, recommendations for future efforts in this area will be proposed.

6. Rear-Projection Viewer Study (Task VI)

In addition to the above efforts, an analytical investigation of the feasibility of applying modulated-light techniques to rear-projection viewing will be made. Also, recommendations for future efforts in this area will be proposed.

B. BREADBOARD ELECTRONIC IMAGE-PROCESSING SYSTEM

1. General Description

The present test setup which constitutes the feasibility demonstration unit is a two-kinescope system, as shown in Figure 12. The sensing kinescope is an STAT [redacted] 5ZP-16 and the modulating kinescope is the same type of tube except for the phosphor, which is the yellow component of silicate P-4. The deflecting equipment STAT is the same as used on an [redacted] Recording Project* and consists of two yokes

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* Lenticular Film Color Project



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operated in parallel with a single deflecting driver, which also produces 27 kilovolts at 1 milliampere of current in a flyback circuit for the ultor supply. Individual focus supplies are obtained from a regulated RF supply. These are adjustable above and below 6 kilovolts which is the center voltage. A single lens is used in conjunction with a light splitter. The lens is a Wollensack f/1. 9 Oscillo-Raptar in an Alphax shutter. The condensing optical system on the sensing side of the transparency consists of two 4-inch diameter Fresnel lenses (equivalent to convex-side to convex-side) spaced 1/2-inch apart. The photomultiplier is an [redacted] 8575 with a 12-stage multiplier operated at 1000 to 1500 volts. Video amplifiers have a bandwidth of 20 megacycles per second. The power supplies are Lambdas, a Sorensen Nobatron, and a Northeast Scientific. Two views of the test setup are shown in Figure 13.



2. Operation

The sensing kinescope scans the original photographic negative with a fine spot of violet light at a low intensity. This light passes through the copyfilm and is picked up by the photomultiplier and an electrical signal is generated.



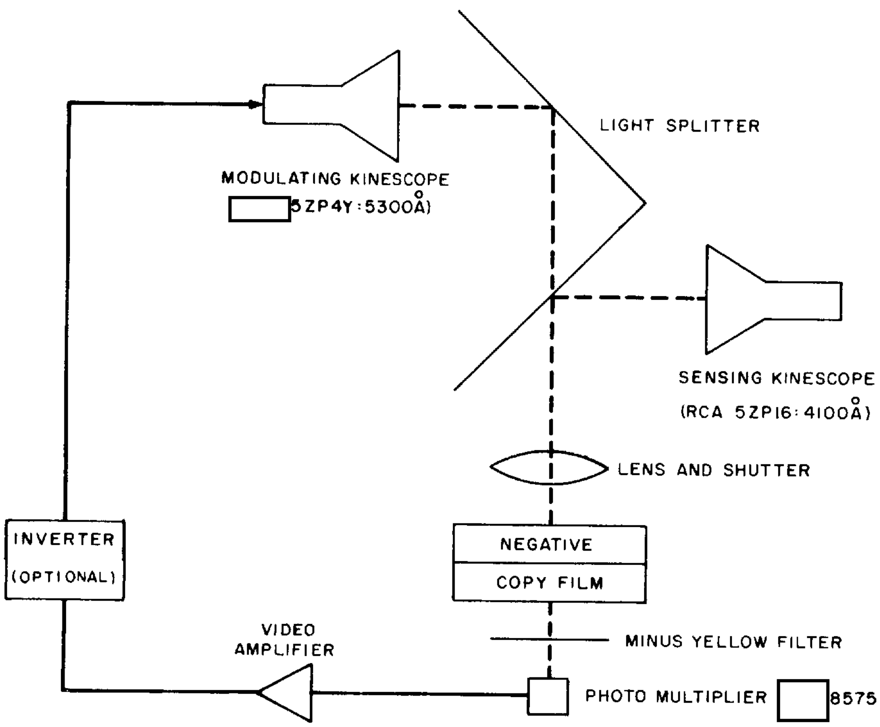
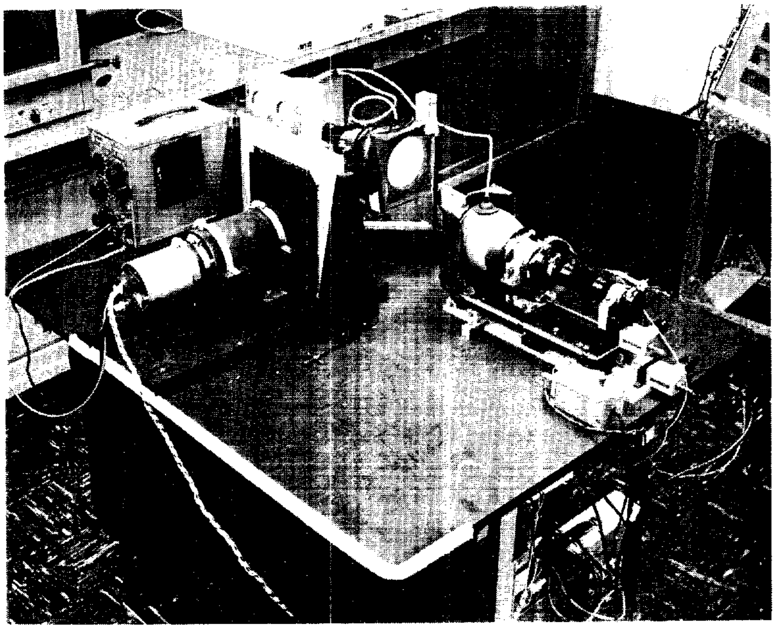
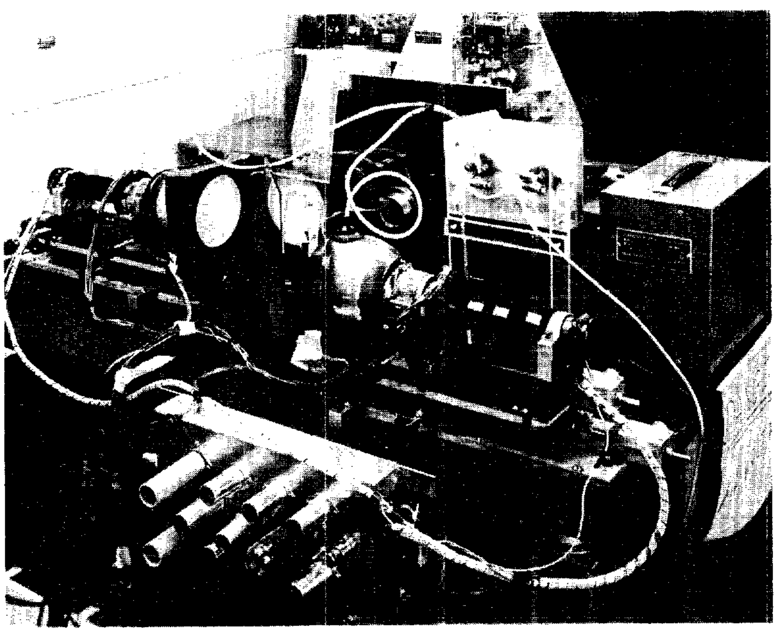





Figure 12. Breadboard Electronic Image-Processing System, Schematic Diagram



A. FRONT VIEW



B. REAR VIEW

Figure 13. Breadboard Electronic Image-Processing System



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This signal is amplified, processed, and applied to the modulating kinescope. The fine spot of yellow-green light generated by the modulating kinescope exposes the copy film through the original negative. The minus yellow filter prevents the yellow-green light from reaching the photomultiplier and affecting the signal.

Exposure of the copy film emulsion depends on the product of the transmittance of the negative and the sum of the sensing and modulating illumination. The exposure, in this process, is performed from point to point sequentially as the negative is scanned by the light.

Compensation for the propagation delay between the two scanning beams is made by an optical register of the rasters so that the light from the modulating kinescope passes through the same portion of the negative as the corresponding light from the sensing kinescope.

## C. EXPERIMENTS

The fundamental problems were carefully investigated with the results described below.

### 1. System Stability

Achieving system stability with a 20-megacycle video bandwidth using feedback with the loop closed is difficult when the phase shift in the system is over 180 degrees. In the test setup described previously, the phase shift from dc to 20 megacycles is 720 degrees, or two complete loops; it is linear with frequency. Based on past experience, it was decided to achieve the effect of feedback by color separating the sensing and modulated light sources by means of colored optical filters.



By employing a combination of [redacted] dichroic filters between the multiplier phototube and the transparency, practically none of the modulated yellow light gets through to the multiplier phototube, but the sensing light source is attenuated only a small amount. The two wavelengths of light eventually reaching the transparency are 4100 Angstroms for the sensing light and 5300 Angstroms for the yellow-green modulated light.



With this system, the video gain has been increased to the point where the modulation is mostly noise without system oscillation. This condition corresponds to a current gain of several million.

## 2. Signal-to-Noise Ratio

Achieving a high system signal-to-noise ratio requires reduction of the noise generated by the input element, which, in this case is the multiplier phototube and circuit. Besides the usual thermal noise it was found that much noise is generated by leaky components. The following precautions were, therefore taken: (1) A multiplier phototube was chosen with a high current gain and
STAT low dark current [redacted] 8575). (2) All insulation connected with the tube, the socket, and the voltage divider is teflon. (3) All filter capacitors use Mylar insulation or the equivalent. (4) The multiplier phototube uses no plug, instead the pins come directly out of the glass envelope. A special teflon socket comes with the tube. (5) The voltage divider was made with encapsulated metalized resistors for low thermal noise. These were mounted on teflon discs arranged coaxially in a shielded cylinder. (6) The input amplifier stage is an [redacted] 6CW4 STAT
nuvistor used as a cathode follower driving a 75-ohm line to the phosphor-correcting amplifier and mounted in the photomultiplier unit close to the anode terminal.

All these precautions resulted in a much improved signal-to-noise ratio. Based on the system operating with 50 microamperes ultor current for the sensing kinescope, the lens set at f/2.8, and the video gain adjusted for a highlight brightness equivalent to 50 microampere ultor current in the modulating kinescope, signal-to-noise ratios were obtained, as follows:

(1) Film No. S05427 was the most opaque to 4100-Angstrom light and gave a signal-to-noise ratio of fifteen decibels, based on the ratio of peak signal to rms noise.

(2) Films SO243 or SO3404 were the least opaque and gave signal-to-noise ratios of 25 decibels.

All other films tested, SO 235, SO 266, SP474, SO2427, royal blue X-ray, and gravure copy, fell between these values.

## 3. Resolution

Achieving over 25 cycles per millimeter resolution over an area of 2 by 2 inches requires equipment not yet received. The present raster optically reduced 5 to 1 produces 508 television lines per inch on the transparency, which corresponds to 254 cycles per inch or 10 cycles per millimeter. The two kinescope rasters are mechanically brought into register by means of precision mounts. Registration is essentially perfect over most of the central area of the picture, being only slightly misregistered around the edges. Improved registration requires a more rigid mount for all optical components and yokes that are more identical. This is being planned for the high resolution setup.

4. Exposure

Test exposures were made using the kinescope light sources both separately and in combination. For the same ultor current in each of the two kinescopes, the same exposure times gave an 8-to-1 ratio of actual exposure on No. SO 243 film. The modulated light source gave the higher exposure so that the sensing light will dilute the modulated light only 12 percent for SO 243 film. During the next reporting period data will be taken with other film.

All of the photographs shown in Figures 14 through 21 were made from contact-printed negatives that were one inch in diameter with the prints enlarged three diameters. Figures 14 through 19 show the effect on the film when exposure times for the individual light sources are varied.

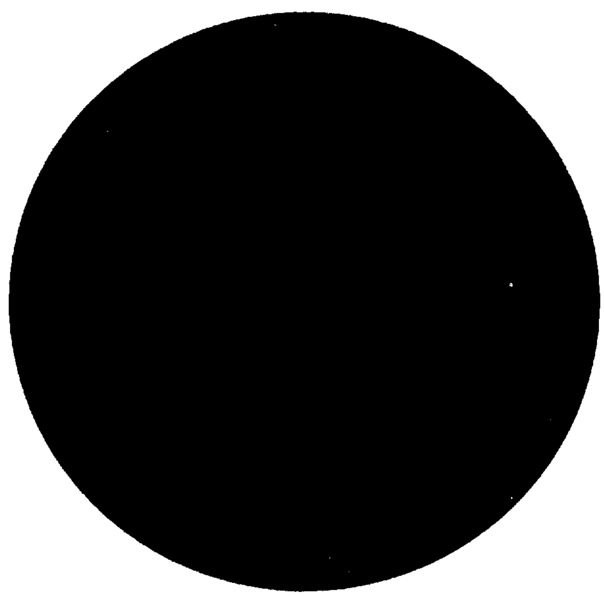

Figure 14. Exposure of Four Fields (4/60 Second)
Modulating Light Source Only

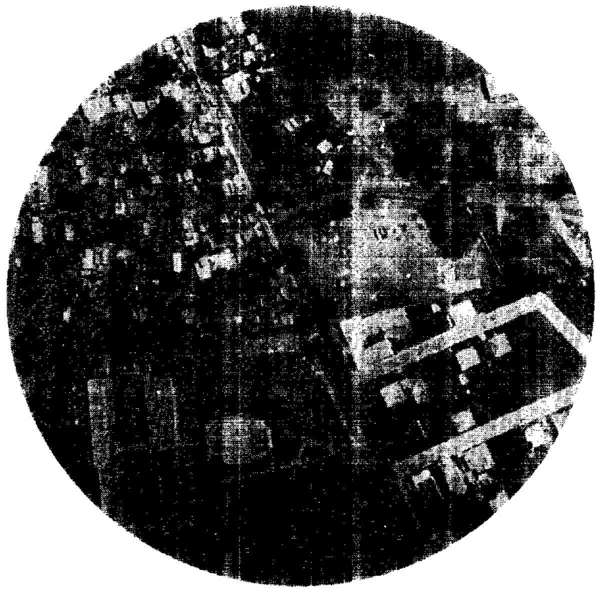

Figure 15. Exposure of Eight Fields (8/60 Second)
Modulating Light Source Only

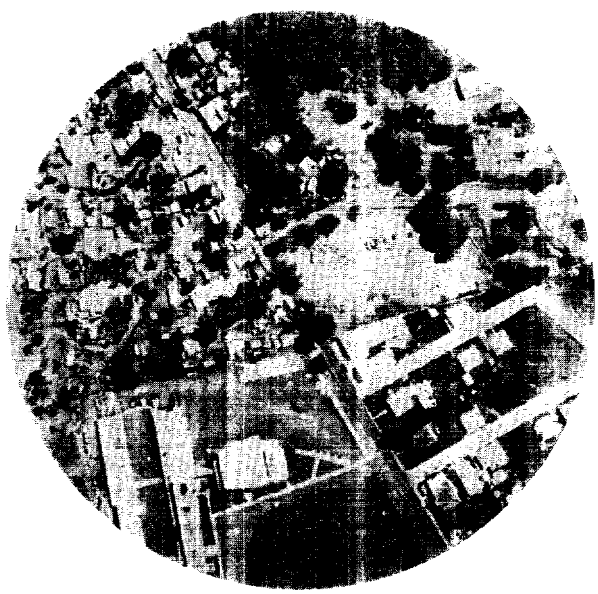

Figure 16. Exposure of 16 Fields (16/60 Second)
Modulating Light Source Only

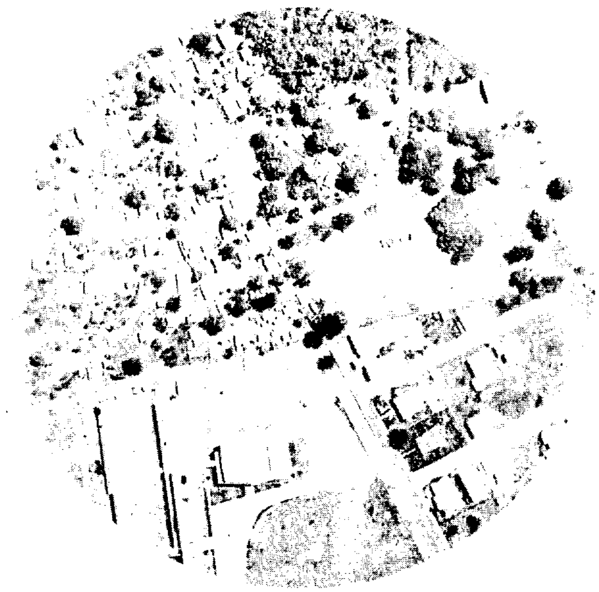

Figure 17. Exposure of 32 Fields (32/60 Second)
Modulating Light Source Only

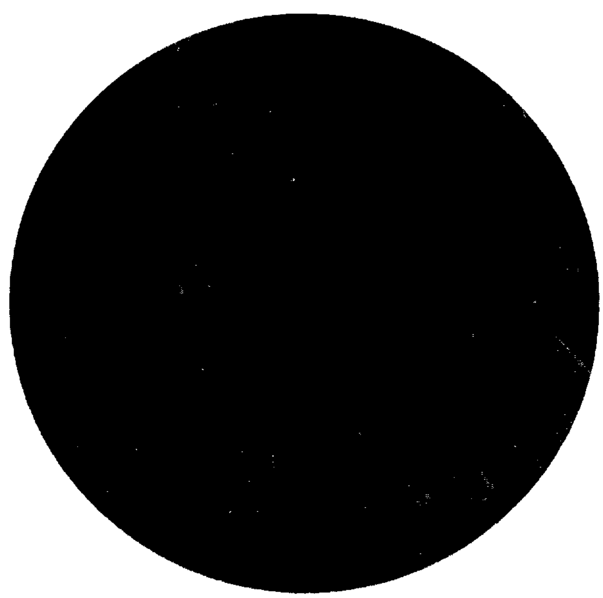

Figure 18. Exposure of 32 Fields (32/60 Second)
Sensing Light Source

Figure 19. Exposure of 64 Fields (64/60 Seconds) Sensing Light Source

Figure 20 shows a combination exposure for a registered light mask. In this case, contrast has been increased for both large and small areas.

Figure 20. One-Second Exposure With Mechanical Shutter Using Both Light Sources and a Positive Light Mask

Figure 21 shows a combination exposure for a registered negative light mask. In this case contrast is decreased for both large and small areas.

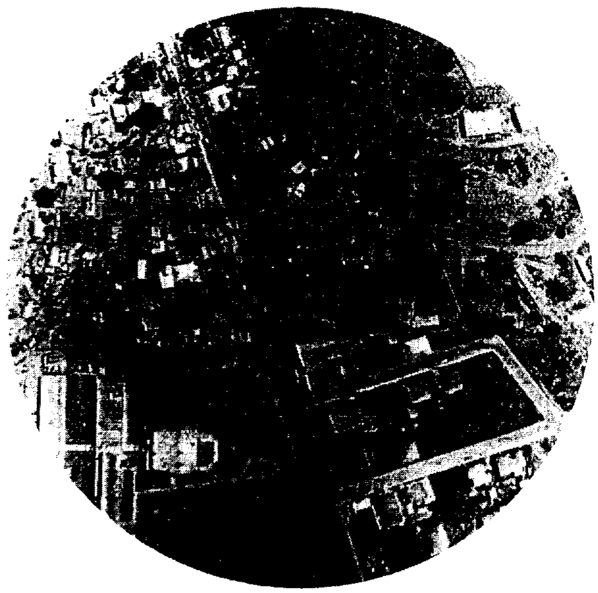

Figure 21. One-Second Exposure With Mechanical Shutter Using Both Light Sources and a Negative Light Mask

D. CONCLUSIONS

It is now possible to design filter circuits to enhance edges represented by differing video frequencies. For example, it may be feasible to provide a positive mask for the edges and a negative mask for the large central area. De-blurring of smear that is in one direction only (due to unidirectional scanning) appears feasible.

Before the conclusion of the contract period, sufficient data should be available to ascertain whether or not a single high-resolution kinescope with mixed phosphors would be suitable for a printer. Use of a single kinescope would eliminate the existing problem with mechanical registration of two rasters.