SECRET

[redacted] 25X1

Copy 1 of 23 copies

[redacted]

Dist: #1 - File
#2 - Helen
#3
4
5 } [redacted] 25X1

NGA Review Complete

SECRET

GROUP 1
EXCLUDED FROM AUTOMATIC DOWNGRADING AND DECLASSIFICATION

[redacted] 25X1

This document contains 38 pages

Copy 1 of 23 copies

PAR 255A

FINAL REPORT

Preparation of Simulations of
High-Altitude Aerial Photography

15 June 1970

Prepared by:

[redacted] 25X1

Approved by:

25X1 [redacted]

[redacted] 25X1

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Approved For Release 2004/08/25 : CIA-RDP78B04770A000400050007-7

PAR 255A

SUMMARY

The contractor has prepared and delivered negatives and contact duplicates which simulate high-altitude aerial photography of specific ground targets at several scales and quality levels. Original photography of six scenes was provided by the customer. Using these scenes, or the particular area of interest within the scenes, positives were made which represent the appearance of typical ground targets from high altitude. These positives were then reduced onto 3404 film at the desired scale using a controlled optical system, and subsequent dual-gamma processing.

After making contact duplicates of these reduced negatives onto 2430 film, one set of negatives and 3 sets of dupes were transmitted to the customer. These negatives simulate scale, tone reproduction and ground resolution typical of high-altitude photography. Some modifications in standard simulation techniques were required to achieve the desired quality in larger scale photography. All techniques are described in the discussion section and appendixes.

The following characteristics were simulated: 25X1

Condition	Scale
1	1:6000*
2	1:12000
3	1:30000
4	1:54000
5	1:110000
6	1:188000

[redacted]

* The scale for condition 1 was made at approximately 1:2500 in order to achieve [redacted] 25X1

PAR 255A

SUBJECT: Preparation of Simulations of High Altitude Aerial Photography

TASK/PROBLEM

1. Prepare simulated black-and-white aerial negatives and dupes from original photography provided by the customer. The simulations shall depict high-altitude photography with ground resolution [redacted] 25X1

25X1 [redacted]

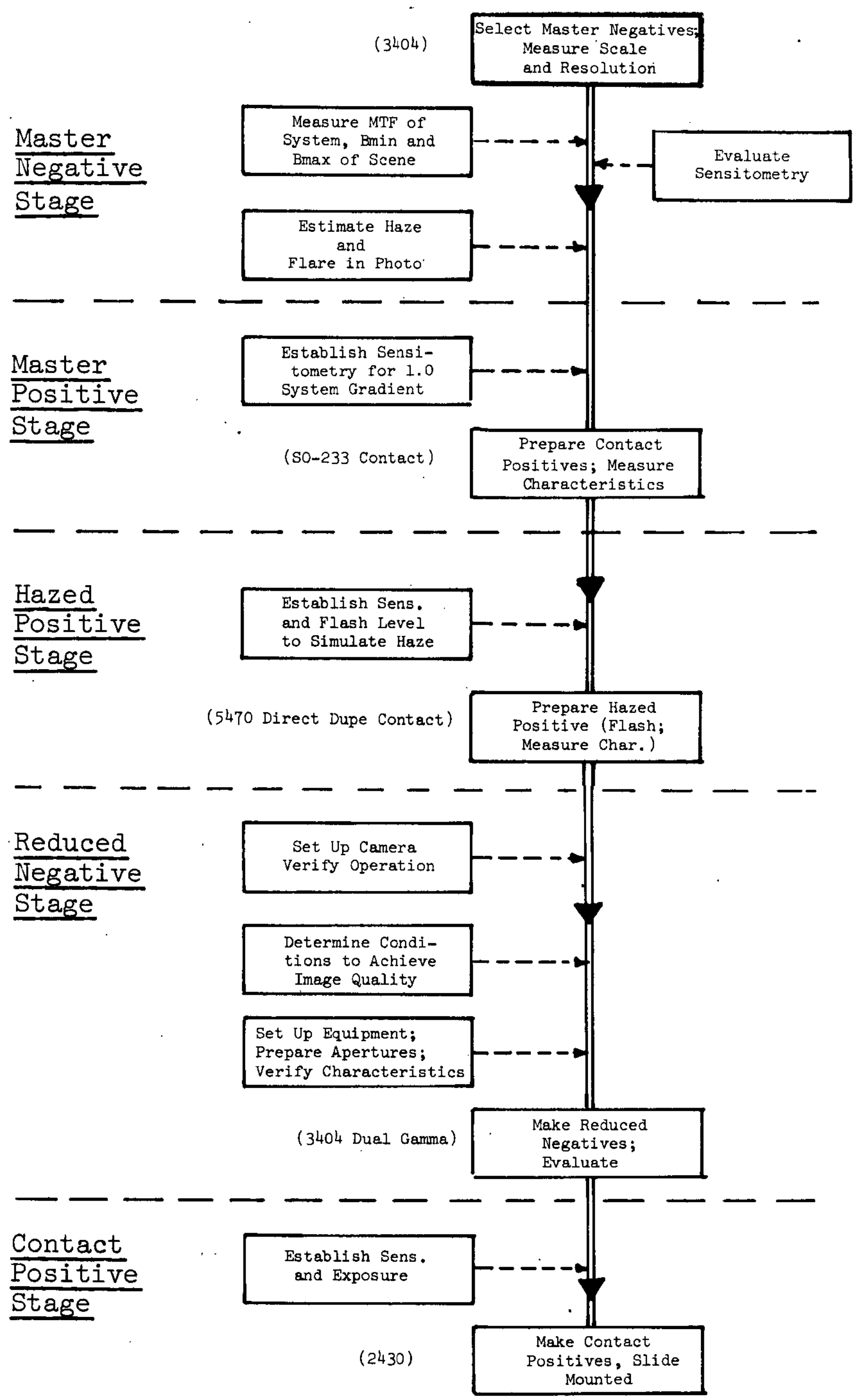
INTRODUCTION

2. The customer required high-altitude aerial negatives and contact dupes of specific military targets for detection/recognition studies. The contractor had previously developed a technique for simulating high-altitude photography using high-quality, low-altitude photography as an input. This report is not intended to fully describe the theories and procedures employed in making simulations but only those pertinent factors relative to this specific task.

3. The flow chart for the simulation process is shown in Figure 1. As shown, the original, or master negative, is acquired and analyzed for image quality and tonal content. From this original, a master positive is made by contact printing. Tone reproduction is controlled to produce this rendition of the original scene at a system gradient of 1.0. A hazed positive is then made by contact printing the master positive onto a reversal dupe film, and adding an overall flash exposure to simulate haze. This positive simulates the appearance of the ground target from very high altitude, and provides the input for preparation of reduced negatives. The positive is photographed with a controlled optical system onto the proper aerial negative film, and the optical system provides the reductions to achieve the desired scale in the negative. Apertures used with the lens can be modified in size and shape to simulate the MTF of typical high-altitude acquisition systems and to control the limiting resolution in the negative. However, only limiting resolution is depicted in these simulations. The negative film is properly processed so that resultant negatives simulate the scale, resolution, MTF and tone reproduction of high-

Figure 1

Flow Diagram of the Simulation Procedure



altitude photography. Standard test objects are carried through the entire sequence to verify quality and tone reproduction. From the reduced negatives, contact positives can be made on aerial duplicating films.

4. Optimum simulation quality results when the characteristics of the master negatives meet quite specific requirements. The image quality must be such that image modulation at the desired limiting ground resolution exceeds a minimum value defined by the parameters in the reduction stage. In order to determine image quality in the originals, a target which permits measurement of system MTF should be included in the scene. In addition, the scale in the original negative should be such that the final reduction exceeds 5X. Other targets of known brightness should be included in the scenes and these targets should be large enough so that image density is not influenced by micro characteristics of the lens, film and process. These targets are used to control tone reproduction through the simulation process.

5. Basic information and guidelines were established as follows:

a. Requirements were defined by the customer in terms of scale and ground resolution.

b. Six original scenes were to be provided at a scale of about 1:2000, and resolution required in the original negatives to achieve the desired ground resolution in the simulations was defined.

c. The limitations that would be imposed if these requirements were not met were described.

d. It was agreed that, if possible, modulation transfer function (MTF) would be simulated.

e. If deficiencies existed in the master negatives, the customer and contractor would agree upon the deficiencies that would be permitted in the final simulations prior to the start of the simulation procedure.

f. The customer agreed to complete acquisition of photography and delivery of the films to the contractor eight weeks prior to delivery date for the final simulations.

6. MTF in film systems is subject to many variables, such as adjacency effects and measurement errors, especially with dual-gamma processing. The tone reproduction is a function of object size, contrast and the densities in adjacent areas. When simulations are made with small optical reductions, grain print-through from previous stages increases the apparent granularity in the reduced negative. To a certain extent these effects are ignored, and the macro-characteristic curve is used for tone reproduction and the average of several measurements for MTF are used. However, when reduction of the original photographs is greater than about 20X (as is the case for the three poorest quality simulations) the image quality is dominated by the reduced negative optical system. Micro-image effects become insignificant. With smaller reductions, these errors are present to some extent but are well within normal variability associated with measurement of MTF. It was not within the scope of this study to analyze the effect of these small errors.

7. The original negatives received from the customer did not meet the requirements for making optimum quality simulations. These deficiencies were discussed with the customer. Image quality was inadequate for simulating 2-inch quality at 1:6000 scale. One of the negatives had received dual gamma processing which introduces distortion in macro-scale tone reproduction which cannot be fully compensated for in later steps in the simulation process. Targets were not included for measurement of MTF or densities of known ground brightnesses. Two of the

scenes did not have sufficient image quality to simulate [redacted] ground resolution. Agreement was reached that simulations should be prepared with the following limitations: 25X1

a. System MTF would not be simulated.

25X1 b. Simulation of [redacted] ground resolution at the scale of the originals, about 1:2000, by contact printing.

c. "Haze" would be added to reduce the apparent brightness range in all scenes to 5:1.

d. For scenes 2 and 6, simulations representing [redacted] 25X1
25X1 [redacted] ground resolution would be made at the desired scale, even though ground resolution would be inadequate.

DISCUSSION

8. <u>Master Negative Stage</u>

a. <u>General</u>

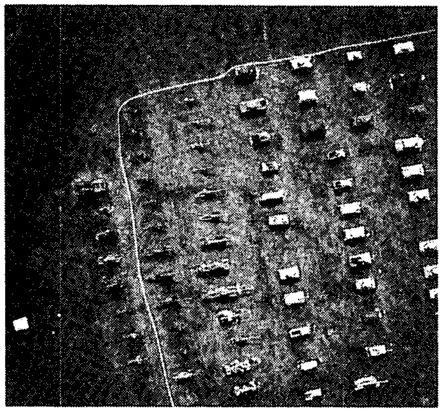
(1) Original photography was made on 3404 film* with a 3 inch lens in a camera with intrack image motion compensation (IMC) at an altitude of approximately 500 feet above ground level (AGL). The customer provided these photographs to the contractor for processing and subsequent treatment to make the prescribed simulations. Figure 2 is a contact print of the six scenes selected for the simulation program. The measured characteristics of the original negatives are shown in Table 1.

* Kodak High Definition Aerial Film 3404 (Estar Thin Base)

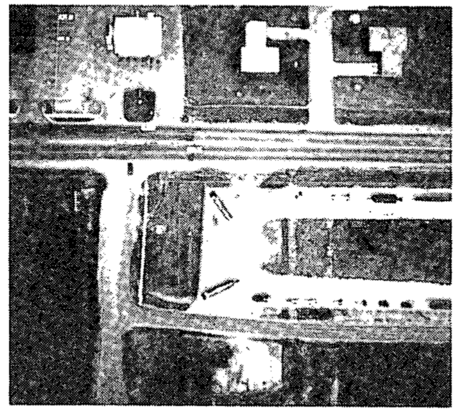
Figure 2

Contact Prints of Scenes 1 Through 6

Scene 1

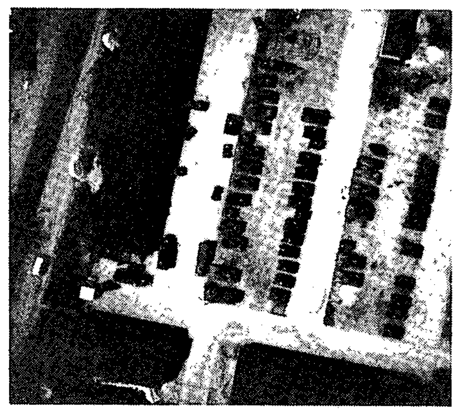


Scene 2



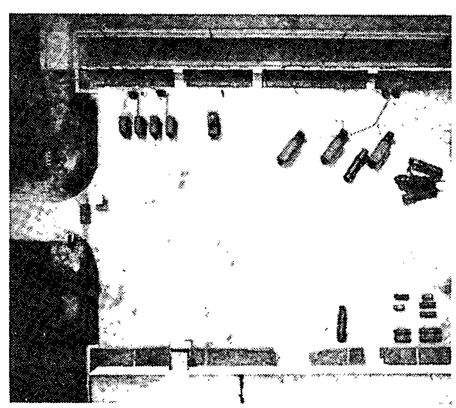
Scene 3

Scene 4



Scene 5

Scene 6



Approved For Release 2004/08/25 : CIA-RDP78B04770A000400050007-7

SECRET

Table 1

Measured Characteristics of the Master Negatives

Scene Number	Dmax	Dmin	Scene Contrast	Average* Gradient	Scale
1	1.74	0.34	20:1	1.10	1:2450
2	2.51	0.60	24:1	1.43	1:2835
3	2.50	0.56	22:1	1.43	1:2160
4	2.30	0.66	11:1	1.60	1:1910
5	2.60	0.75	19:1	1.50	1:1920
6	2.38	0.60	13:1	1.61	1:2835

(2) Effort made at the master negative stage is to analyze the tone reproduction and image degradation introduced by the original negative photography, so that these effects can either be removed or compensated for in subsequent stages. Included in the tone reproduction of the original material is the combined effect of lens flare, atmospheric haze, and the brightness distortion caused by the film characteristic curve. It is also necessary to know the MTF of the entire master negative system (lens, film, smear, defocus, etc.) in order to obtain the proper resolution in the reduced negative stage.

b. Scale. The measured scale of the master negatives is also shown in Table 1. Notice that the scenes can be classified into two groups. Scenes 1, 2 and 6 have a scale of approximately 1:2650 and Scenes 3, 4 and 5 have a scale of approximately 1:2000. These two scale values were used in calculating the reductions required in the reduced negative stages.

* The average gradient is the slope of the line connecting the scene Dmin and Dmax.

c. Tone Reproduction

(1) Scene 1 was photographed and processed prior to customer-contractor discussions, and images were processed in the dual-gamma viscous process to the characteristic curve shown in Figure 3. Since the dual-gamma process was designed to optimize tone reproduction for high-altitude photography with haze, the characteristic curve is inappropriate for maintaining accurate tone reproduction in low-altitude photography without haze. The nature of the dual-gamma 3404 characteristic curve imposes the requirement for a unique characteristic curve in the master positive stage to achieve proper tone reproduction in the master positives. This specialized curve cannot be achieved with normal photographic films and processes.

(2) The remaining scenes (2, 3, 4, 5 and 6) were processed in the Fultron processor to achieve the characteristic curve shown in Figure 4. This process produces more linear relationship between the log ground brightness and density in the original negative, and permits better control of tone reproduction in the simulation process.

(3) In order to measure the combined effect of lens flare and atmospheric haze, it is necessary to know the brightness of at least two objects of different reflectances in the scene. These objects should be uniform Lambertian reflectors, and large enough not to be influenced by either the MTF of the system or adjacency effects in the process. Some brightness data was obtained from the customer for vehicles in Scene 1. However, the area measured had neither unform brightness nor the approximate Lambertian reflectance properties required to calculate haze from brightness measurements. Reflectance measurements were not available for Scenes 2 through 6. In the absence of direct brightness measurement, certain assumptions must be made in subsequent steps and a less rigorous method used in adding haze and controlling tone reproductions. However, the method used does produce images which are typical of high-altitude photography.

(4) The effect of lens flare and haze is an equal addition of non-image forming light to the whole photograph. This flare light reduces the contrast of low brightness areas more than high brightness areas, causing a distortion in tone reproduction. In high-altitude

Figure 3

Characteristic Curve for Master Negative -- Scene 1
(exposed in IB Sensitometer)

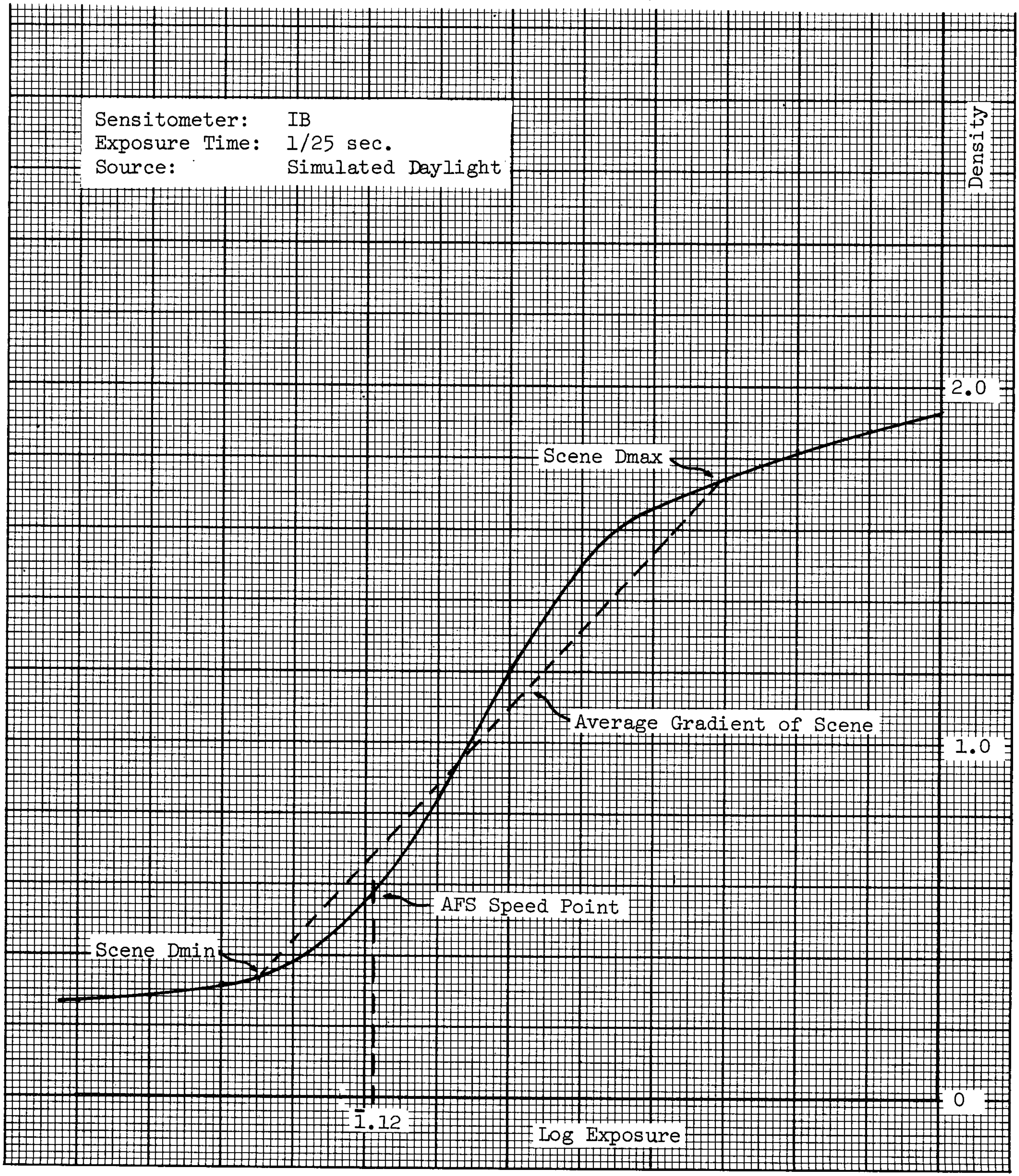
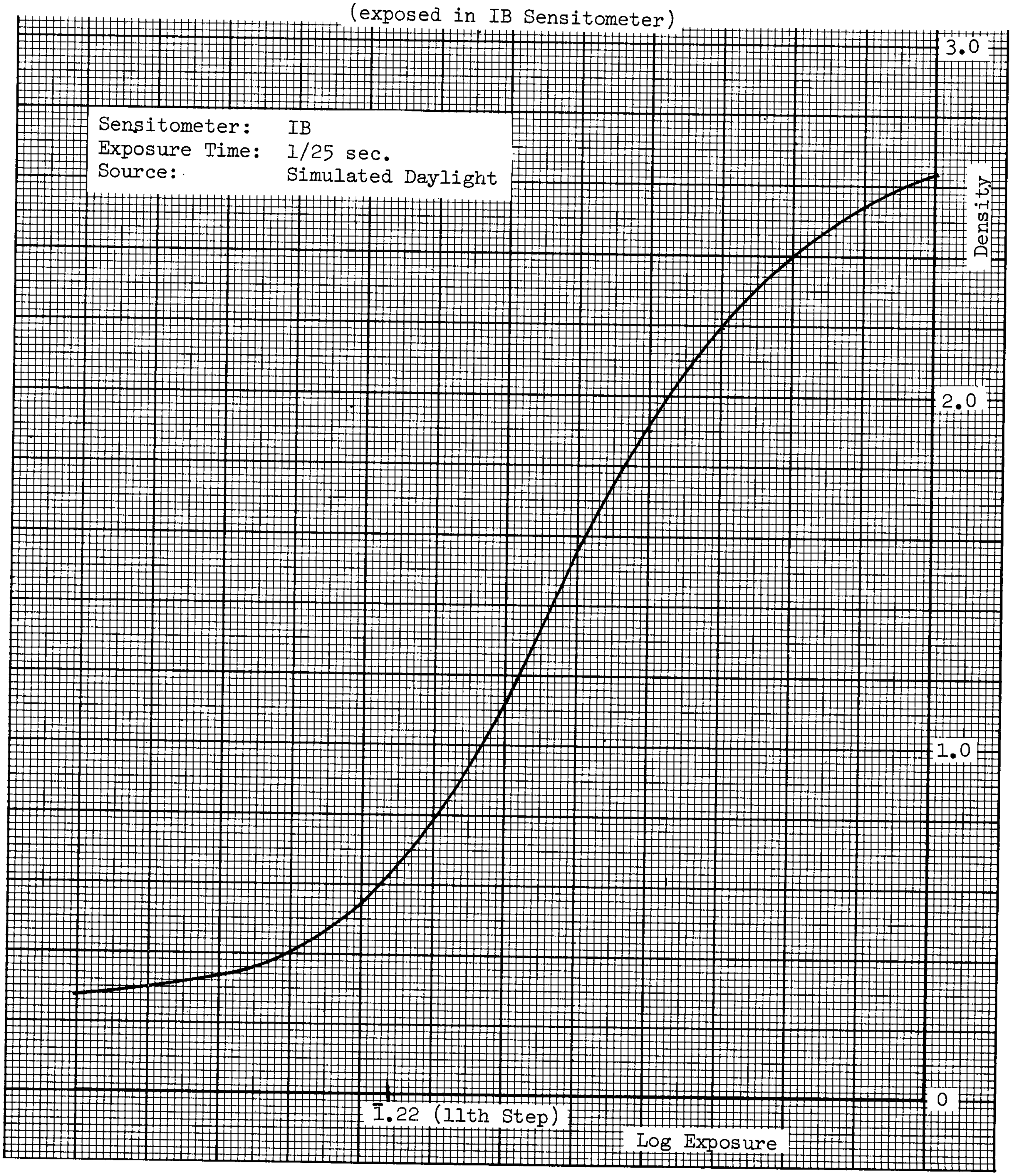


Figure 4

Characteristic Curve -- Scenes 2 Through 6
(exposed in IB Sensitometer)



graphy, the tone reproduction is significantly altered by haze; therefore, the effect does not have to be removed. Only its magnitude has to be measured so that the correct amount of additional haze can be added to simulate high-altitude photography. See Appendix B for a more detailed description of the effect of haze.

(5) The expected scene contrast in a low-altitude photograph is about 100:1. The Dmin and Dmax were measured with a 0.5mm aperture on a Kodak Model 31A densitometer for each scene and the contrast obtained by transferring these densities through the appropriate 3404 characteristic curve. Measured values for scenes used in the simulation vary from 11:1 to 24:1 (Table 1), indicating a significant reduction in scene contrast from haze and lens flare. Since the amount of haze in the original photographs could not be measured, the haze required to reduce each scene to 5:1 contrast was added in the hazed positive stage. This will be discussed later in paragraph 7, "Hazed Positive Stage."

(6) The scenes exhibited $\cos^4$ fall-off in exposure* of approximately 0.12 log E at the frame edge (3-inch focal length, 70mm film format). It was necessary to compensate for this effect also in the hazed positive stage.

d. Image Quality

(1) Visual examination of the images showed that the leading edges of photographs were considerably better for image quality than the trailing edges. Therefore, the usable portion of the scenes was limited to less than one half of the total frame area. It should be noted, however, that there was a continuous variation in image quality across the frame, so that the quality varied within the area used.

(2) Edge gradient analysis was performed within the usable area of Scenes 1 through 5 to obtain the MTF of the entire master negative stage. The MTF determined in this manner includes the combined effect of lens, image motion, and film. Crosstrack and intrack measurements were made for each of the scenes to estimate the effect of smear. Only minor

* The $\cos^4$ variation is the fall-off in illumination corresponding to the angular distance off the optical axis for low distortion lens systems with an internal aperture.

differences were detected with the exception of Scene 5, which had a somewhat better MTF in the intrack direction. The average MTF for Scenes 3, 4 and 5, and the average MTF for Scene 2 are shown in Figure 5. The MTF measured for Scene 1 was in error because there were no edges suitable for edge gradient analysis. Resolution measurements in an adjacent frame and visual examination indicated that Scene 1 was very similar in image quality to Scenes 3, 4, and 5. Therefore, average MTF of these latter scenes was used as the best estimate of the MTF for Scene 1. The MTF for Scene 2 was used as the estimate of the MTF for Scene 6, since they were closely located in the same flight pass. Table 2 shows the resolution predicted for 2:1 contrast targets based on the measured MTF. 25X1

(3) Resolution test results supplied by the customer for the flight lens gave an AWAR** of 64 cycles/mm on 3404 film for an unspecified target contrast. The observed resolution values in flight (Table 2) of about 40 cycles/mm are conceivable for a lens of this relatively poor quality.

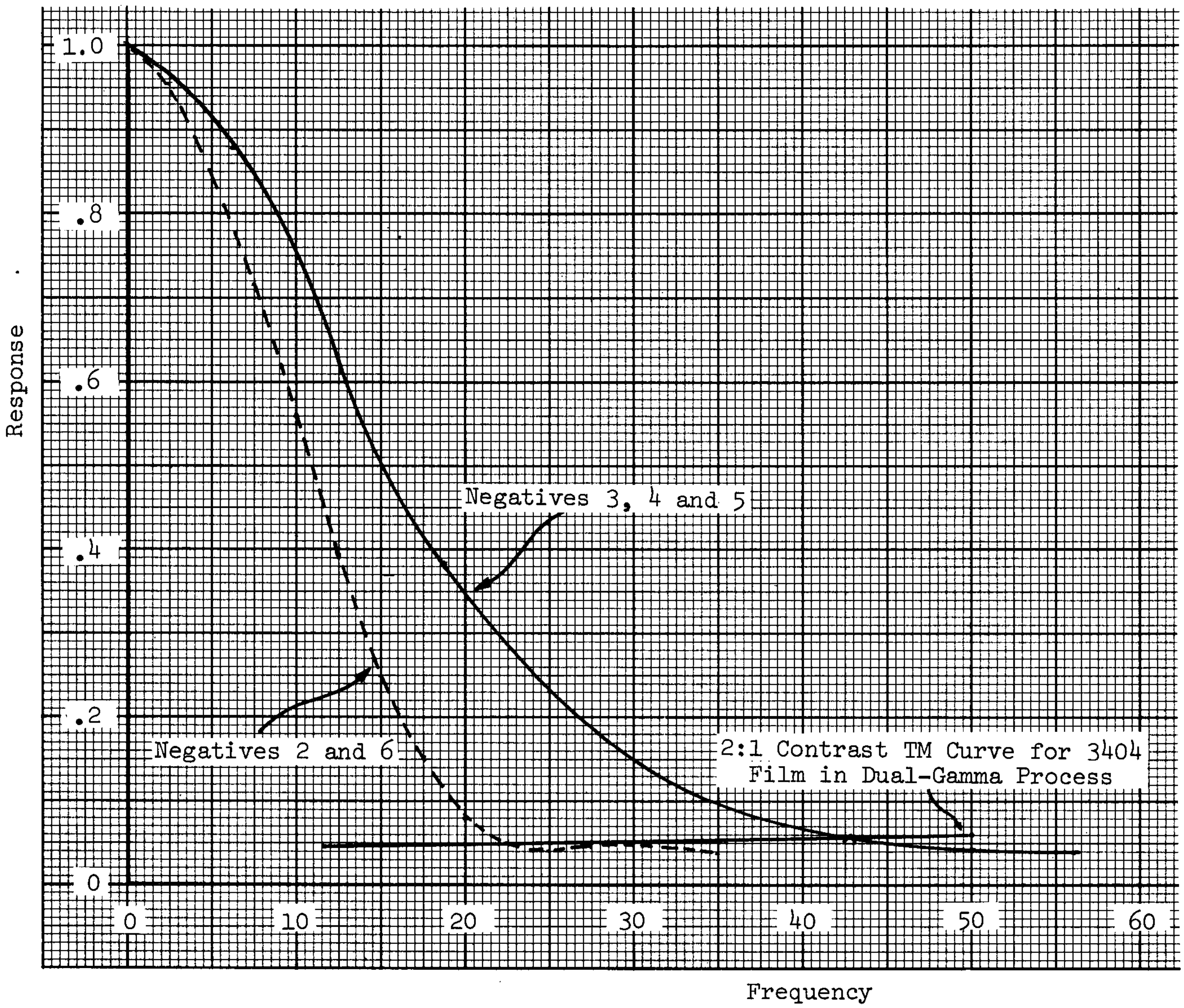
(4) Since the MTF curves are generally the same in the crosstrack and intrack* orientation, smear would not seem likely as the cause for the difference between laboratory tests and flight results. The most

* These 2:1 contrast resolution values were obtained by crossing the 3404 thresold modulation (TM) curve with the MTF curves measured by edge gradient analysis.

** Area Weighted Average Resolution (72 cycles/mm on-axis).

Figure 5

MTF Curves for the Master Negatives



likely source of degradation is random image motion caused by aircraft vibration. Visual examination of other frames did indicate that photographs made with longer exposure times had poorer quality than scenes with the shorter exposures. However, there was no evidence of lack of intrack IMC except at the longest exposure times. The images just appeared unsharp, which is the way they would appear if random motion degraded the photograph.

(5) MTF values for Scenes 2 and 6 are significantly poorer than for other scenes. This would not normally be expected, as good weather was reported at acquisition. On the other hand, this anomaly has been noted with color acquisitions made the same day, again with clear weather. Since the aircraft probably flew at a lower airspeed to minimize smear, the poorer image quality might be related to an increase of aircraft vibrations.

(6) It should be remarked that, with a good quality f/4 lens, 3404 film is capable of recording 200 cycles/mm at 2:1 contrast. Since customer lab tests report AWAR resolutions of only 64 cycles/mm at f/2.8, almost all of the degradation comes from poor lens quality. But as it is probably not possible to stop the lens down to achieve better quality because of the slow speed of 3404 film, the best solution might be a better quality lens with a focal length of about 6 inches to improve image quality and reduce $\cos^4$ fall-off at the edges of the frame.

(7) The quality of Scenes 1, 3, 4, and 5 is sufficient to
make simulations at the prescribed ground resolutions [redacted] 25X1
5X1 [redacted] Slight modifications in procedure are required to obtain [redacted] 25X1
ground resolution. Although this program called for simulating both scale and ground resolution, the quality of the original material is not sufficient to obtain 2-inch ground resolution at the proper scale. By agreement with
5X1 the customer, therefore, [redacted] simulations were made by contact printing

the hazed positives onto 3404 film. These images have the appropriate ground resolution but the scale -- and hence the film resolution -- is low by a factor of about 2.5. Also, the grain of the preceeding stages are printed onto the 3404 image giving the image a somewhat grainier appearance than normally would be achieved. The grainier image, however, is not unlike an actual system image, since the images would be approximately 2.5 times smaller in scale. The quality of Scenes 2 and 6 is not sufficient to achieve the proper ground resolution [redacted] ground resolutions, 25X1
so that while simulations are made at the proper scale (except for the 2-inch condition), the ground resolution is considerably poorer than required. Later, actual resolutions are tablulated in the reduced negative section of the report, paragraph 7.

9. Master Positive Stage

a. In the master positive stage, the master negative is contact printed to obtain a positive image with the tone reproduction corrected to an average system gradient of -1.0. Density difference in the positive will accurately represent scene brightness differences as they would appear at low altitude with only a small amount of haze present. The exposure and processing characteristics of the print film are adjusted to make the tone reproduction as linear as possible between the densities representing scene minimum and maximum brightness.

b. Scene 1 was processed in the dual-gamma process, which has an extremely non-linear tone reproduction. In order to obtain a system gamma of -1.0 over the entire density range encompassed by the scene, the characteristic curve for the print film would have to be the reverse of the dual-gamma curve. Since films with such a curve shape are not available, an average gradient technique was used with a print film having a normal characteristic curve. The criterion was to have an average gradient of -1.0 between the points representing scene Dmin and Dmax, and to minimize deviations from a constant slope of -1.0.

Approved For Release 2004/08/25 : CIA-RDP78B04770A000400050007-7

c. All master negatives were vacuum contact printed on SO-233 film*. This film is similar in image structure to 2430**, except for a lower gamma.

d. Exposure and processing time were varied in making contact positives to minimize deviations in tone reproduction while maintaining an average system gradient of -1.0. Negatives of Scenes 2 through 6 were processed in the Fultron processor to yield a conventionally shaped characteristic curve for 3404 film. A more linear tone reproduction was obtained for these scenes.

e. Previous MTF tests have shown the vacuum contact printer with a specular light source to have maximum response (1.0) out to 100 cycles/mm. Therefore, effect of the printer can be neglected as a significant source of degradation. Virtually all degradation added in the master positive stage comes from the MTF of SO-233 film. The degradation is very small at the quality level of the original negative scenes. However, the measured MTF for each scene was multiplied by the MTF of SO-233 film in the calculations for predicting resolution at the reduced negative stage.

10. Hazed Positive Stage

a. Tone reproduction of master positives are altered in the hazed positive stage to simulate effect of haze in high-altitude photography. Appendix B discusses effect of haze on tone reproduction of a scene. Since it was not possible to add a constant haze level to each scene (because amount of haze in each negative was unknown), the scenes were all hazed to a 5:1 contrast. This contrast ratio is typical for maximum and minimum scene brightness in high-altitude aerial photographs taken under clear conditions.

---

* Kodak Special Low Contrast Fine Grain Aerial Duplicating Film SO-233. This film is no longer available, but has been replaced by Kodak Low Contrast Fine Grain Aerographic Duplicating Film (Estar Base) SO-355.

** Kodak Fine Grain Aerial Duplicating Film 2430 (Estar Base)

PAR 255A

b. The technique used in making the hazed positives is to add a uniform flash exposure to a contact print of the master positive which reduces the scene contrast to 5:1. The master positives are contact printed on 5470* film, a direct reversal material with a gamma of -1.0. With this product it is possible to maintain a positive image and obtain the proper tone reproduction in one photographic step. The exposure for each scene is adjusted to place the scene Bmin at a density of 1.20. A common exposure can then be used in the reduced negative stage. Table 3 gives the measured characteristics of the hazed positives.

Table 3

Measured Characteristics of the Hazed Positives

Scene	Dmax	Dmin	Contrast
1	1.26	.46	6.3:1
2	1.14	.32	6.6:1
3	1.12	.40	5.2:1
4	1.15	.45	5.0:1
5	1.14	.46	4.8:1
6	1.14	.40	5.5:1

c. The $\cos^4$ fall-off in illumination caused by the taking lens was compensated for when making the hazed positives. A photograph of a uniform illuminator was made with a 75mm Biogon lens on 2430 film processed to a gamma of 1.0. Since the Biogon lens has the same focal length as the flight lens, the $\cos^4$ fall-off will be essentially the same. The measured variation in density of the mask was 0.12 less density at distance of about one inch from the optical axis. Master negatives averaged 0.13 less log exposure at one inch from axis. The mask was superimposed on the scene when

* Recordak Direct Duplicating Intermediate Film, 5470.

contact printing to make the hazed positive. This technique eliminated variation in average density across the field to avoid causing a corresponding variation in the simulations. A 0.060-inch piece of glass was used as spacer between the mask and the master positive to minimize the transfer of the mask grain through the system.

d. The MTF for the 5470 film is essentially 1.0 over the frequency range covered by the master negatives, so this stage does not significantly degrade image quality of the system.

11. Reduced Negative Stage

a. General

(1) The stages through the hazed positive are designed to alter a low-altitude photograph so that it represents the scene as it would appear at high altitude. In the reduced negative stage, the hazed positive is optically reduced with a lens with controlled MTF onto the film used in the system being simulated. This reduced negative has essentially the same optical characteristics as a small film chip taken out of a photograph made with that system. The image will depict the film characteristics, processing, ground and film resolution, tone reproduction, and granularity typical of the system.

(2) It was not possible to simulate the actual system MTF curves except at the three lowest quality levels. Since MTF of the original negatives was a major contributor to the degradation in these simulations, it was not useful to attempt simulating system MTF even at the poorest quality levels. Firstly, edge gradient analysis is very susceptible to error, and generally gives only a first cut at the actual MTF in the original negatives. This MTF must be known accurately to simulate a total system MTF. Secondly, the different MTF's for each master negative would require a different MTF in the reduced negative stage, requiring a modification of the pupil function of the reducing lens for each scene. Manipulating numbers with such uncertainty, especially considering the variation in quality across the frame, would be a wasteful effort.

(3) The lens used for making the reduced negative is a 90nm f/2.0 Leitz Summicron. The through focus MTF for apertures from f/4 to f/16 has been calculated by a computer program based on the lens design data in 546mm light. Subsequent measurements made with an electronic MTF measuring device, and lab tests with resolution and sine wave test targets, have verified the calculated MTF curves.

(4) The limiting tri-bar resolution in the reduced negative stage was predicted using MTF/TM techniques. The threshold modulation concept (TM) is discussed in Appendix A. The simulation output MTF used for predicting resolution is the combined MTF's of each stage multiplied by the target modulation. The intersection of the combined MTF curve for the system and the TM curve of the reduced negative film should occur at the frequency of limiting resolution. This limiting resolution should be equal to the limiting resolution of the simulated system, within the error associated with resolving power measurement. Since the MTF's of the master negative, master positive and hazed positive stages are already determined, the MTF of the reduced negative stage must be varied to control the reduced negative resolution.

b. Selection of Reduced Negative Lens f/Number

(1) To determine the output MTF curve for a specific simulation it is necessary to know the MTF and scale of the master negative, master positive, and hazed positive stages, and the MTF of the reduced negative lens. Mathematically, we can describe the process for calculating the output MTF curve as :

$$OM_S(\upsilon) = \frac{(MTF_{MN}\upsilon)\ (MTF_{MP}\upsilon)\ (MTF_{HP}\upsilon)}{R}(MTF_{RN}\upsilon)\left[\frac{C-1}{C+1}\right]$$

where: OM_S = Output modulation of the simulation system

υ = Spatial frequency in the reduced negative

R = Reduction in the reduced negative stage

$MTF_{MN}\upsilon$ = MTF of the master negative stage

$MTF_{MP}\upsilon$ = MTF of the master positive

$MTF_{HP}\upsilon$ = MTF of the hazed positive

$MTF_{RN}\upsilon$ = MTF of the reduced negative lens

C = target contrast

$\frac{C-1}{C+1}$ = target modulation

(3) To predict limiting tri-bar resolution for a given reduced negative, lens f/number and reduction, the appropriate reduced negative MTF curve was multiplied by the MTF of the master negative-positive stages at several frequencies close to the limiting resolution of the system to be simulated. Crossing this curve with the appropriate TM curve gave an estimated limiting resolution.

c. Equipment

(1) Three set ups were used to make the reduced negatives. Table 4 lists the data on each condition used to make simulations. For Condition 1, 7, and 13 [redacted] vacuum contact prints were 25X1 made with a specular light source. Conditions 2, 3, 8, 14 and 15 employed the Summicron lens and a collimator. Scale of the hazed positive was adjusted by an optical system that presented an aerial image at the focal point of the collimator. Focal length of the collimator was adjusted by changing the working distance.

(2) Resolution measurement data is to be supplied with all simulations sent to the customer. Such data, based on preliminary results, compares very well with the predicted values shown in Table 4.

Table 4

Conditions for Making the Reduced Negatives

Condition	Scene Number	Required Reduction	Desired Film Resolution (cycles/mm)	Predicted Film Resolution (cycles/mm)	Predicted 2:1 Contrast Lens Resolution	f/No. Used
*1	1	2.27X	118	42	-	Contact
2	1	4.55X	118	114	180	5.6
3	1	11.36X	170	165	215	4
4	1	20.45X	134	132	139	9
5	1	41.67X	155	160	170	6.9
6	1	71.21X	155	163	170	6.9
*7	3,4,5	3.0X	118	42	-	Contact
8	3,4,5	6.0X	118	118	167	6.3
9	3,4,5	15.0X	170	162	197	5.6
10	3,4,5	27.0X	134	134	139	9.0
11	3,4,5	55.0X	155	161	170	6.9
12	3,4,5	94.0X	155	165	170	6.9
*13	2,6	2.27X	118	23**	-	Contact
14	2,6	4.55X	118	86**	180	5.6
15	2,6	11.36X	170	145**	215	4
16	2,6	20.45X	134	129	139	9
17	2,6	41.67X	155	159	170	6.9
18	2,6	71.21X	155	162	170	6.9

d. Procedure

(1) All final photography was made on 3404 film processed in the dual-gamma process. The exposure criterion used was to place the scene Bmin at the AFS speed point (0.30 above fog). Figure 6 shows the characteristic curve for the film/process combination.

---

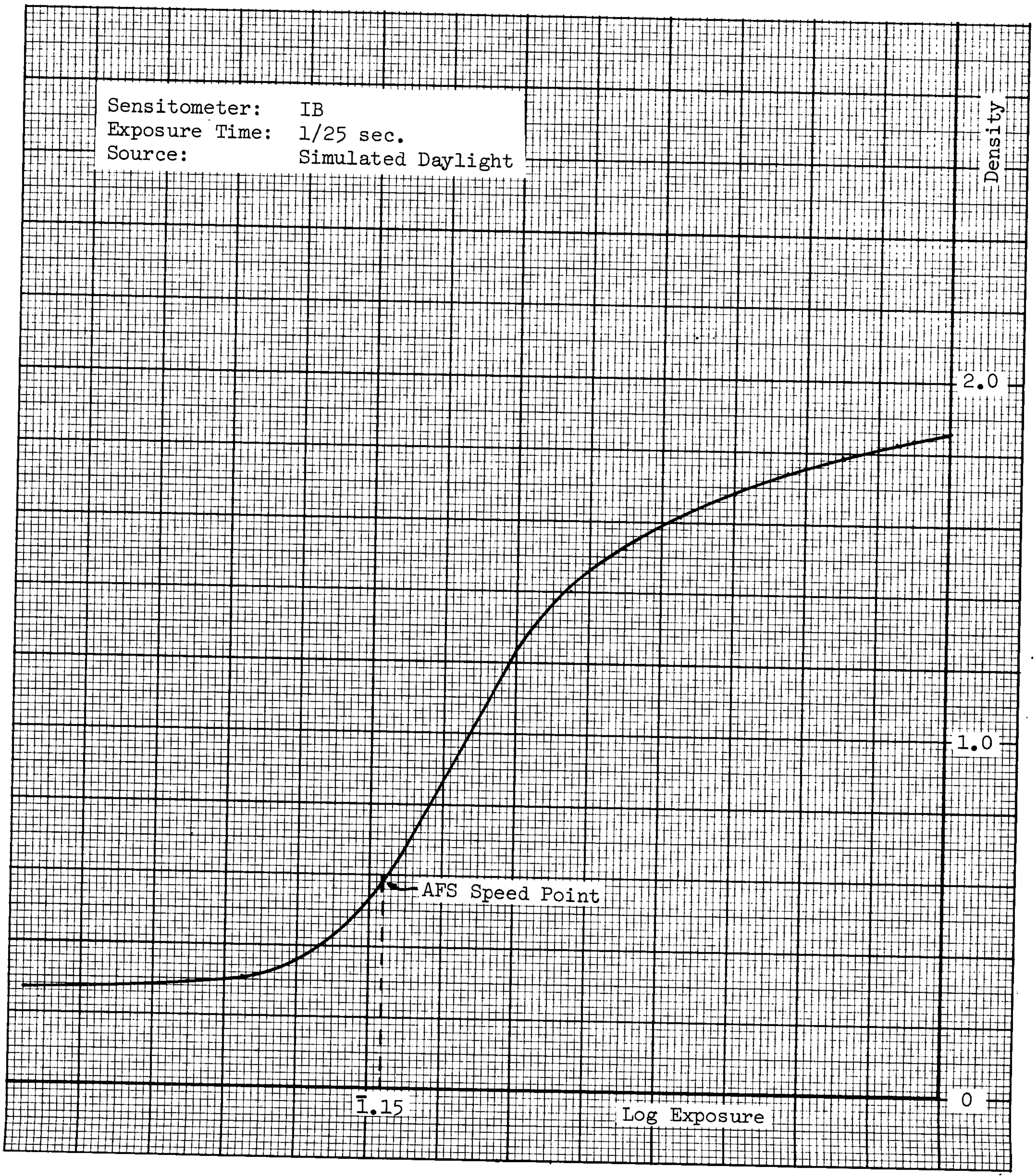
* Simulations were not made to required scale, so ground resolution could be maintained as specified.

** Image quality does not meet specifications.

Figure 6

Characteristic Curve for 3404 Film in Dual-Gamma Process

(exposed in IB Sensitometer)



(2) For each scale-f/number combination, the following procedure was used to establish that the simulations would have the required characteristics.

(a) First, resolving power tests were made with a 2:1 contrast test target to verify that the system was achieving the appropriate resolution.

(b) Second, an exposure series was made with a 1.20 density patch to determine the exposure required to place the scene Bmin at the film speed point.

(c) After it was verified that the system was achieving the proper resolution and the exposure was correct for the scenes, simulations were made.

(d) Ten reduced negatives were made for each scene.

(e) Resolution targets and density patches representing the scene Bmin were also made at each condition to demonstrate that the system was operating as required when the final images were made.

e. Reduced Negative Characteristics. Table 5 summarizes pertinent characteristics of the reduced negatives. High-quality targets are used to checkout the lens in the reduction system. Resolution measured in this manner is usually better than predicted resolution for simulations. This is because the hazed positives are actually degraded images. To achieve the proper ground resolution in the reduced negative it is necessary to have a lens MTF better than the actual system. The predicted resolution shown in the table in the best estimate of the actual 2:1 contrast resolution in the reduced negative.

12. Contact Positive Stage

a. Reduced negatives were contact printed using a vacuum print frame with a specular light source onto 2430 film processed to a gamma of 1.4. The characteristic curve for the film-process combination with the nominal density range covered by the scenes is shown in Figure 7.

Table 5

Characteristics of the Reduced Negatives

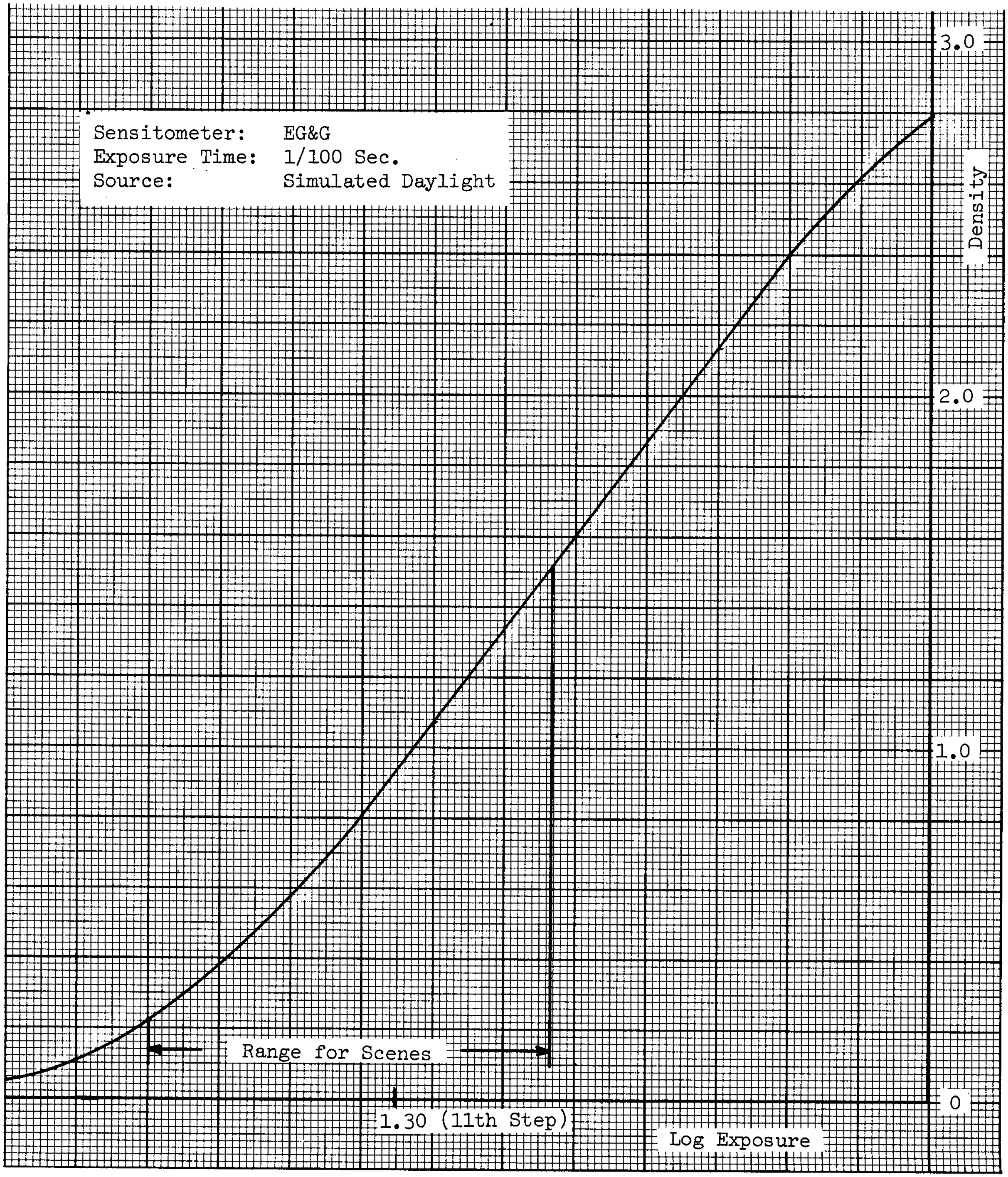
25X1

Condition	Scene Number	Scale
1	1	1:2,450
2	1	1:11,100
3	1	1:27,800
4	1	1:50,000
5	1	1:102,000
6	1	1:174,000
7	3,4,5	1:2,000
8	3,4,5	1:12,000
9	3,4,5	1:30,000
10	3,4,5	1:59,000
11	3,4,5	1:110,000
12	3,4,5	1:188,000
13	2,6	1:2,840
14	2,6	1:13,000
15	2,6	1:32,200
16	2,6	1:58,000
17	2,6	1:118,000
18	2,6	1:202,000

Approved For Release 2004/08/25 : CIA-RDP78B04770A000400050007-7

Figure 7

Characteristic Curve for 2430 Film in the Kodak Versamat Film Processor, Model 11C-M



b. Scenes were sandwiched between glass, and mounted in 2" x 2" slide mounts for ease of handling and viewing. Each scene was labeled with a number from 1 through 54 selected by drawing a number out of a hat. The code for identifying the simulation images was transmitted to the customer along with the images.

13. Delivered Images. Delivered images included three sets of contact positives mounted in 2" x 2" slide mounts and one set of unmounted reduced negatives. The remaining images, including master positives, hazed positives, reduced negatives and contact positives, are on file at the contractor's facility.

CONCLUSIONS

14. Objectives defined by the customer have been met with respect to simulations -- the contractor produced simulations for each of six scenes at six different quality levels.

15. Master negatives did not have sufficient image quality to make simulations demonstrating both scale and resolution at the [redacted] 25X1 ground resolution condition. By agreement with the customer the approximate ground resolution was obtained by contact printing the hazed positive and thus not obtaining the desired scale. Quality of the master negatives for Scenes 2 and 6 was inadequate for simulating ground resolution at the 25X1 [redacted] levels.

16. The lens used in acquiring the flight negatives was the principal contributor to the poor image quality at the master negative stage.

17. Only limiting 2:1 contrast ground resolution is depicted by these simulations. No attempt was made to simulate system MTF, since it could only be simulated for the two poorest quality systems.

18. Inclusion of both reflectance and edge targets in the same acquisition frame simplifies the preparation of simulations. Characteristics for these target types are given in the recommendations, paragraph 18.

19. Master negatives acquired at low altitude normally have a high scene contrast range, and should therefore be processed to use as much as possible of the straight-line portion of the characteristic curve.

RECOMMENDATIONS

20. Consider using a higher quality lens for making master negatives. It would also be preferable to use a longer focal length lens to reduce the $\cos^4$ fall off in the image plane. (However, consultation with the contractor is suggested to determine compatibility of the required simulation characteristics and equipment limitations before any future original negatives are made.)

21. In future efforts, attempt to photograph the following targets in the same frame as (or the closest possible frame to) the objects of interest in the simulation:

a. Reflectance Targets. These targets should be large enough so they are not influenced by the micro characteristics of the lens, and include ground measured brightnesses, made at the time of photography.

b. Edge Targets. A 2:1 to 5:1 contrast edge target should be included in the scene with an average reflectance of approximately 12 percent. The size of such targets should be at least 100 microns on the master negative film.

APPENDIX A

Threshold Modulation Theory and Application

1. In the simulation process, the TM (threshold modulation) concept is used to establish the conditions required to produce proper resolution in the images.

2. TM theory and measurement is described more extensively in a recent article in Applied Optics.* Basically, however, a film TM curve describes the amount of modulation in an aerial image required to produce a resolvable tri-bar image in the film. The film TM curve is a specific characteristic for a film process combination. Such a curve is somewhat unique in that it is determined by the use of both MTF and tri-bar resolution. The product of lens MTF and tri-bar target contrast is a measure of the modulation in the aerial image presented to the film. The TM curve is a plot of the minimum modulation required in the aerial image to produce a resolvable image in the film at a given frequency in cycles/mm. The curve is derived in exactly this manner in the laboratory by photographing targets of known contrast with lenses of known MTF. Images are read by a group of readers to determine limiting resolution. A series of data points are determined relating resolution and aerial image modulation and a curve is fit to these points. The form of a typical curve is shown in Figure A-1.

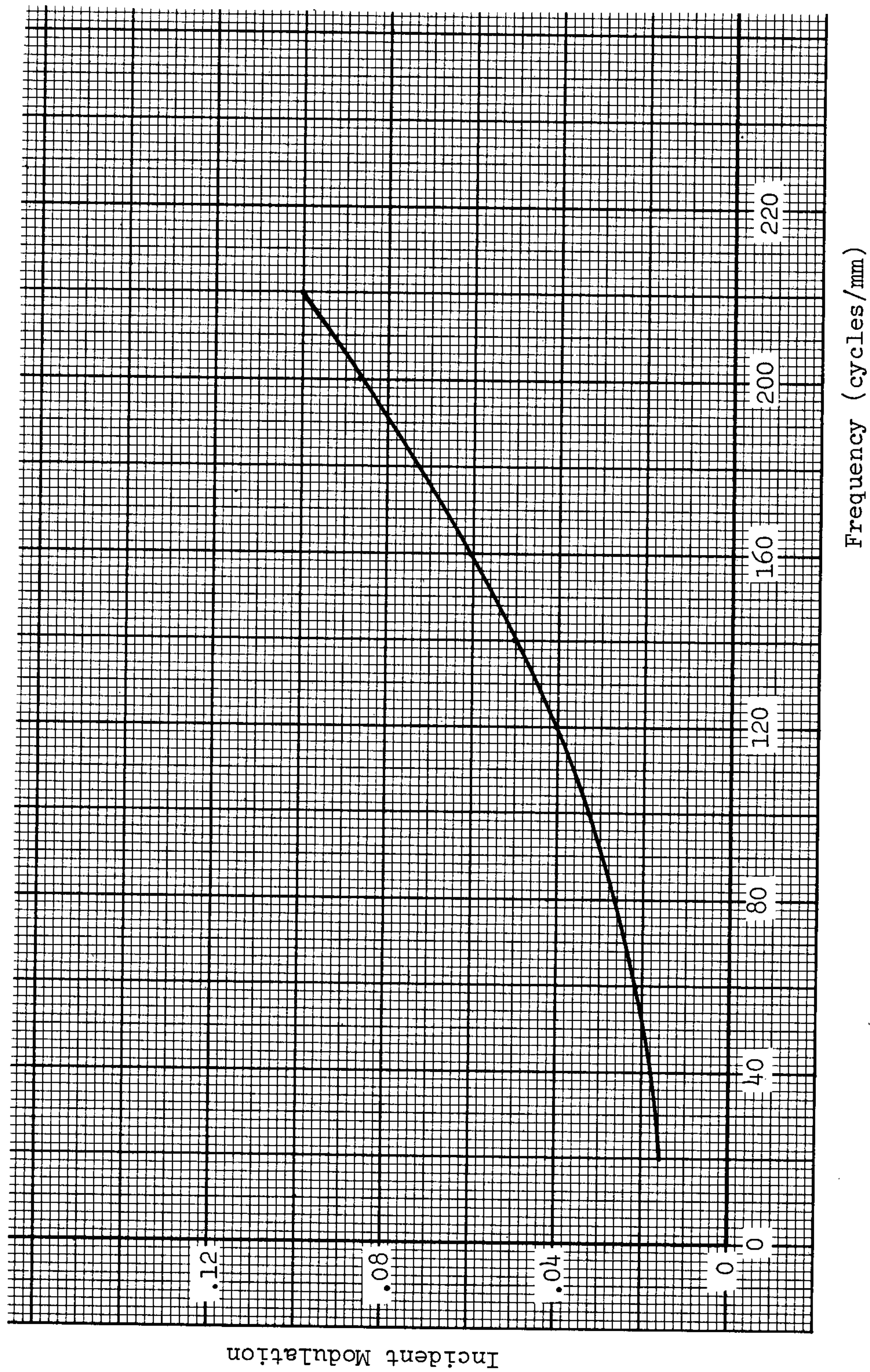
3. The curve can be used to predict the limiting resolution that will be obtained with other lenses and targets for which MTF and contrast are known. Limitations in the use of such curves, and some measure of confidence intervals, are described in the Applied Optics article mentioned earlier.

---

* T.J. Lauroesch, G.G. Fulmer, J.R. Edinger, G.T. Keene, and T.F. Kerwick, "Threshold Modulation Curves for Photographic Films," Applied Optics, Vol. 9, No.4, pp. 875-887, April 1970.

Figure A-1

TM Curve for 3404 Film in the Dual-Gamma Process



4. In the simulation process, the ultimate resolution in final simulations can be predicted by cascading the MTF of the various stages and combining these data with the TM curve for 3404 film. The MTF of the original negatives are determined by edge gradient analysis or from knowledge of the original acquisition system. MTF of the contact printing stages was determined in previous laboratory studies. The final step is to modify the optical system used in reductions to produce the proper total system MTF in presenting images to the 3404 film in the reduced negative stage (text, paragraph 8).

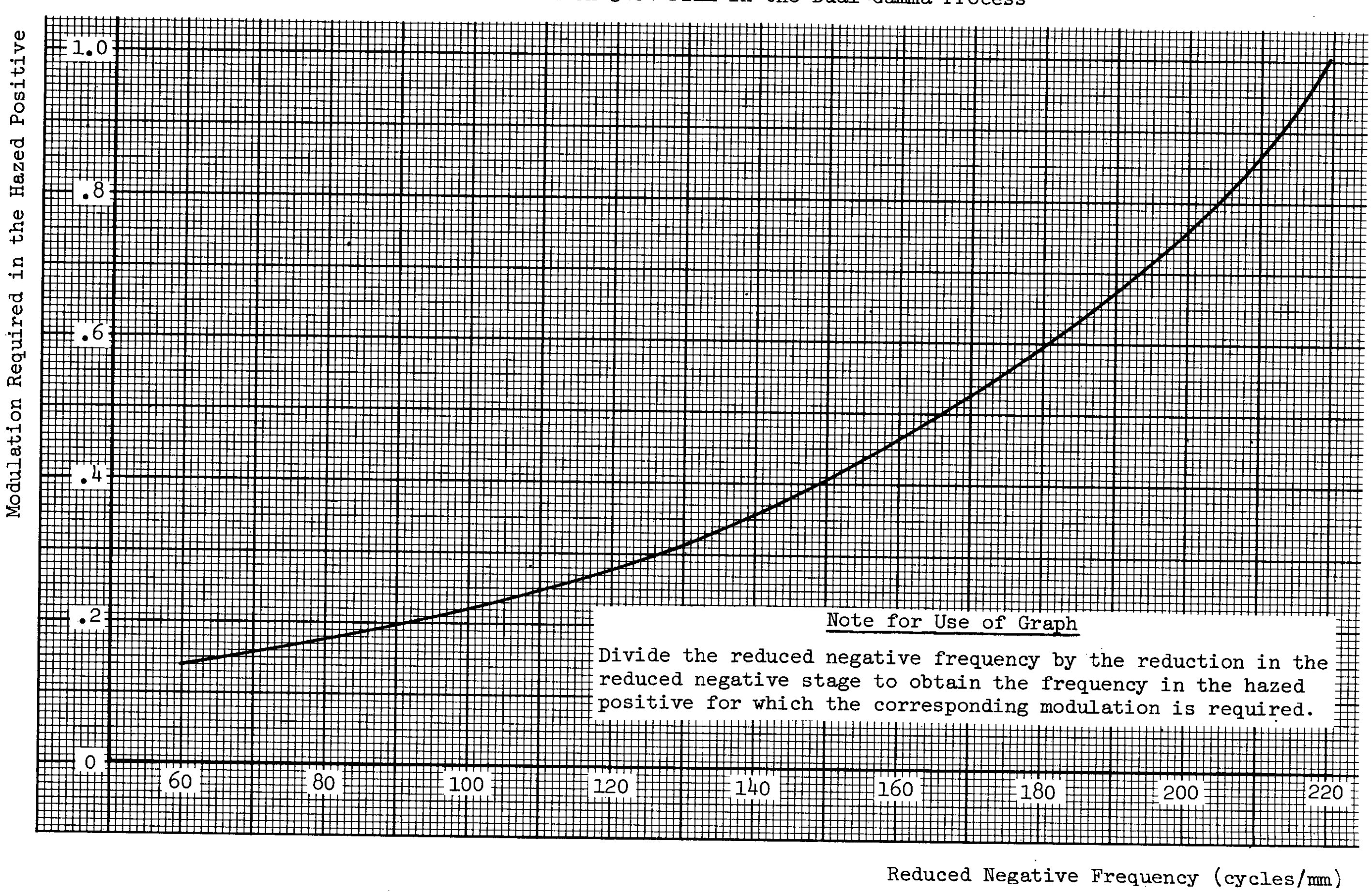
5. Previous studies, carrying specific test objects through the entire system, have shown that predictions are valid within the confidence limits placed on TM curves and MTF measurements. This technique permits the establishment of requirements for the original photography.

6. The optimum situation is to deal with only coarse frequencies in the original in the final reduction stage. However, to achieve fine ground resolution in a final reduction, it is necessary to deal with fairly high frequencies in the original. If MTF is sufficiently degraded in the original, it becomes impossible to achieve the proper ground resolution in the simulation.

7. Ideally, an original should be such that a reduction of at least 10X is required, and the modulation in the hazed positive stage (text, paragraph 7) at the desired limiting ground resolution must exceed a minimum value described by the curves in Figure A-2. If these conditions do not exist, a valid simulation cannot be made, proper ground resolution cannot be achieved and system MTF cannot be simulated. In any case, the characteristics desired in the simulation impose definite requirements on the original photography. The original photography thus should be geared for the intended job.

Figure A-2

Modulation Required in the Hazed Positive to Obtain Limiting 2:1 Contrast Resolution on 3404 Film in the Dual-Gamma Process



APPENDIX B

Effect of Haze on Tone Reproduction

1. At high altitudes, haze luminance has a significant effect on photography. Solar illumination incident on the atmosphere is scattered, and a portion of this radiation is seen by the camera, adding a uniform haze luminance to the luminance of ground objects. The haze luminance is not constant, but varies as a function of such factors as solar altitude, weather, and camera look angle. In addition, the atmospheric layer does not have 100 percent transmittance. Therefore, the atmosphere affects the apparent brightness of ground objects viewed from high altitudes according to the following approximate expression:

$$B_e = (B_o)\ (T) + B_H$$

where: B_e is the apparent brightness above the atmosphere in foot-lamberts

B_o is the ground object luminance in foot-lamberts

T is the transmittance of the atmosphere

B_H is the haze luminance in foot-lamberts

Since B_H is constant for a given photograph, haze luminance reduces the brightness range and scene contrast. It is important that simulations include the effects of haze, because scene contrast has a significant effect on image quality.

2. A study of scene luminance characteristics has shown that the average haze luminance at a solar altitude of 40 degrees is about 400 foot-lamberts. If a 5:1 contrast target having ground brightnesses of 200 and 1000 foot-lamberts is photographed in the presence of this amount of haze, the apparent contrast is reduced to less than 3:1 (600 and 1400 foot-lamberts). Experience has shown that 5:1 contrast targets are required to provide a 2:1 contrast input to high-altitude photographic

Approved For Release 2004/08/25 : CIA-RDP78B04770A000400050007-7

systems. Similarly, it has been observed that the average apparent brightness range in scenes as viewed in clear weather from high altitude is about 5:1.

3. In making simulations, the optimum situation is to have known brightnesses photographed in the master negative. Using photographic photometry, the amount of haze and flare in the original negative can be determined.

4. In the simulation process additional haze can be added to simulate any haze level. To prepare typical simulations, a total of 400 foot-lamberts of haze would be added. In the absence of calibrated brightnesses, the best compromise is to reduce the brightness range in the hazed positive to 5:1. This is a reasonable approximation if the scenes contain a typical range of ground objects from dark foliage and shadows to bright, man-made objects.

5. All scenes used in this project were considered typical. The brightness range in each hazed positive was reduced to 5:1 by applying a uniform flash exposure. Densities in the positives were balanced so that a common exposure could be used in making the reduced negatives. Exposure in the reduced negative stage was controlled to place the minimum brightness at the speed point of 3404 film. This produced simulations which are typical of properly exposed high altitude photographs.