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144649

TECHNICAL REPORT

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Contract NAS 9-11500

IMAGE DEGRADATION IN AERIAL IMAGERY DUPLICATES

Prepared By

Harold E. Lockwood
Photoscientist

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Photographic Technology Division
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

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LYNDON B. JOHNSON SPACE CENTER
Houston, Texas

IMAGE DEGRADATION IN AERIAL IMAGERY DUPLICATES

This report has been reviewed
and is approved.

SUBMITTED BY: Harold E. Lockwood
Harold E. Lockwood, Photoscientist

APPROVED: Gerard E. Sauer
Gerard E. Sauer, Manager
Photo Science Office

CONCURRENCE: D Howe
Denis H. G. Howe, Operations Manager

APPROVED: Noel T. Lamar
Noel T. Lamar, Technical Monitor

CONCURRENCE: R. C. Thompson for
John R. Brinkmann, Chief
Photographic Technology Division

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Technicolor Graphic Services, Inc.

IMAGE DEGRADATION IN AERIAL IMAGERY DUPLICATES

Introduction

Investigators working with JSC Earth Resources Aircraft Program (ERAP) imagery seldom have access to original camera films for analysis. They work with either a second or third generation duplicate.

The procedure for investigators to obtain duplicates, until recently, was specification of a second generation duplicate (made directly from the original) which was made and delivered by JSC. The current procedure calls for many investigators to order their duplicates from the EROS Data Center (EDC) in Sioux Falls, South Dakota.

JSC delivers a second generation duplicate to EDC therefore many investigators would receive a duplicate of that duplicate, a third generation copy of the original test film.

Problem

Image degradation is inherent in any duplication process. Resolution losses resulting from resolution characteristics of the film types used and printer slippage as well as contrast and color balance changes can be expected. Color duplicates, in general, are degraded more than black-and-white films because of the limitations imposed by the available aerial color duplicating stock.

Kodak Ektachrome Aerographic Duplicating film, type 2447, is the film used by PTD and EDC for aerial (wide film format) color film duplication. The rated high contrast (1000:1 target brightness range) resolution is 125 lines per millimeter (mm). Low contrast (1.6:1) resolution is rated at 63 lines per mm. Using manufacturer's published resolution values, the severity of the problem may be seen when duplicate resolution values are estimated by the usual calculation method;

$$1/R^2 = 1/R^2_1 + 1/R^2_2 \text{ where}$$

R = resolution in duplicate

R_1 = resolution of original or material being duplicated

R_2 = resolution of duplication material.

LOW CONTRAST CALCULATED RESOLUTION

Film Type	1.6:1 Resolution*	2nd Gen	% Loss from Orig.	3rd Gen	% Loss from Orig.
SO-397	40	34	15	30	25
SO-356	100	53	47	41	59
2443	32	29	9	26	19

HIGH CONTRAST CALCULATED RESOLUTION*

Film Type	1000:1 Resolution	2nd Gen	% Loss from Orig.	3rd Gen	% Loss from Orig.
SO-397	80	49	40	35	56
SO-356	200	77	62	48	76
2443	63	42	33	31	51

*High contrast subjects are not representative of photographic subjects, especially aerial subjects where atmospherics tend to reduce effective subject contrast. High contrast values are commonly cited and are included here for that reason.

Additionally the 2447 film/EA-5 process has a gamma higher than 1.0; therefore, the image contrast may be expected to rise with each duplication step making the exposure latitude narrower.

These problems were evaluated using available ERAP imagery and duplicates to evaluate and quantify actual system results.

Procedure

A series of ERAP data flights were made over the Fort Huachuca aerial test range in Arizona during evaluation of the large format Zeiss RMK cameras acquired for ERAP. Both medium altitude and high altitude flights were made to test and evaluate a series of color as well as black-and-white films. Some of the original color films from these tests were obtained and duplicated to produce second and third generation duplicates. The films obtained and evaluated were:

7 samples of SO-397, Kodak Ektagraphic EF Aerographic
2 samples of SO-356, Kodak High Definition Ektachrome
4 samples of 2443, Kodak Aerochrome Infrared

The number of samples for each film type varied because image degradation resulting from improper camera exposures and image motion due to aircraft altitude precluded consideration of many samples for resolution measurements.

The Fort Huachuca targets (Attachment 1) in each frame were read using a 50X magnifier to determine limiting resolution for each scene.

Resolution was calculated using the formula:

$$R = \frac{(0.0396)\ (h)}{(X)\ (f)}$$

where;

R = resolution in line pairs per mm.

h = aircraft altitude in feet

f = camera lens focal length in inches

X = target bar plus space width in feet (of smallest target set where bars and spacings may be observed)

Limiting resolution, determined subjectively by viewing the image of the Fort Huachuca targets and selecting the smallest target set in which the bars and spacings may be observed, is one method of specifying resolution.

A second method for evaluating degradation is to scan a selected target set in the original and duplicates to observe loss in modulation between the target bars and spacings. Although density differences in these cases may be a function of exposure the values achieved give a clear quantitative measure of degradation if the exposures are good. In this case, two frames of SO-397 original imagery along with second and third generation duplicates made on 2447 were scanned using the Optronics International Specscan microdensitometer. A 2 X 100 micron slit was used to scan and sample densities at 1 micron intervals across high contrast target set 12. Plots of these scans are attached here (Attachment 2).

Gamma was determined by reading the densities of the tail sensitometric step tablets on each roll of film. The density versus log exposure data for each roll of film is attached here. (Attachment 3).

RESULTS

A summary of resolution losses from the original determined by measuring limiting resolution is:

Film Type	2nd Generation	3rd Generation
SO-356	20 to 40% loss	40 to 70% loss
SO-397	10 to 20% loss	30 to 40% loss
2443	10 to 35% loss	20 to 40% loss

Image degradation determined by measuring loss of modulation or difference in density between resolution bar spacing in the imagery is as follows.

Density (max) - Density (min) Differences

SO-397 Sample 1 "low frequency"

Original	2nd Generation	3rd Generation
$\Delta D = 0.32$	$\Delta D = 0.23$	$\Delta D = 0.15$

SO-397 Sample 2 "high frequency"

$\Delta D = 0.16$	$\Delta D = 0.06$	$\Delta D = 0.03$

These two samples of the single film SO-397 were included to demonstrate that image degradation occurs in varying degrees depending on the spatial frequencies in the image. At the higher frequencies as demonstrated by sample 2, the degradation is greater. The plots included in Attachment 2 offer an even clearer demonstration of this degradation. Modulation transfer function data published in some areas is a clear description of this phenomenum.

Contrast gain was evaluated by measuring the gamma of the original, and second and third generation duplicates curves included in Attachment 3. These results were:

	- - - - - - - - Gamma- - - - - - - - -		
Original type	Original	2nd Gen	3rd Gen
SO-356	2.55	3.48	4.22
SO-397	1.65	2.19	3.00
2443	2.40	2.76	3.60

Cibachrome prints of appropriate frames of SO-397 original, first and second generation imagery are included as Attachment 4. These demonstrate the resolution and contrast degradation shown in the results.

CONCLUSIONS

Image degradation due to duplication is obvious. Each step in the duplication process results in increased degradation as measured by both resolution and contrast. Less obvious is the fact that degradation relative to the original imagery increases as the resolution of the original image increases.

Specifically, the following may be concluded from this study. It must be noted that these conclusions are not different than those expected intuitively or from other available data.

- Greater resolution loss may be expected when the original has higher resolution. The duplication stock is the limiting factor. Type 2447 film is capable of no more than 125 lines per millimeter high contrast; therefore, a duplicate of SO-356, for example, is restricted to this limit.

- The detail resolvable is a function of numerous factors including aircraft altitude and camera lens focal length, but the added factor of duplication is severe. The following chart shows ground target sizes resolvable with three test films.

GROUND TARGET SIZE RESOLVABLE

(expressed in meters)

Original Film	Altitude	Original	2nd Gen	3rd Gen
SO-356	3384	0.30	0.36-0.42	0.42-0.51
SO-397	5091	0.50	0.55-0.60	0.65-0.70
2443	5091	1.10	1.21-1.49	1.32-1.54

These losses represent at least 10 to 20% drop in resolution at each duplication step as determined by measuring limiting resolution.

Modulation losses within the image as determined by edge sharpness are also severe and degrades the image at all image frequencies although it is most severe at high frequencies or with small details.

- In those cases where high contrast is inherent in the original imagery, the most severe degradation may be caused by an increase in image contrast. Vignetting in the camera, partial cloud cover, urban areas, forest lands, wetlands with beach areas all represent subjects which suffer severe degradation because contrast increase narrows exposure latitude. A comparison of SO-356 data shows a 1 f-stop (40%) loss in latitude and an increase of 20% in density range at the third generation, a severe degradation. This degradation is apparent in the imagery shown in set C, Attachment 4.

- Imagery shown in Attachment 4, sets A and B shows the 10 to 20% loss of detail measured with SO-397. Contrast degradation with SO-397 is less severe as a problem than with 2443 or SO-356. The film's ability to record detail for measurement is degraded, however.

- Every effort should be made to reduce the number of generations involved with duplication of imagery especially where either high resolution or high contrast originals are used for recording.

- Less obvious is the requirement for a high resolution, gamma 1.0 color duplication stock which definitely exists. A resolution of 200 lines per millimeter high contrast (1000:1) would be desirable.

ATTACHMENT 1

The Fort Huachuca, Arizona ground targets and dimensions of target bars and spaces.

TABLE II. - BAR DIMENSIONS

Group No.	Width	Group No.	Width	Group No.	Width	Group No.	Width
1	9'11.38"	14	2'2.94"	27	6.00"	40	1.34"
2	8'10.38"	15	2'0.00"	28	5.33"	41	1.19"
3	7'10.81"	16	1'9.38"	29	4.75"	42	1.06"
4	7'0.50"	17	1'7.06"	30	4.25"	43	.94"
5	6'3.25"	18	1'5.00"	31	3.79"	44	.84"
6	5'7.06"	19	1'3.13"	32	3.38"	45	.75"
7	4'11.75"	20	1'1.50"	33	3.00"	46	.67"
8	4'5.25"	21	1'0.00"	34	2.69"	47	.59"
9	3'11.44"	22	10.69"	35	2.38"	48	.53"
10	3'6.25"	23	9.50"	36	2.13"	49	.47"
11	3'1.63"	24	8.50"	37	1.88"	50	.42"
12	2'9.50"	25	7.56"	38	1.69"		
13	2'6.25"	26	6.75"	39	1.50"		

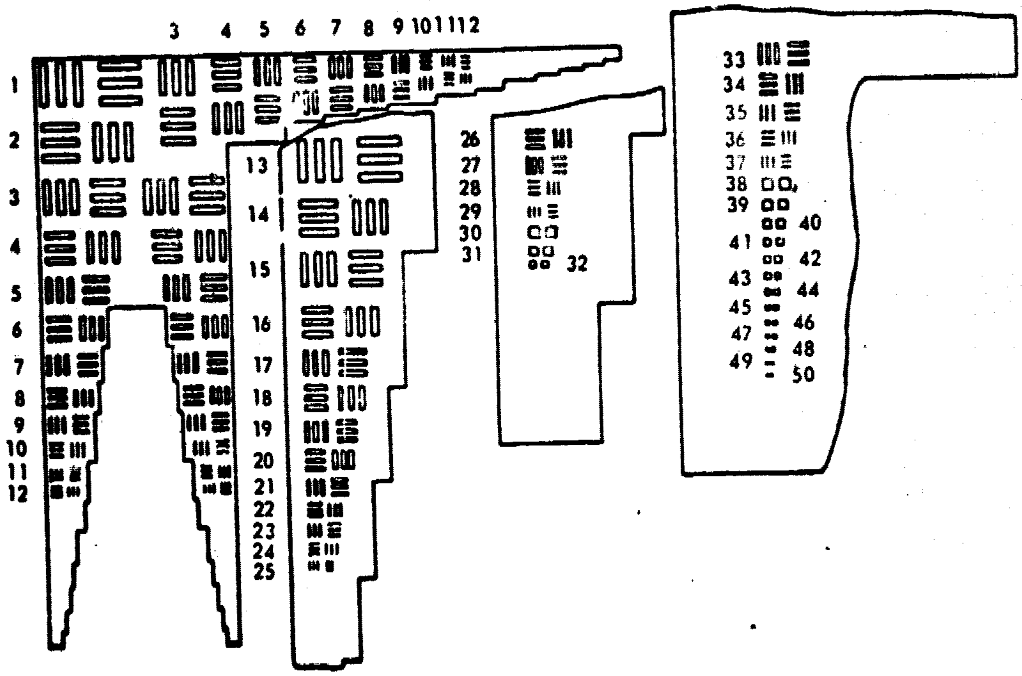

Figure 4.- Fort Huachuca test targets.

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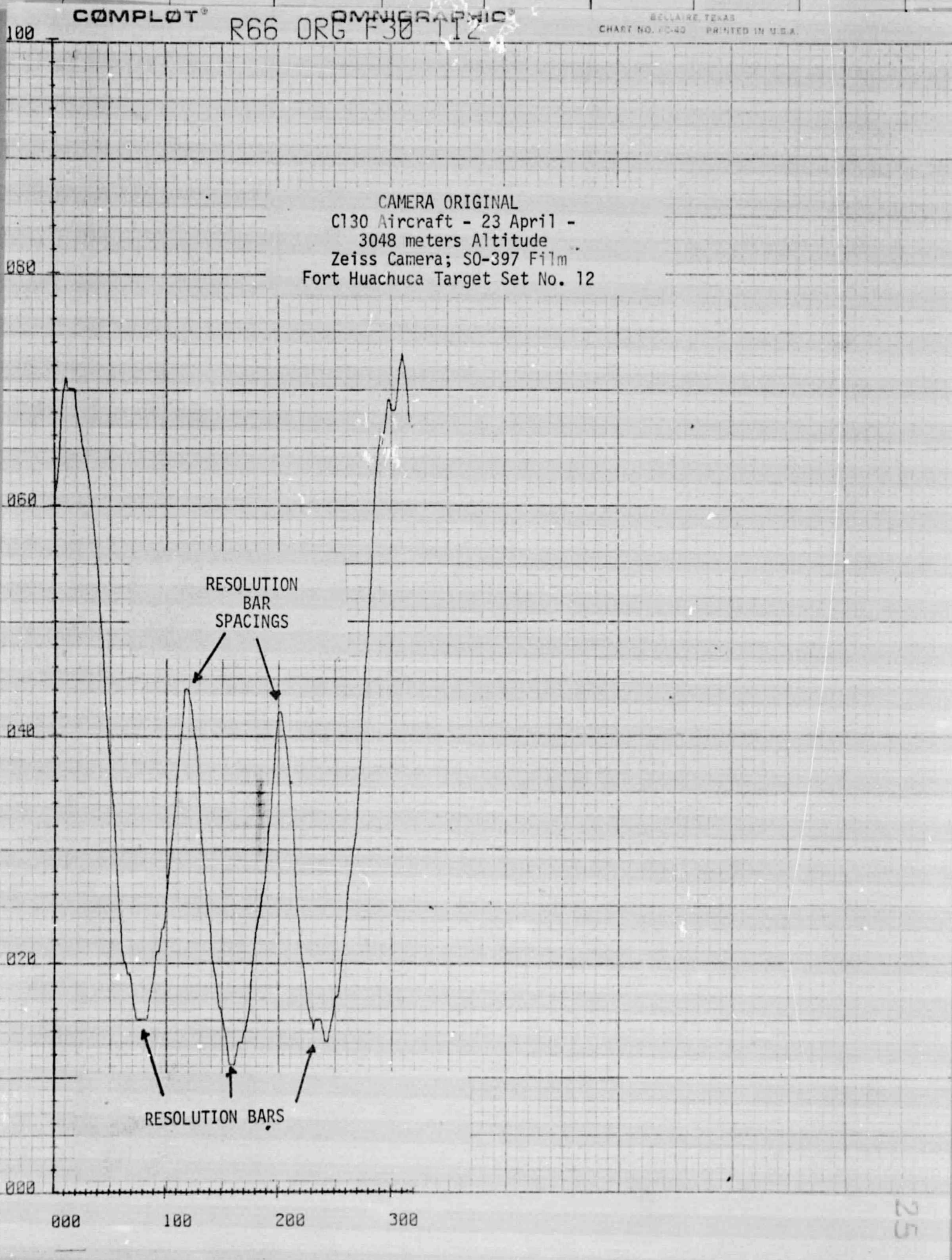
ATTACHMENT 2

Specscan microdensitometer density plots of two original SO-397 images of target bars and second and third generation duplicates of each.



CØMPLØT
OMNIGRAPHIC
R66 ORG F30 T12
BELLAIRE TEXAS
CHART NO. FC-40 PRINTED IN U.S.A.
CAMERA ORIGINAL
C130 Aircraft - 23 April -
3048 meters Altitude
Zeiss Camera; SO-397 Film
Fort Huachuca Target Set No. 12
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RESOLUTION BARS
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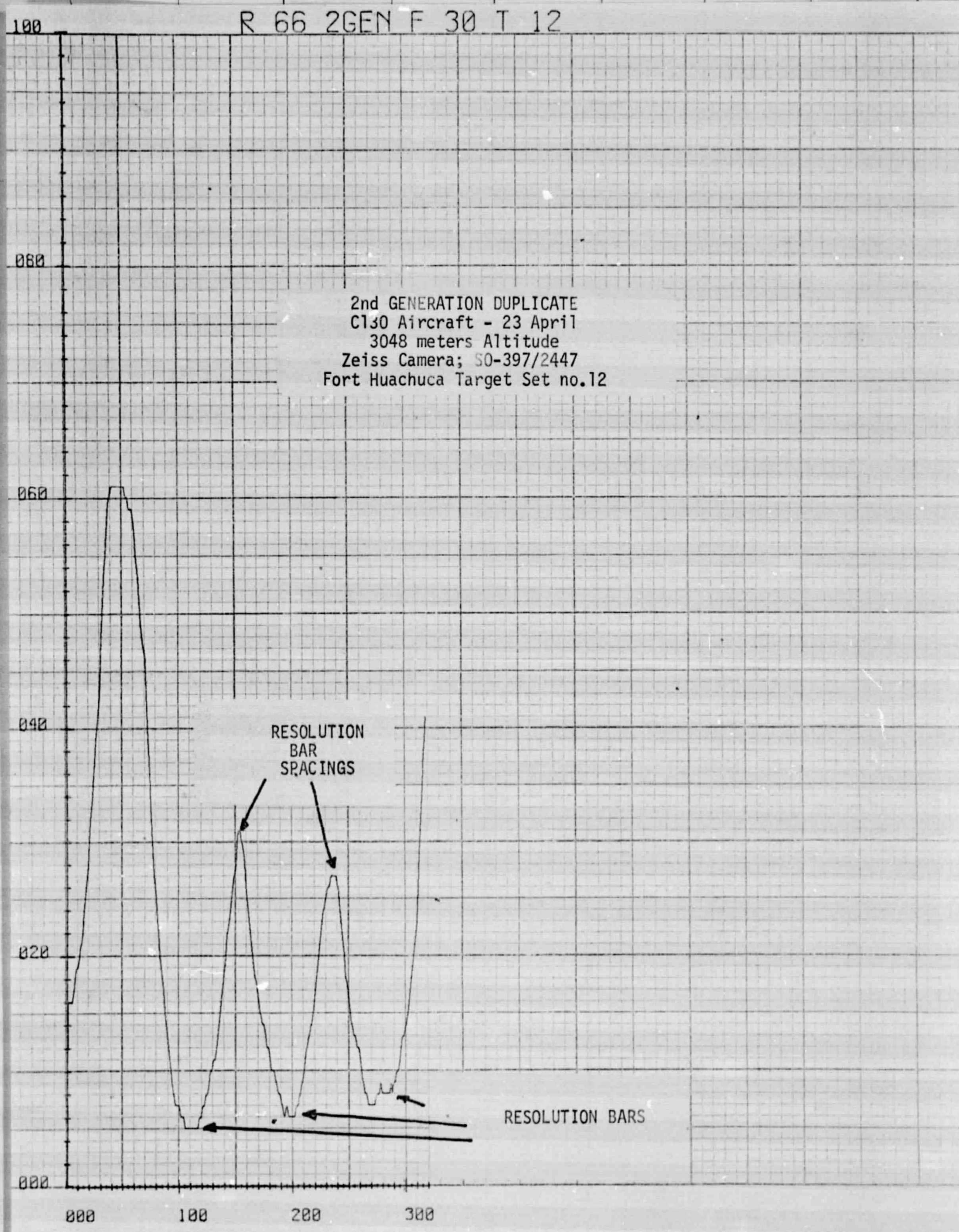
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C130 Aircraft - 23 April
3048 meters Altitude
Zeiss Camera; SO-397/2447
Fort Huachuca Target Set no.12
RESOLUTION
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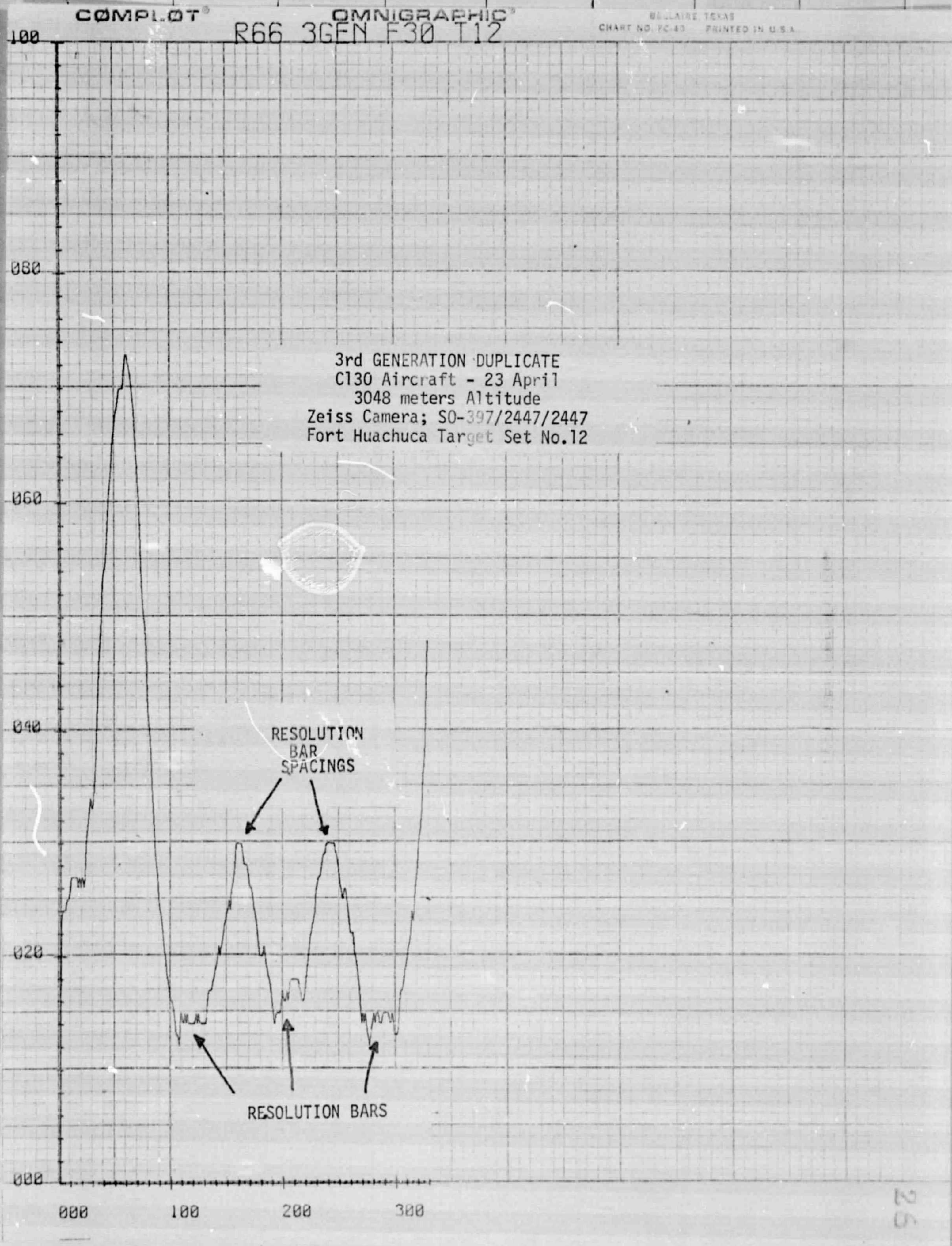
SPACINGS
RESOLUTION BARS



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OMNIGRAPHIC®
BELLAIRE, TEXAS
CHART NO. FC-40 PRINTED IN U.S.A.
R66 3GEN F30 T12
3rd GENERATION DUPLICATE
C130 Aircraft - 23 April
3048 meters Altitude
Zeiss Camera; SO-397/2447/2447
Fort Huachuca Target Set No.12
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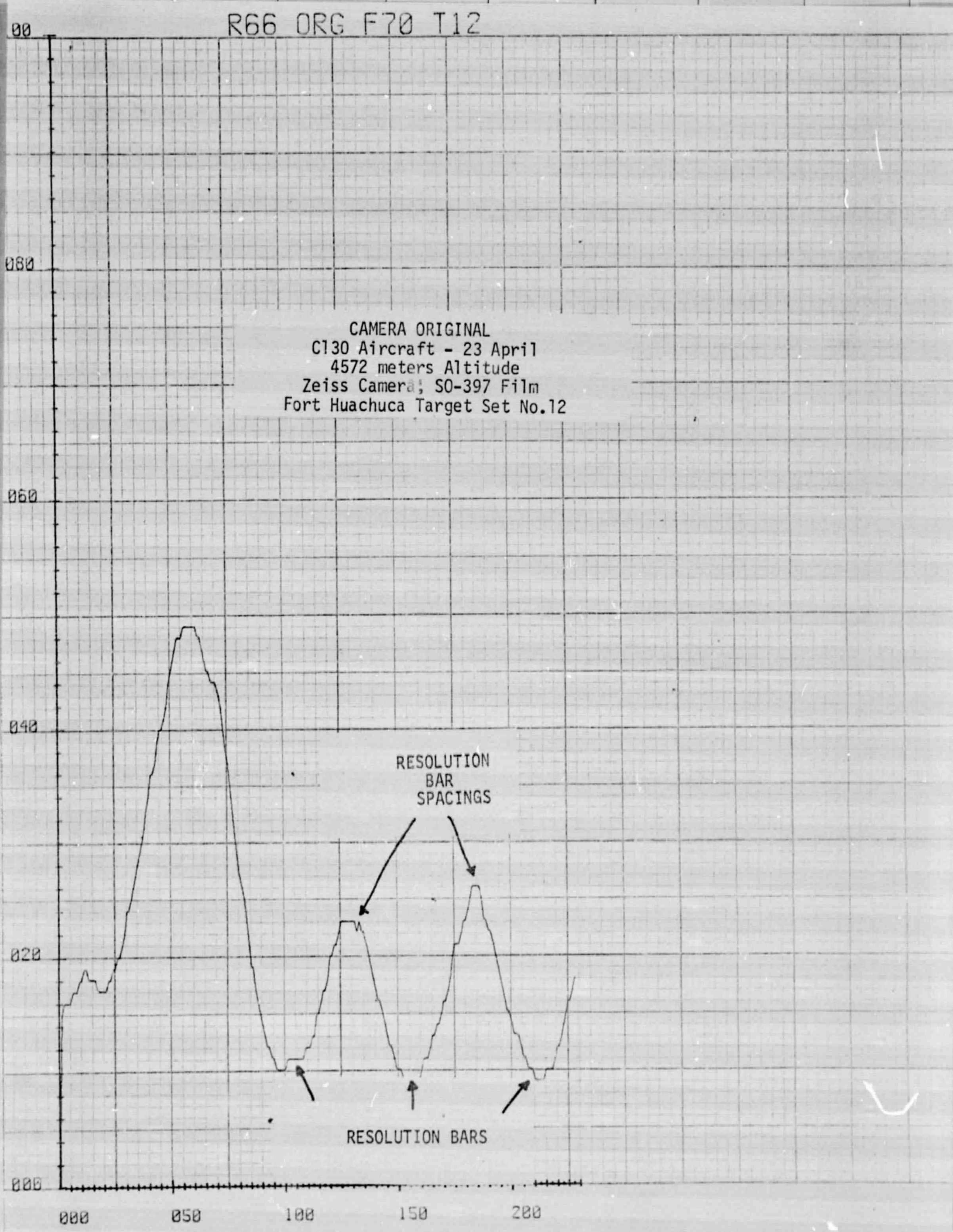

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4572 meters Altitude
Zeiss Camera; SO-397 Film
Fort Huachuca Target Set No.12
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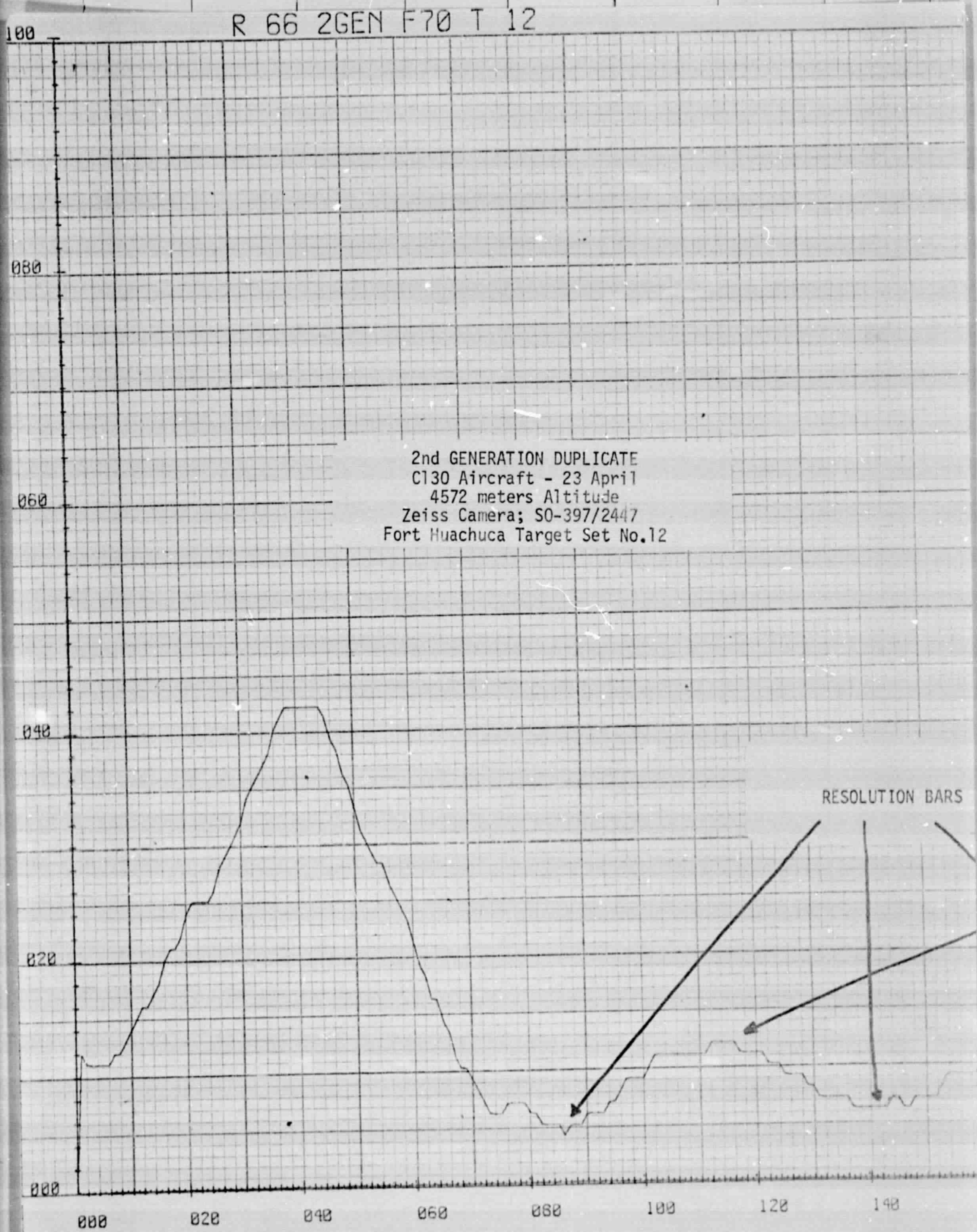

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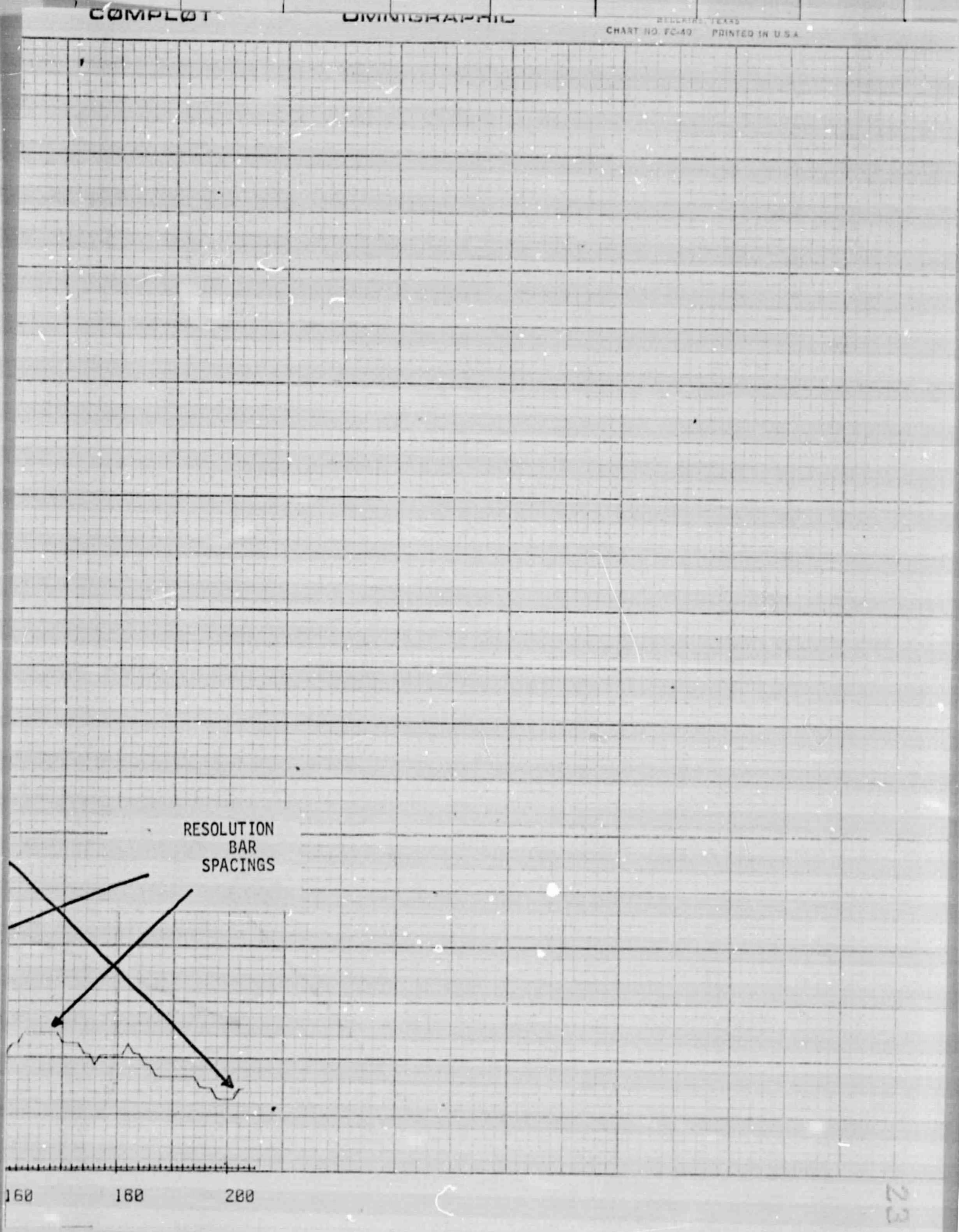
RESOLUTION BARS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RESOLUTION BAR SPACINGS
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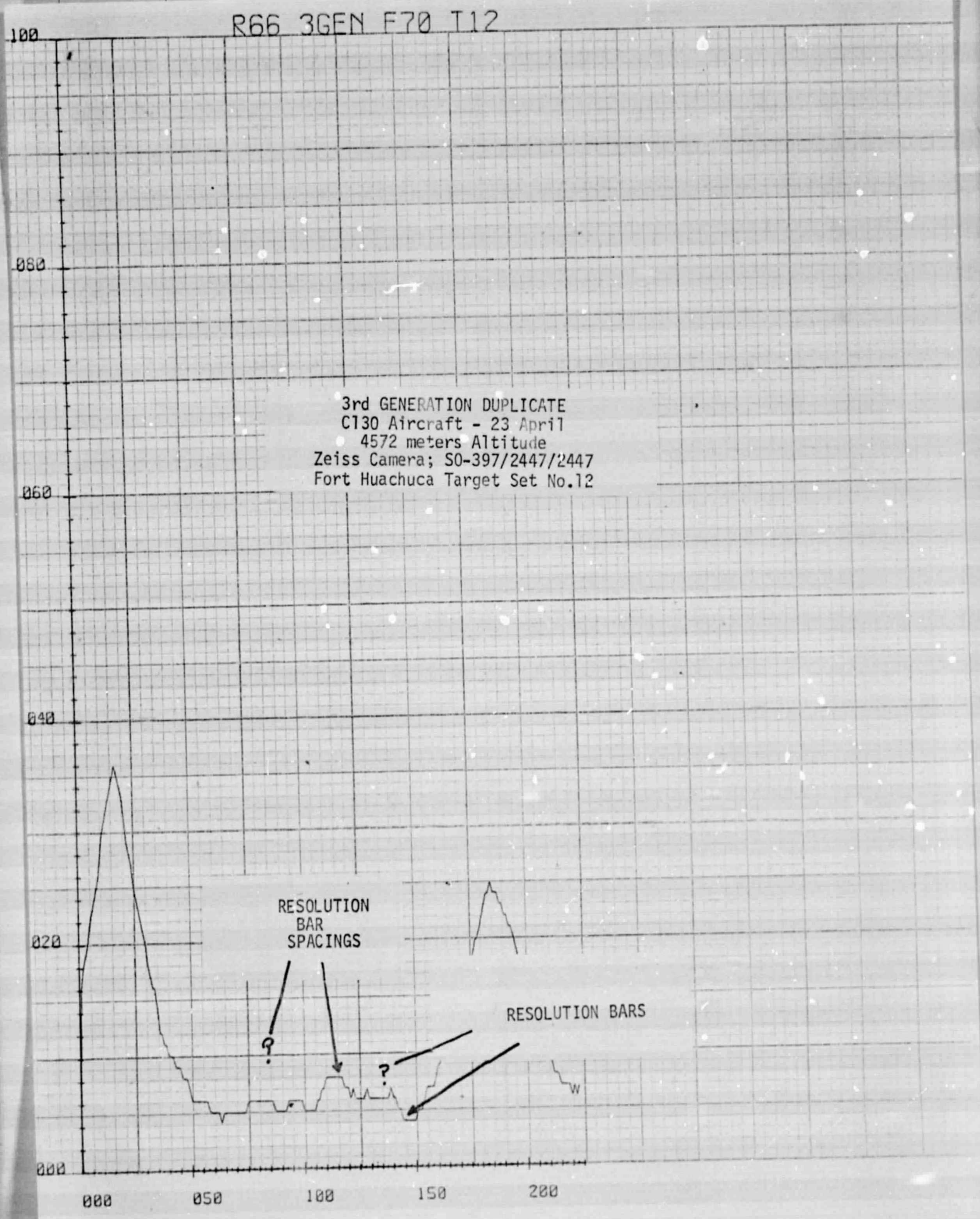
R66 3GEN F70 T12
3rd GENERATION DUPLICATE
C130 Aircraft - 23 April
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ATTACHMENT 3

Density versus log exposure curves for original, second and third generation duplicates of typical rolls of imagery for film types SO-356, SO-397, 2443.

DATE Nov 74 CONTROL # MX 290-R1 29 TASK Zeiss PREPARED BY

FILM SO-356 EMULSION # 19-3 MFG EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER I-B	PROCESSOR 1811 #2	INSTRUMENT MacBeth	SPEED ( )
ILLUMINANT 2850 °K	CHEMISTRY EA-5	TYPE TD504	D-MAX
TIME 1/5 SEC.	SPEED TANKS 5 FPM	APERTURE SIZE 3 MM	GAMMA
FILTER 5500°K	TEMP °F 105 TIME	FILTER Status A	BASE + FOG

CHEMICAL ANALYSIS

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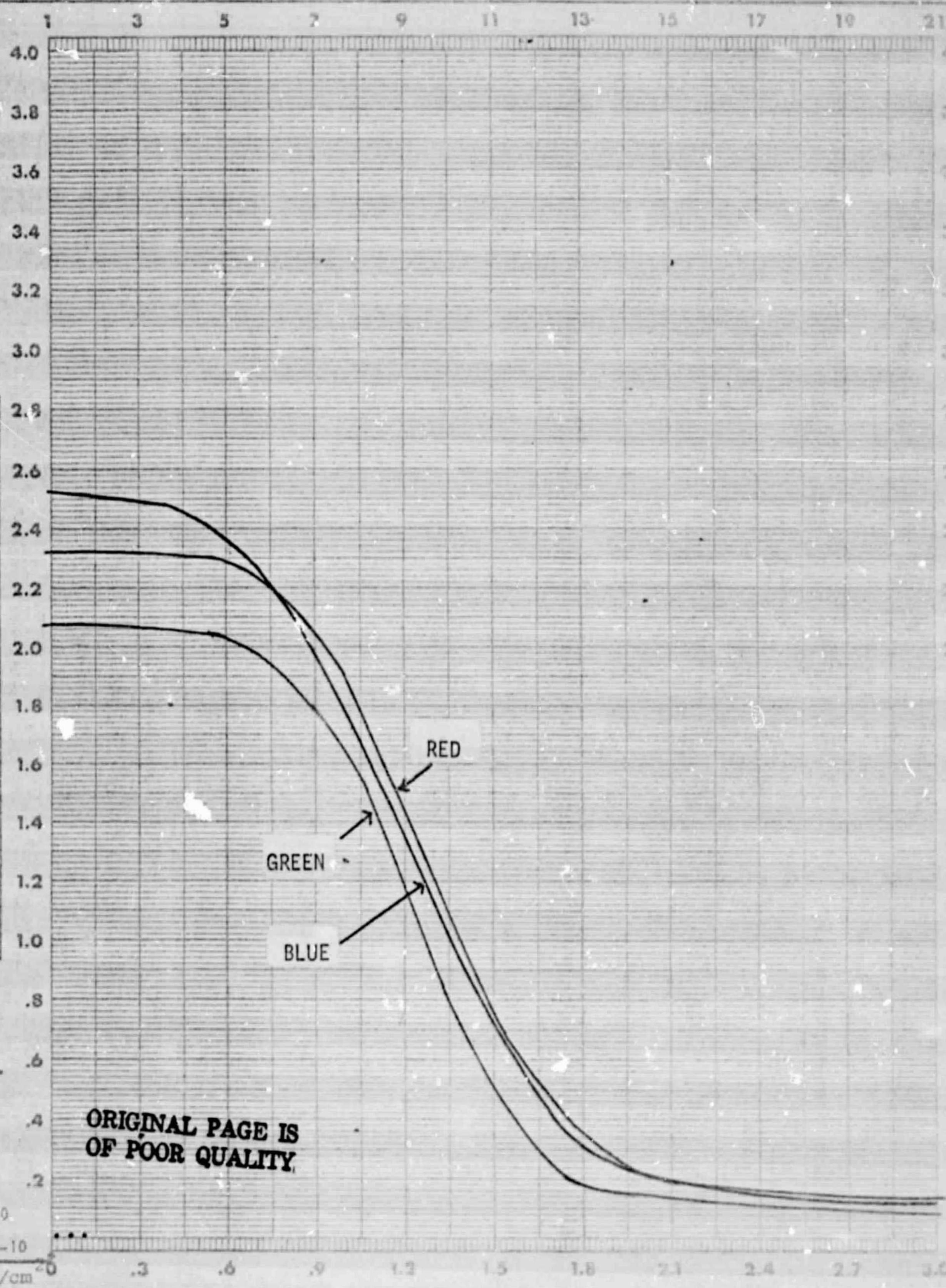

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ABSOLUTE LOG E AT R.L.E. = 0

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DATE Nov 74 CONTROL # MX 290 Roll 29 TASK Zeiss PREPARED BY

FILM SO-356 EMULSION # 19-3 MFG EXPIRATION DATE

EXPOSURE DATA		PROCESSING DATA		DENSITOMETRY			
SENSITOMETER	I-B	PROCESSOR	1811 #2	INSTRUMENT	MacBeth	SPEED	
ILLUMINANT	2850 °K	CHEMISTRY	EA-5	TYPE	TD504	D-MAX	
TIME	1/5 SEC	SPEED	5	APERTURE SIZE	3	GAMMA	2.55
FILTER	5500°K	TEMP °F	105	FILTER	Visual	BASE + FOG	

CHEMICAL ANALYSIS

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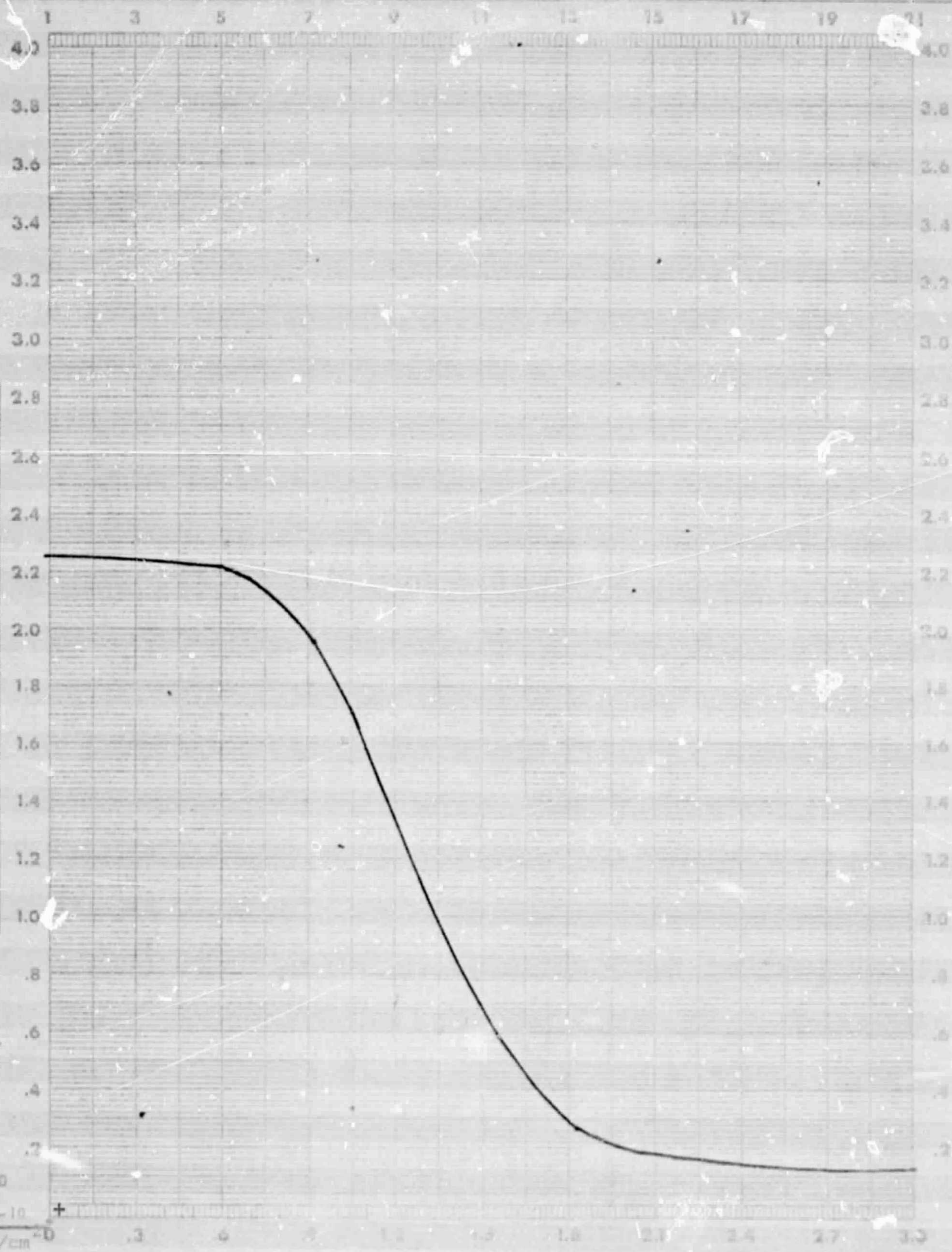

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DATE Aug 75 CONTROL # MX 290 R1 29 TASK 2nd Gen SO-356/2447 PREPARED BY

FILM SO-356 EMULSION # MFG EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER	PROCESSOR	INSTRUMENT	SPEED ( )
ILLUMINANT °K	CHEMISTRY	TYPE	D-MAX
TIME SEC	SPEED TANKS FPM	APERTURE SIZE MM	GAMMA
FILTER	TEMP °F TIME	FILTER	BASE + FOG

CHEMICAL ANALYSIS

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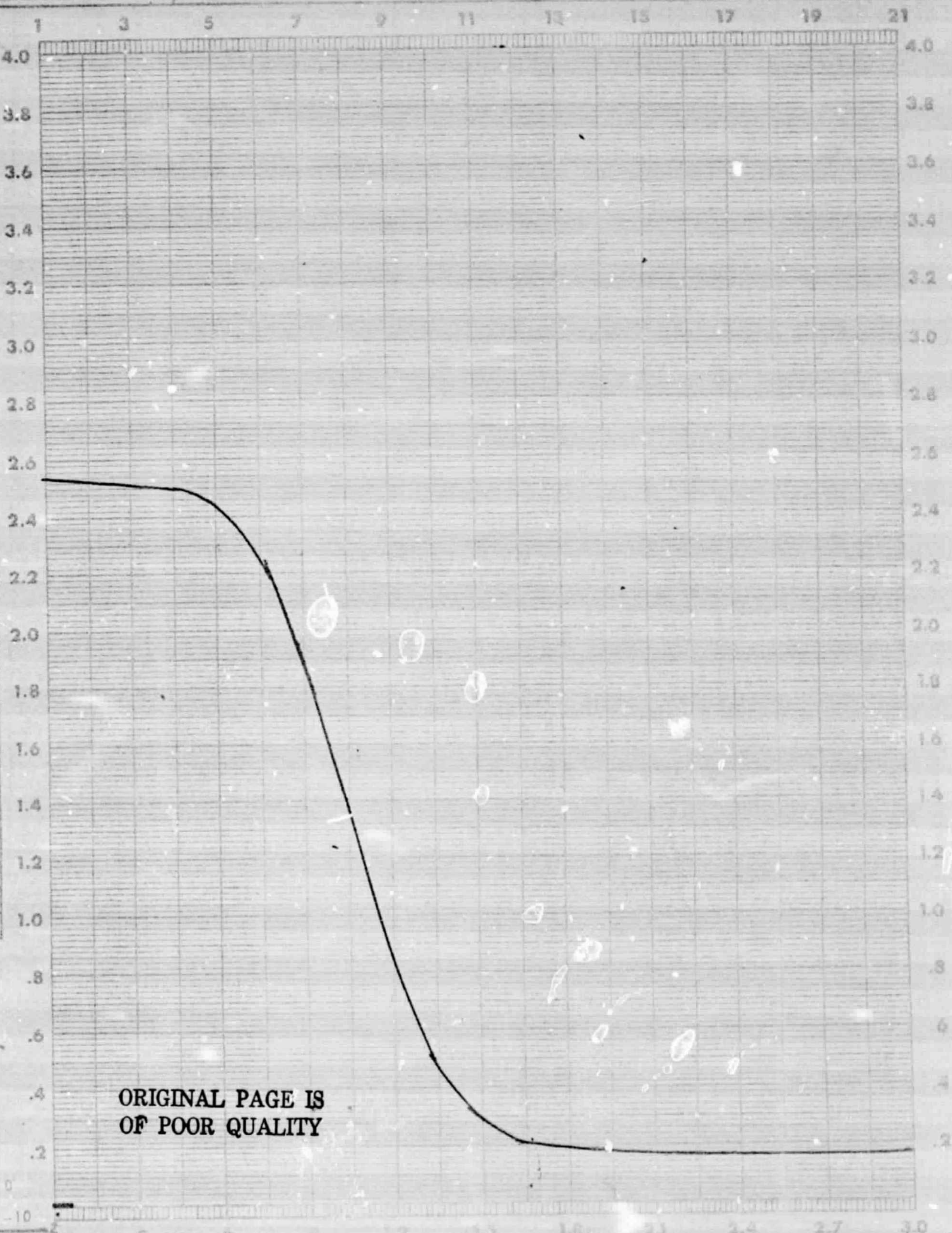

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FILM SO/356 EMULSION # ____ MFG ____ EXPIRATION DATE ____

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER ____	PROCESSOR ____	INSTRUMENT ____	SPEED ( ) ____
ILLUMINANT ____ °K	CHEMISTRY ____	TYPE ____	D-MAX ____
TIME ____ SEC.	SPEED ____ TANKS ____ FPM	APERTURE SIZE ____ MM	GAMMA ____
FILTER ____	TEMP °F ____ TIME ____	FILTER ____	BASE + FOG ____

CHEMICAL ANALYSIS

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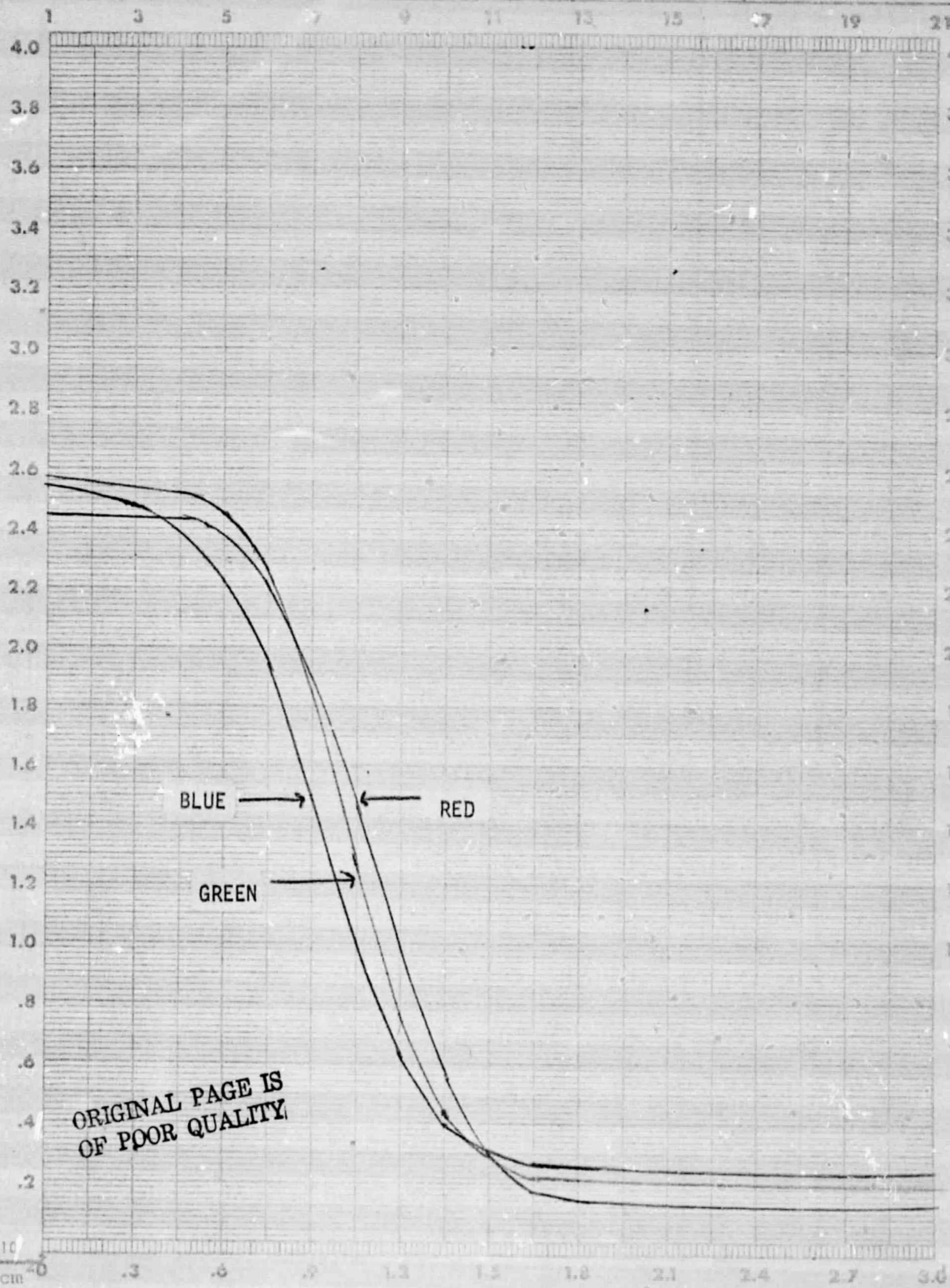

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FILM SO-356 EMULSION # MFG EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER I-B	PROCESSOR	INSTRUMENT	SPEED
ILLUMINANT °K	CHEMISTRY	TYPE	D-MAX
TIME SEC.	SPEED	APERTURE SIZE	GAMMA
FILTER	TEMP °F TIME	FILTER	BASE + FOG

CHEMICAL ANALYSIS

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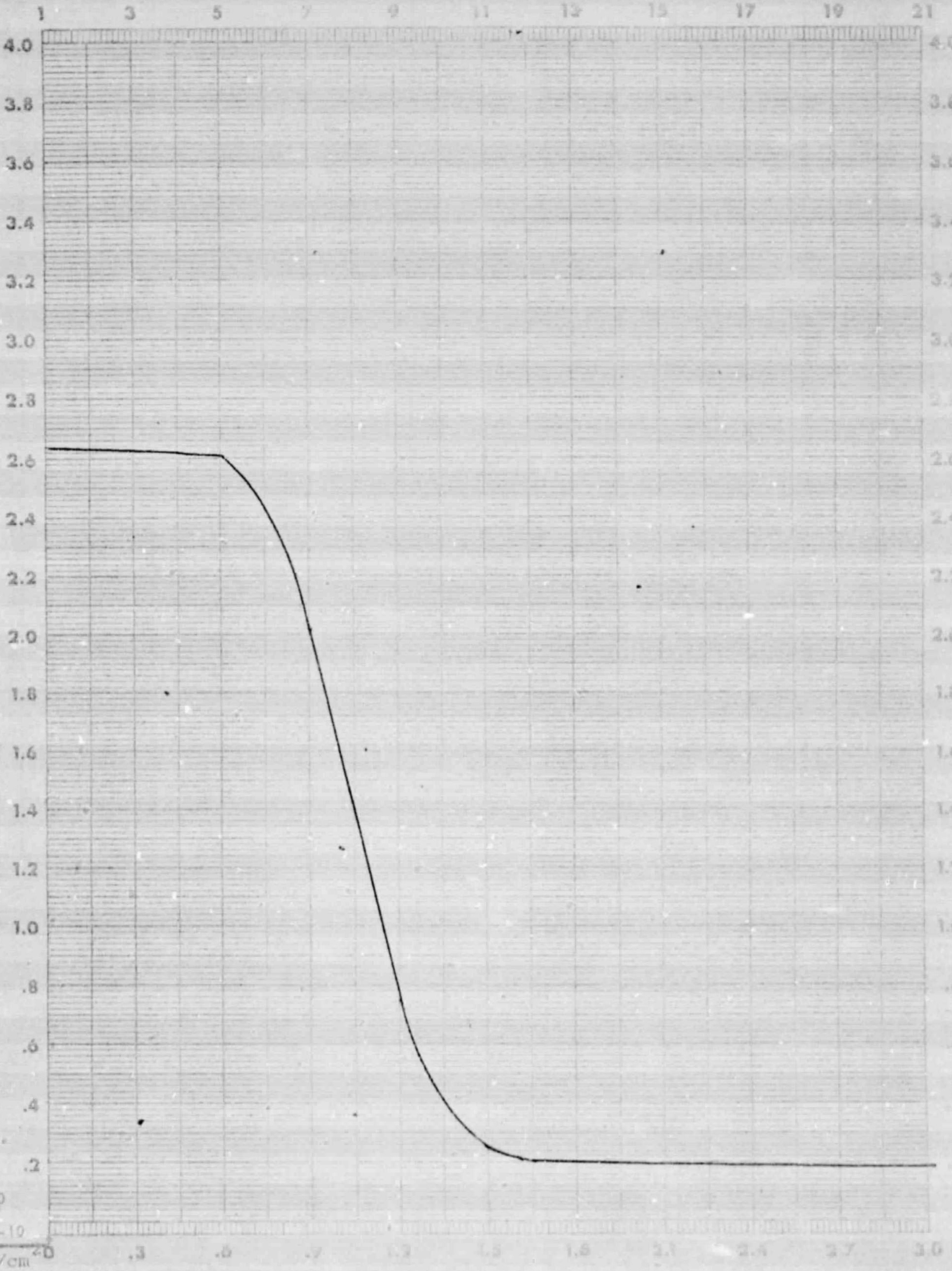

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FILM SO-356 EMULSION # MFG EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER	PROCESSOR	INSTRUMENT	SPEED ( )
ILLUMINANT K	CHEMISTRY	TYPE	D-MAX
TIME SEC.	SPEED TANKS FPM	APERTURE SIZE MM	GAMMA
FILTER	TEMP °F TIME	FILTER	BASE + FOG

CHEMICAL ANALYSIS

SP GR

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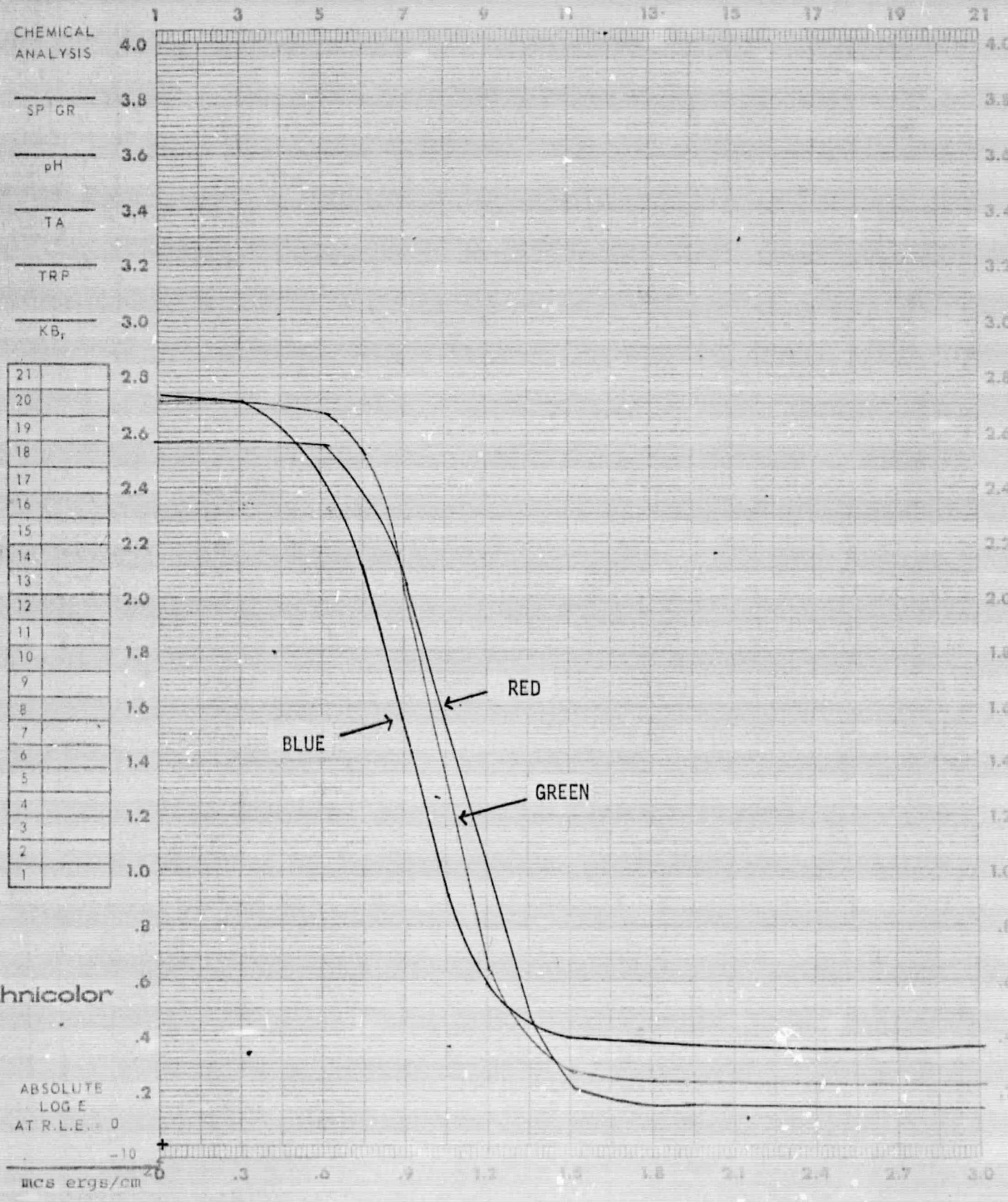

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mcs ergs/cm

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FILM SO-397 EMULSION # 51-1 MFG ______ EXPIRATION DATE ______

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER I-B	PROCESSOR 1811 #1	INSTRUMENT MacBeth	SPEED ( )
ILLUMINANT 2850 °K	CHEMISTRY EA-5	TYPE TD504	D-MAX
TIME 1/50 SEC.	SPEED ___ TANKS 9 FPM	APERTURE SIZE 3 MM	GAMMA
FILTER 5500°K	TEMP °F 115 TIME	FILTER Visual	BASE + FOG

CHEMICAL ANALYSIS

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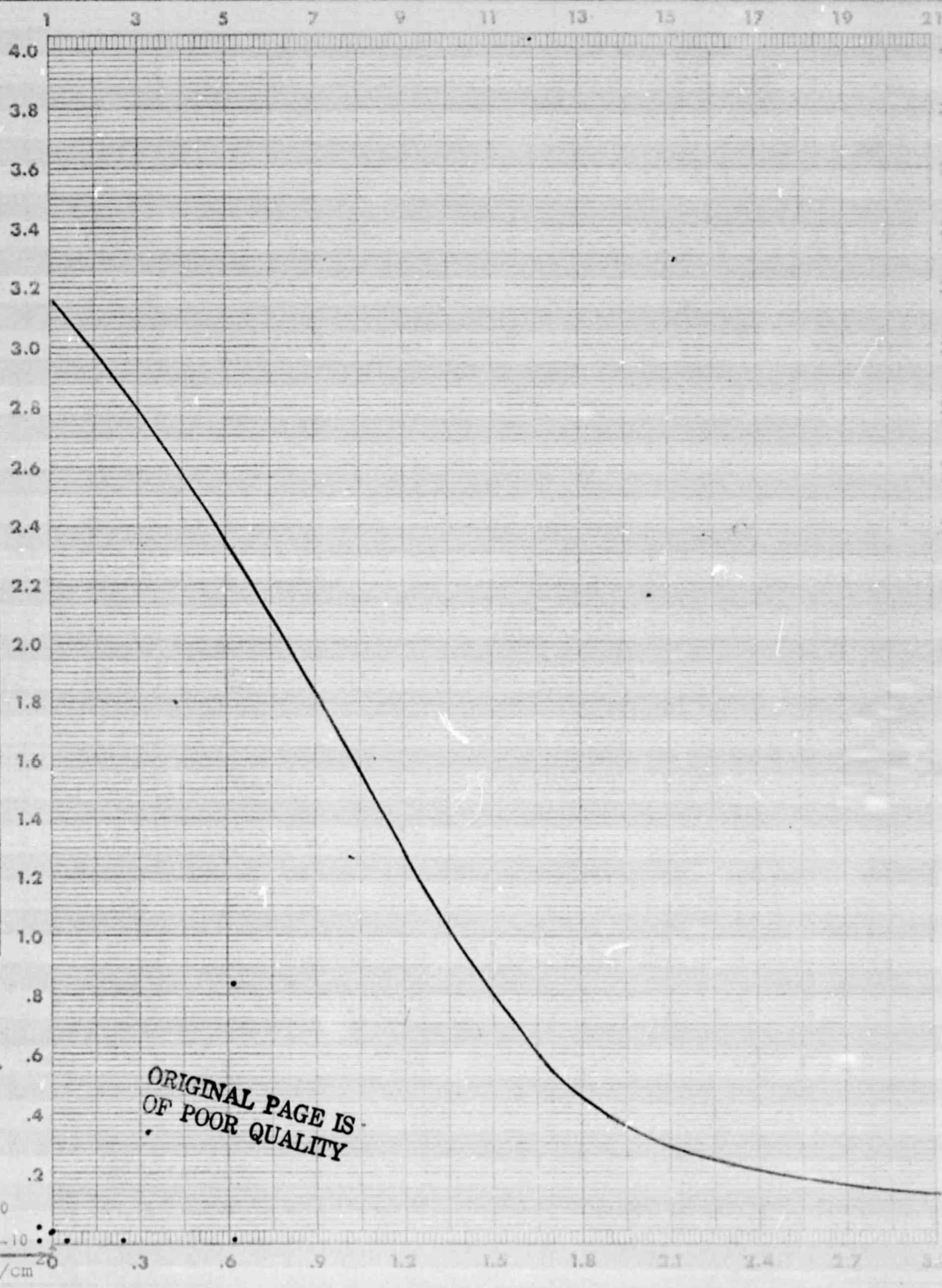

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ABSOLUTE LOG E AT R.L.E. = 0

mcs ergs/cm²

DATE Aug 75 CONTROL # MX 306 R1 66 TASK ______ PREPARED BY ______

FILM SO-397 EMULSION # 51-1 MFG ______ EXPIRATION DATE ______

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
+ SENSITOMETER I-B	PROCESSOR 1811 #1	INSTRUMENT MacBeth	SPEED ( )
ILLUMINANT 2850 °K	CHEMISTRY EA-5	TYPE TD504	D-MAX
TIME 1/50 SEC.	SPEED ___ TANKS 9 FPM	APERTURE SIZE 3 MM	GAMMA
FILTER 5500°K	TEMP °F 115 TIME	FILTER Status A	BASE + FOG

CHEMICAL ANALYSIS

SP GR

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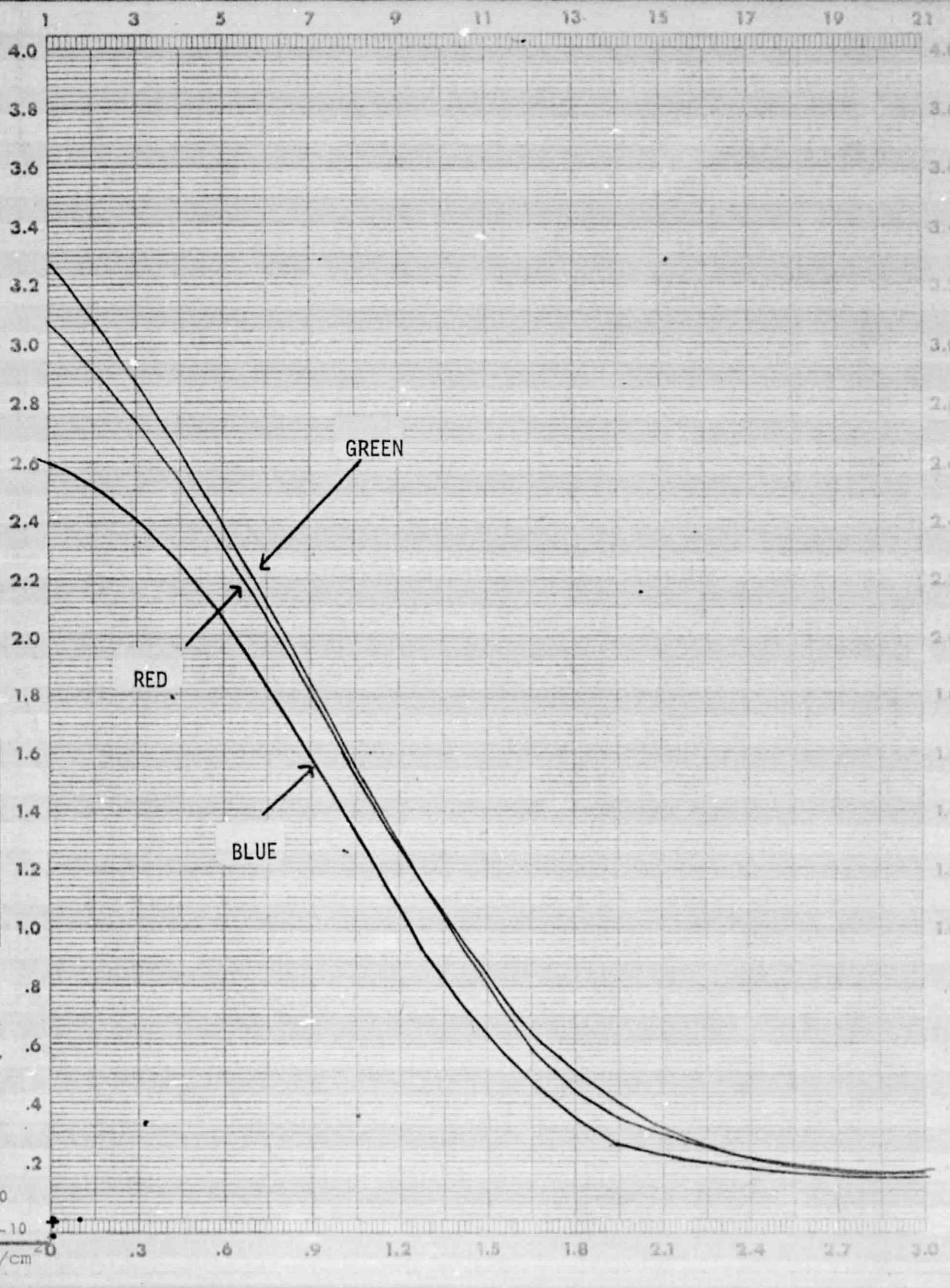

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ABSOLUTE LOG E AT R.L.E. = 0

-10 mcs ergs/cm²

DATE Aug 75 CONTROL # MX 306 R1 66 TASK 2nd Gen S0-397/2447 PREPARED BY ______

FILM S0-397 EMULSION # ______ MFG ______ EXPIRATION DATE ______

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER	PROCESSOR	INSTRUMENT	SPEED I
ILLUMINANT °K	CHEMISTRY	TYPE	D-MAX
TIME SEC.	SPEED TANKS FPM	APERTURE SIZE MM	GAMMA
FILTER	TEMP °F TIME	FILTER	BASE + FOG

CHEMICAL ANALYSIS

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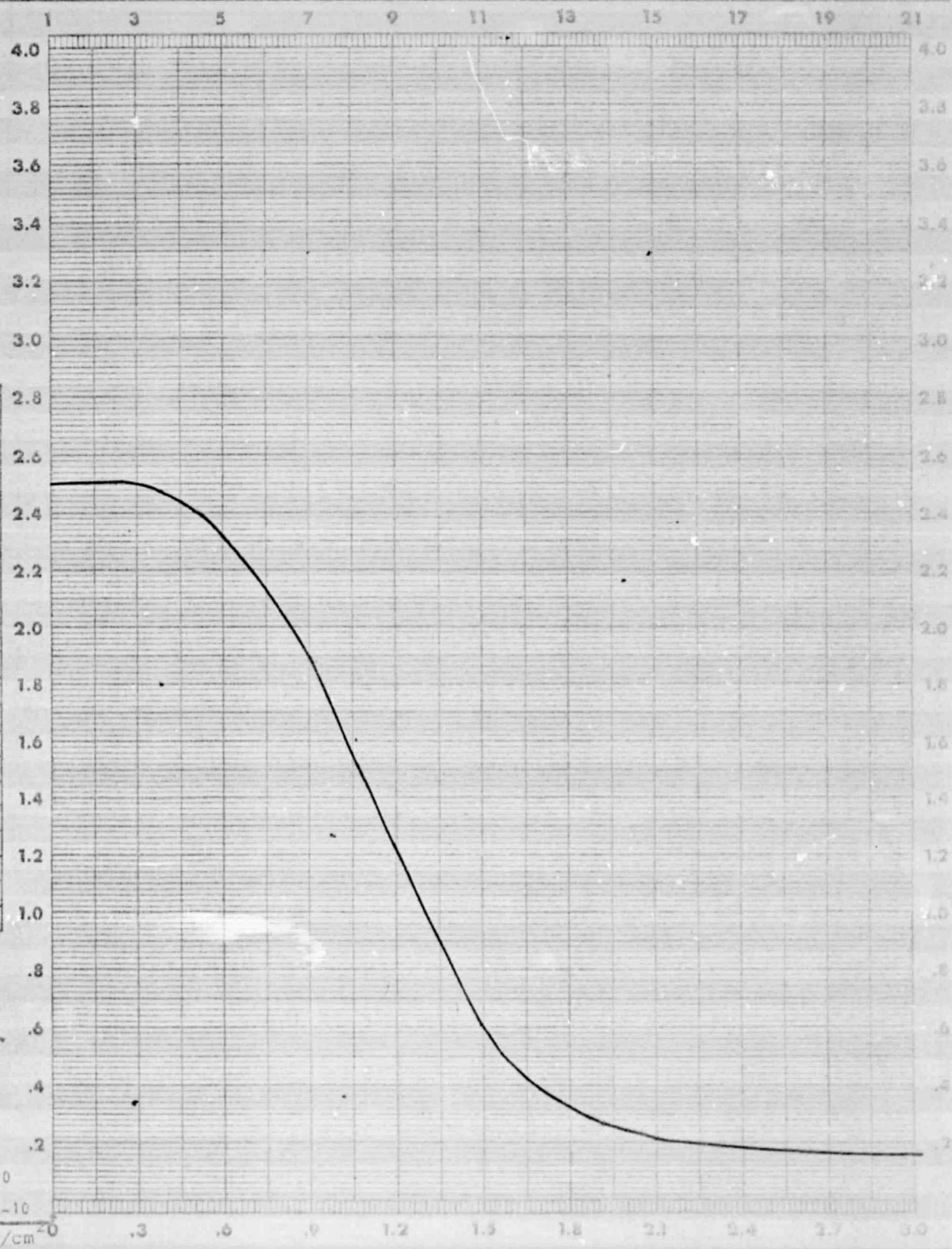

Technicolor

ABSOLUTE LOG E AT R.L.E. = 0

mcs ergs/cm²

DATE Aug 75 CONTROL # MX 306 R1 66 TASK 2nd Gen SO-397/2447 PREPARED BY

FILM SO-397 EMULSION # MFG EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER	PROCESSOR	INSTRUMENT	SPEED ( )
ILLUMINANT °K	CHEMISTRY	TYPE	D-MAX
TIME SEC.	SPEED TANKS FPM	APERTURE SIZE MM	GAMMA
FILTER	TEMP °F TIME	FILTER	BASE + FOG

CHEMICAL ANALYSIS

SP GR

pH

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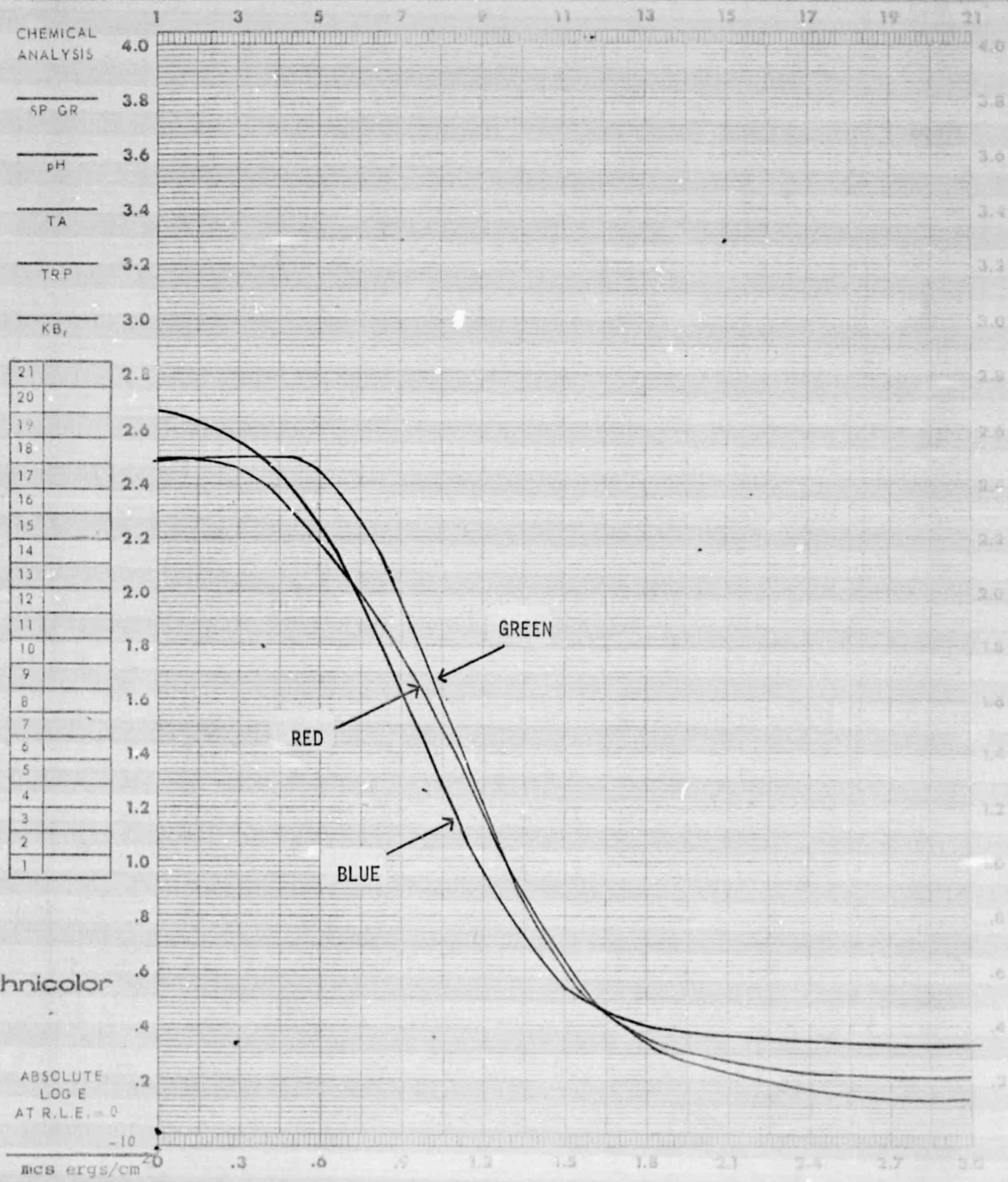

Technicolor

ABSOLUTE LOG E AT R.L.E. = 0

-10

mcs ergs/cm²

DATE Aug 75 CONTROL # MX 306 R1 66 TASK 3rd Gen 2447/2447 PREPARED BY

FILM SO-397 EMULSION # MFG EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER	PROCESSOR	INSTRUMENT	SPEED ( )
ILLUMINANT °K	CHEMISTRY	TYPE	D-MAX
TIME SEC	SPEED TANKS FPM	APERTURE SIZE MM	GAMMA
FILTER	TEMP °F TIME	FILTER	BASE + FOG

CHEMICAL ANALYSIS

SP GR

pH

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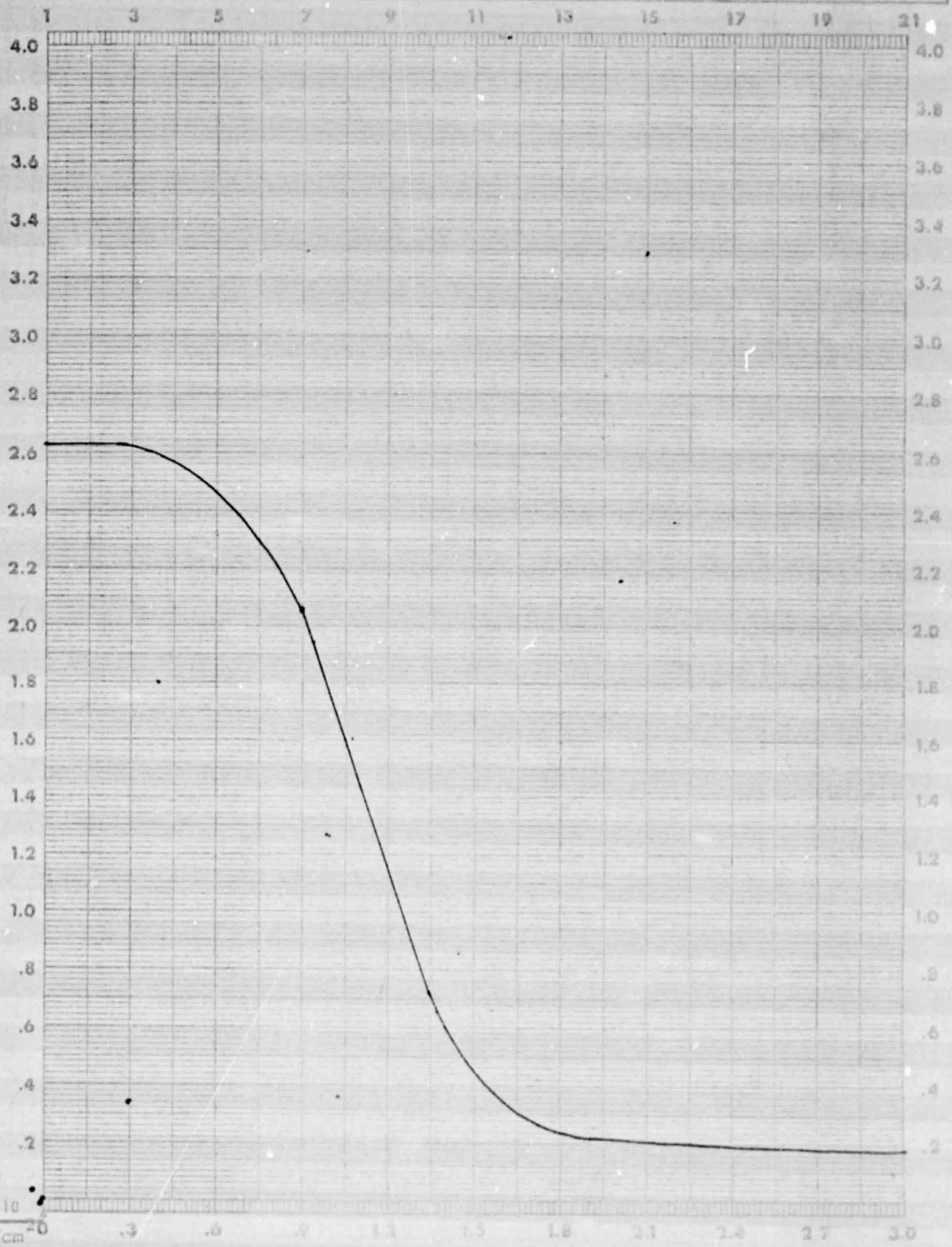

Technicolor

ABSOLUTE LOG E AT R.L.E. 0

-10

mcs ergs/cm²

DATE Aug 75 CONTROL # MX 306 R1 66 TASK 3rd Gen 2447/2447 PREPARED BY

FILM SO-397 EMULSION # MFG EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER	PROCESSOR	INSTRUMENT	SPEED ( )
ILLUMINANT °K	CHEMISTRY	TYPE	D-MAX
TIME SEC	SPEED TANKS	APERTURE SIZE MM	GAMMA
FILTER	TEMP °F TIME	FILTER	BASE + FOG

CHEMICAL ANALYSIS

SP GR

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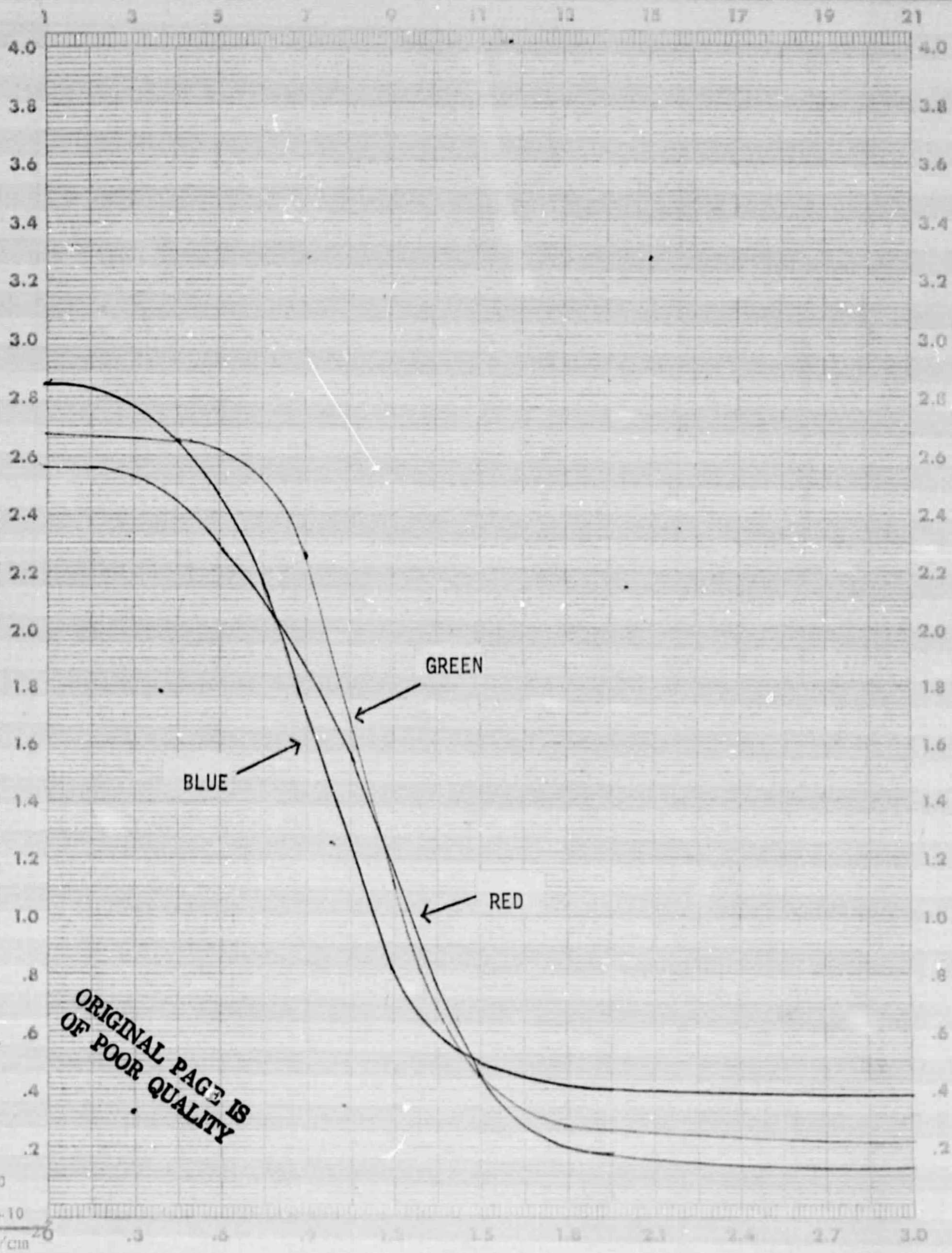

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Technicolor

ABSOLUTE LOG E AT R.L.E. = 0

mcs ergs/cm²

DATE Nov 74 CONTROL # MX 290 R1 32 TASK AMPS PREPARED BY

FILM 2443 EMULSION # 116-2 MFG EXPIRATION DATE

EXPOSURE DATA		PROCESSING DATA		DENSITOMETRY			
SENSITOMETER	I-B	PROCESSOR	1811 #1	INSTRUMENT	MacBeth	SPEED	
ILLUMINANT	2850 °K	CHEMISTRY	EA-5	TYPE	TD504	D-MAX	
TIME	1/50 SEC.	SPEED	TANKS 9	APERTURE SIZE	3	GAMMA	
FILTER	5500°K + W12	TEMP °F	115 TIME	FILTER	Visual	BASE + FOG	

CHEMICAL ANALYSIS

SP GR

pH

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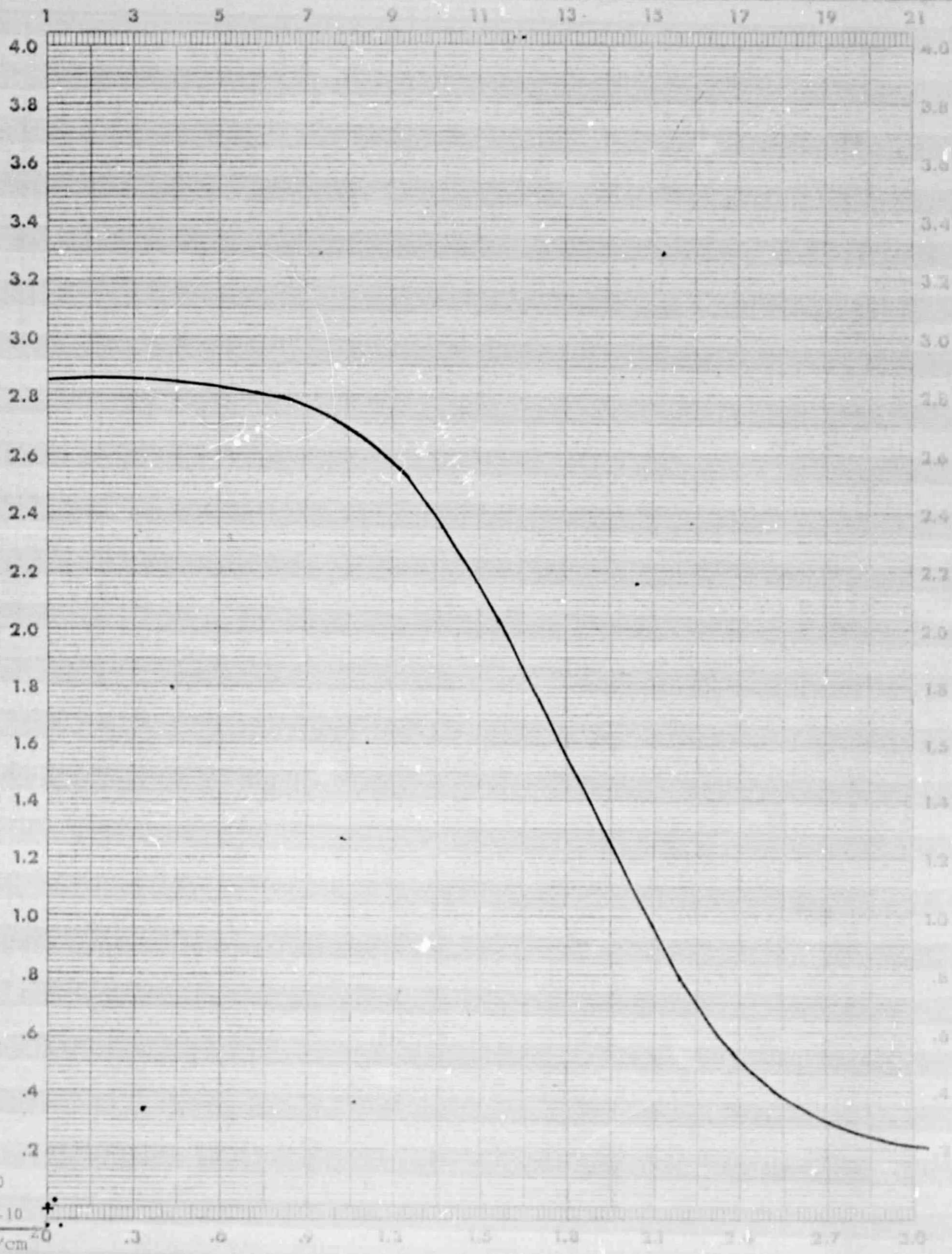

Technicolor

ABSOLUTE LOG E AT R.L.E. = 0

mcs ergs/cm

DATE Mpv 74 CONTROL # MX290 R1 32 AMPS

FILM 2443 EMULSION # 116-2

EXPOSURE DATA		PROCESSING DATA			
SENSITOMETER	I-B	PROCESSOR	1811 #1		MacBeth
ILLUMINANT	2850	CHEMISTRY	EA-5		TD504
TIME	1/50	SPEED	9		3
FILTER	5500°K + W12	TEMP °F	115		Status A

CHEMICAL ANALYSIS

SP GR

pH

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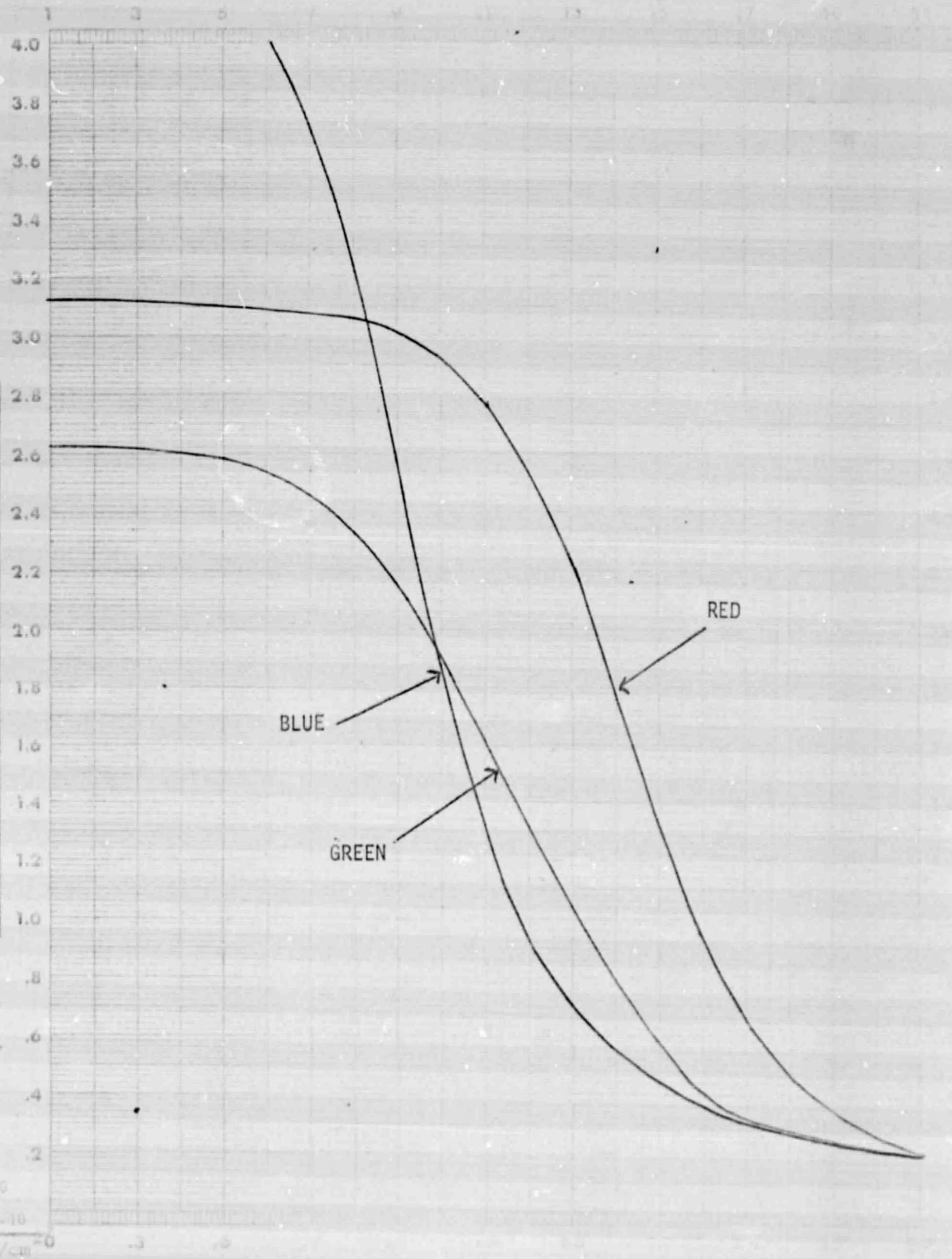


Technicolor

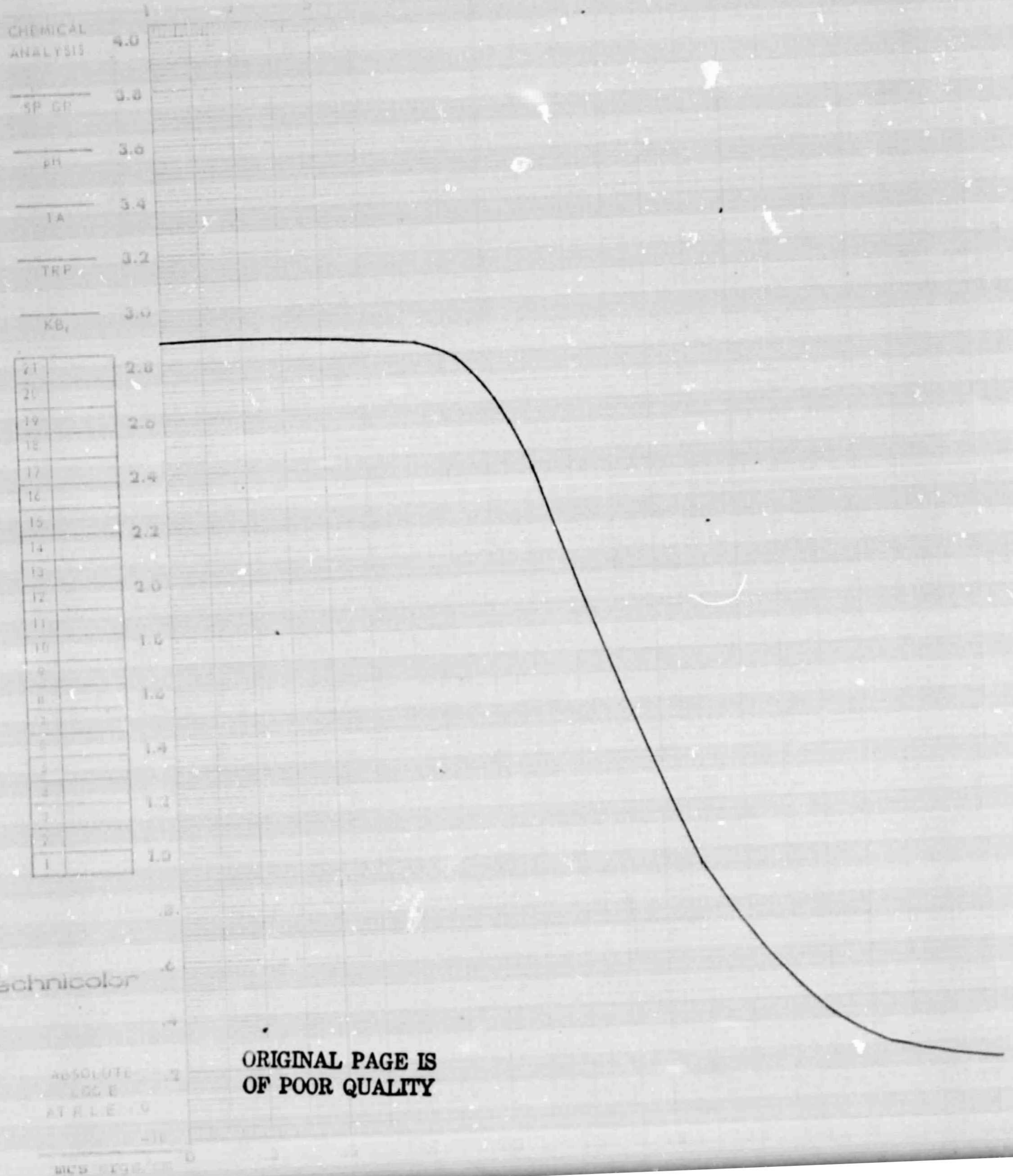
ABSOLUTE LOG E AT R.L.E. 0

mcs ergs/cm²

DATE 3 Sep 75 CONTROL 2nd Gen MX290 R132 2443/2447

FILM 2443 EMULSION

EXPOSURE DATA	
SENSITOMETER	
ILLUMINANT	
TIME	
FILTER	



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DATE 3 Sep 75 CONTROL # 2nd Gen

MX290 R132
2443/2447

FILM 2443 EMULSION #

EXPOSURE DATA

SENSITOMETER

ILLUMINANT

TIME

FILTER

CHEMICAL ANALYSIS

SP GR

pH

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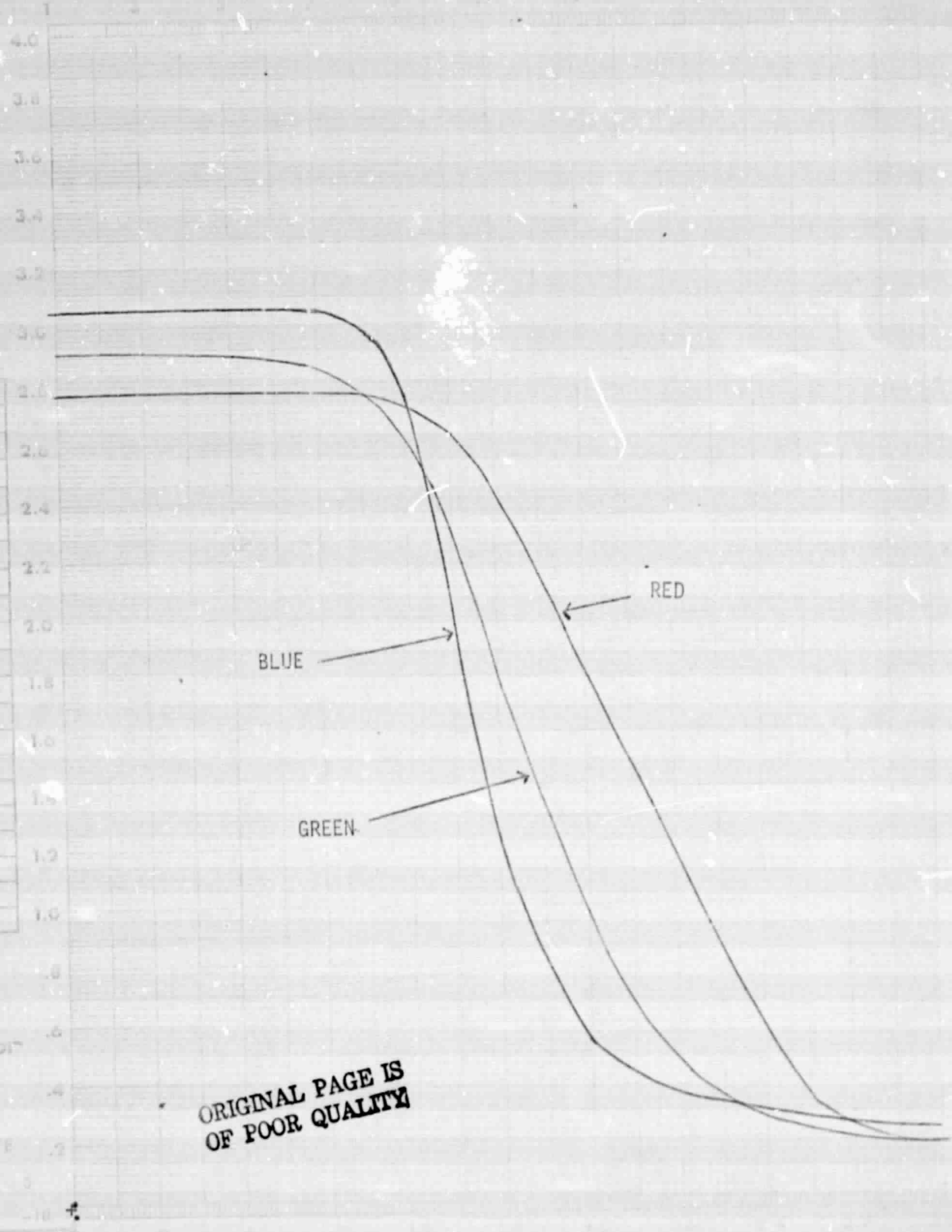

Technicolor

ABSOLUTE LOG E AT R.L.E.

DATE 3 Sep 75 CONTROL # 3rd Gen 2447/2447 TASK MX 290 R1 32 PREPARED BY

FILM 2443 EMULSION # MFG EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER	PROCESSOR	INSTRUMENT	SPEED
ILLUMINANT °K	CHEMISTRY	TYPE	D-MAX
TIME SEC.	SPEED TANKS FPM	APERTURE SIZE	GAMMA
FILTER	TEMP °F TIME	FILTER	BASE + FOG

CHEMICAL ANALYSIS

SP GR

pH

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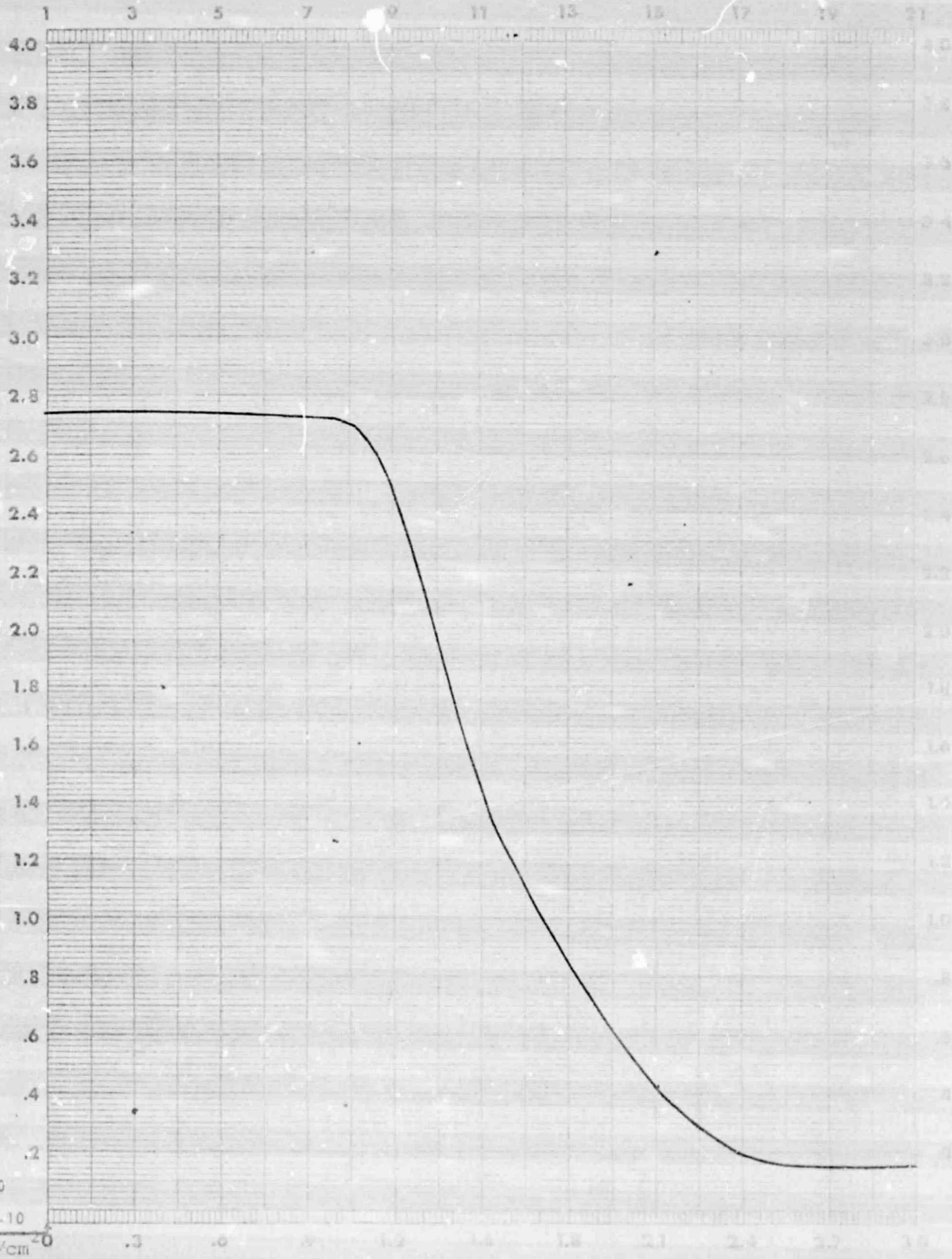


Technicolor

ABSOLUTE LOG E AT R.L.E. = 0

-10

mcs ergs/cm²

DATE 3 Sep 75 CONTROL # 3rd Gen 2447/2447 TASK Mx 290 R1 32 PREPARED BY

FILM 2443. EMULSION # MFG EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER	PROCESSOR	INSTRUMENT	SPEED
ILLUMINANT °K	CHEMISTRY	TYPE	D-MAX
TIME SEC.	SPEED	APERTURE SIZE	GAMMA
FILTER	TEMP °F TIME	FILTER	BASE + FOG

CHEMICAL ANALYSIS

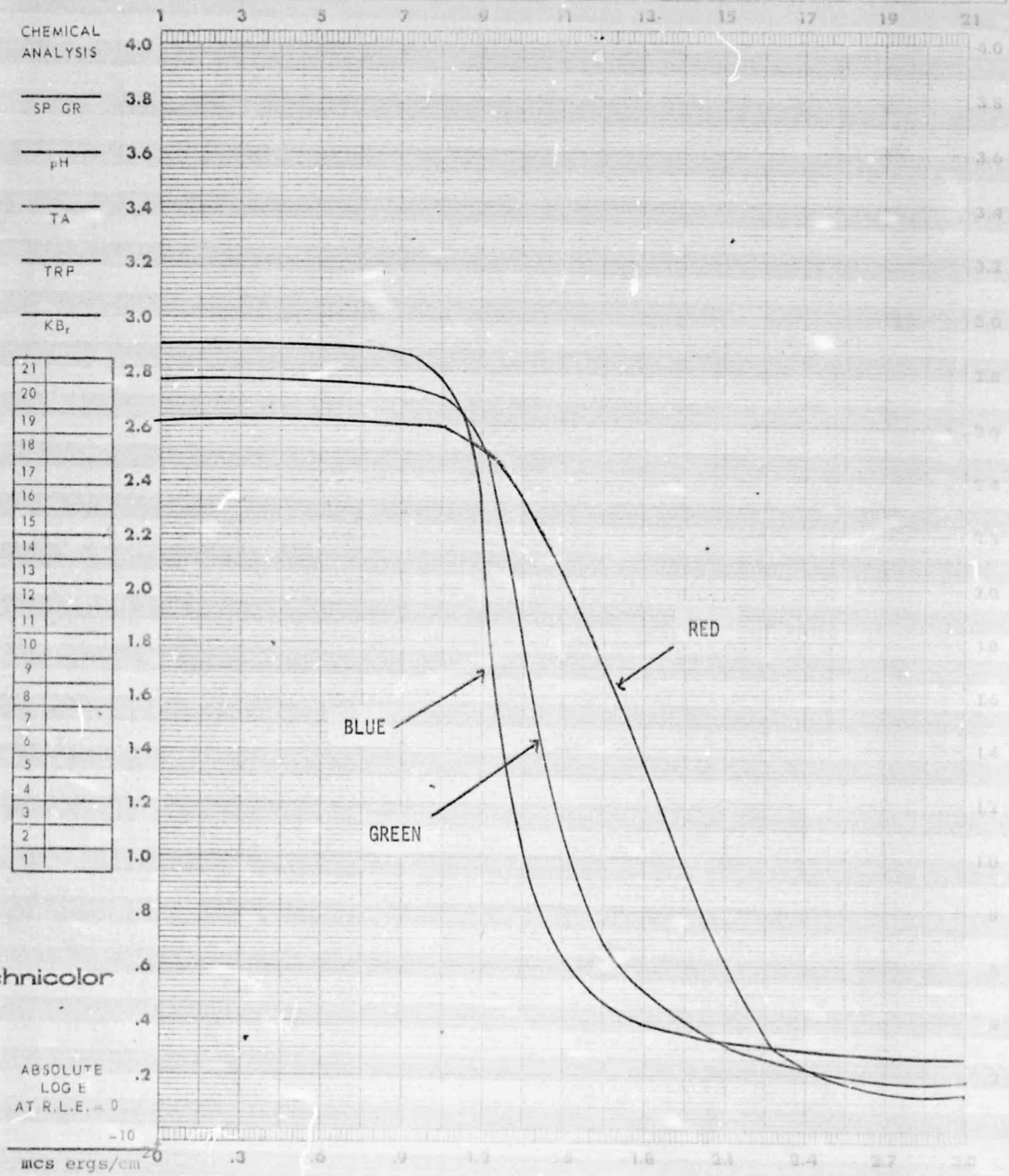
SP GR

pH

TA

TRP

KB_r



Technicolor

ABSOLUTE LOG E AT R.L.E. = 0

-10

mcs ergs/cm²

ATTACHMENT 4

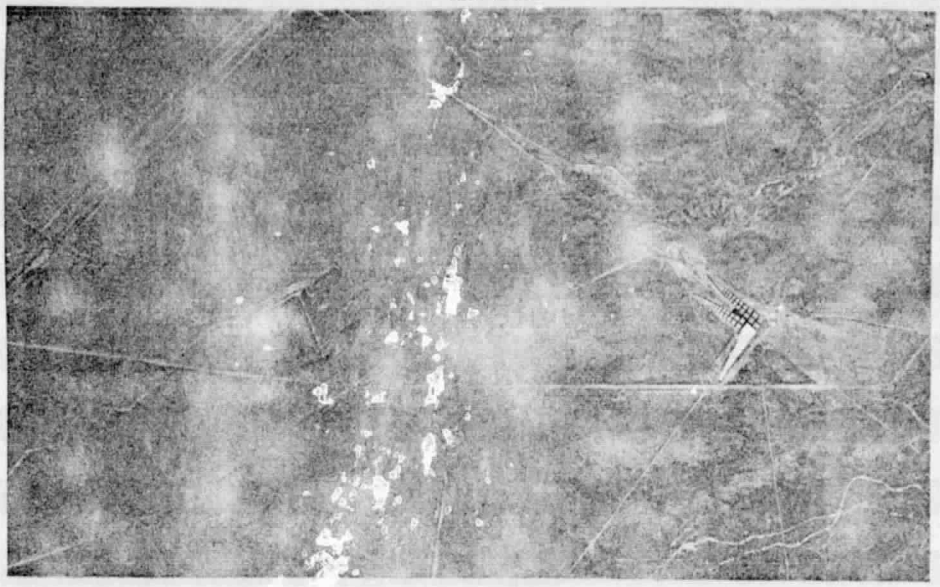
Cibachrome prints of three sets of imagery obtained over the Fort Huachuca test target with descriptions as follows:

- Set A - SO-397 film original duplicated on 2447 to obtain second then third generation results. The aircraft altitude was approximately 15,000 feet.

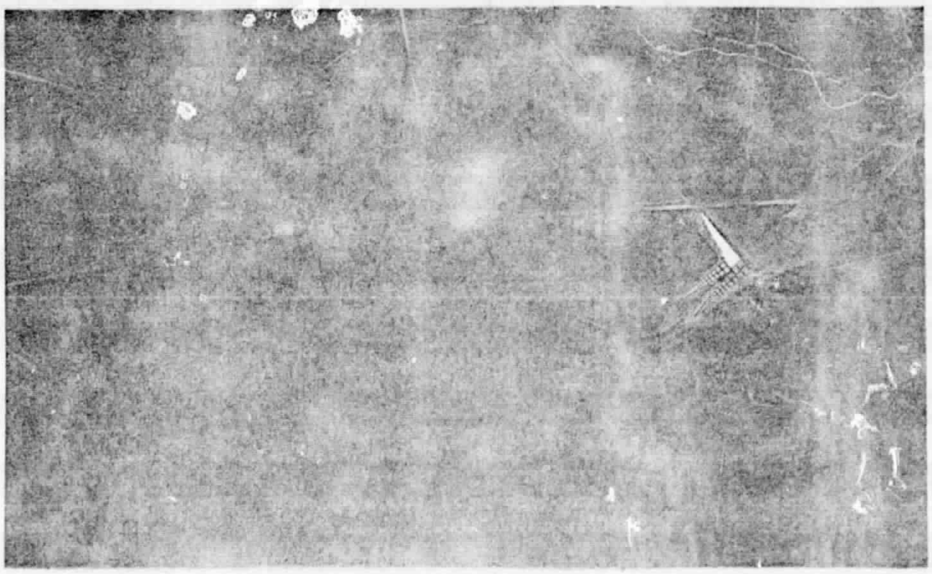
- Set B - The film types were identical to those used for Set A. The aircraft altitude was approximately 21,000 feet.

- Set C - The original film type was SO-356. The duplicates displayed here were second and third generations made on 2447. Notice the effects of higher gamma in the vignetting at the picture corner.

SET A



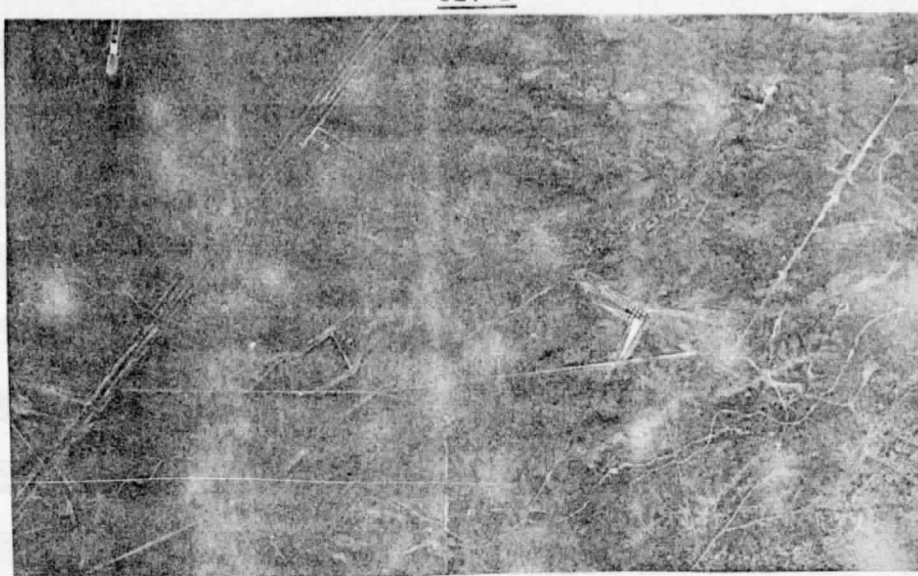
Original
(SO-397)



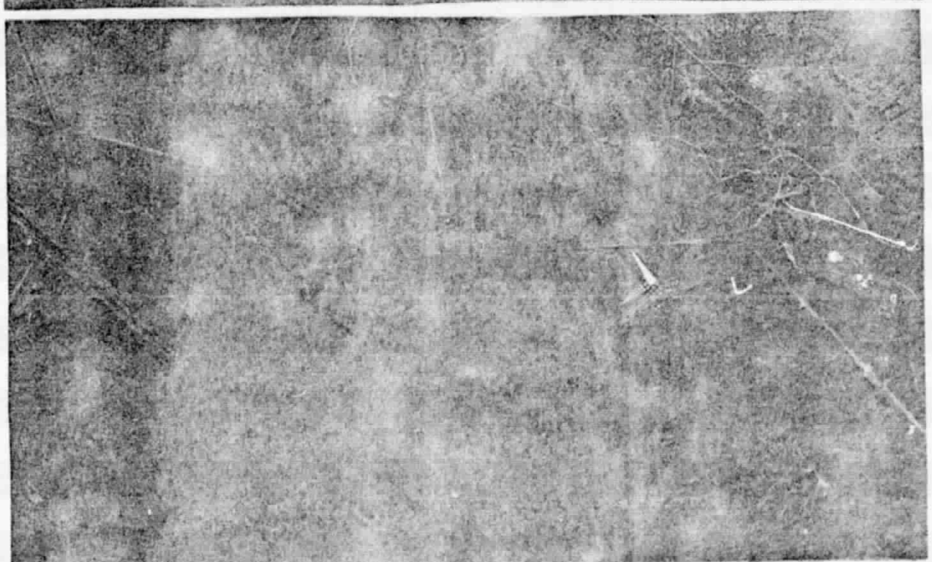
Second
Generation
(2447)

Third
Generation
(2447)

SET B



Original
(SO-397)

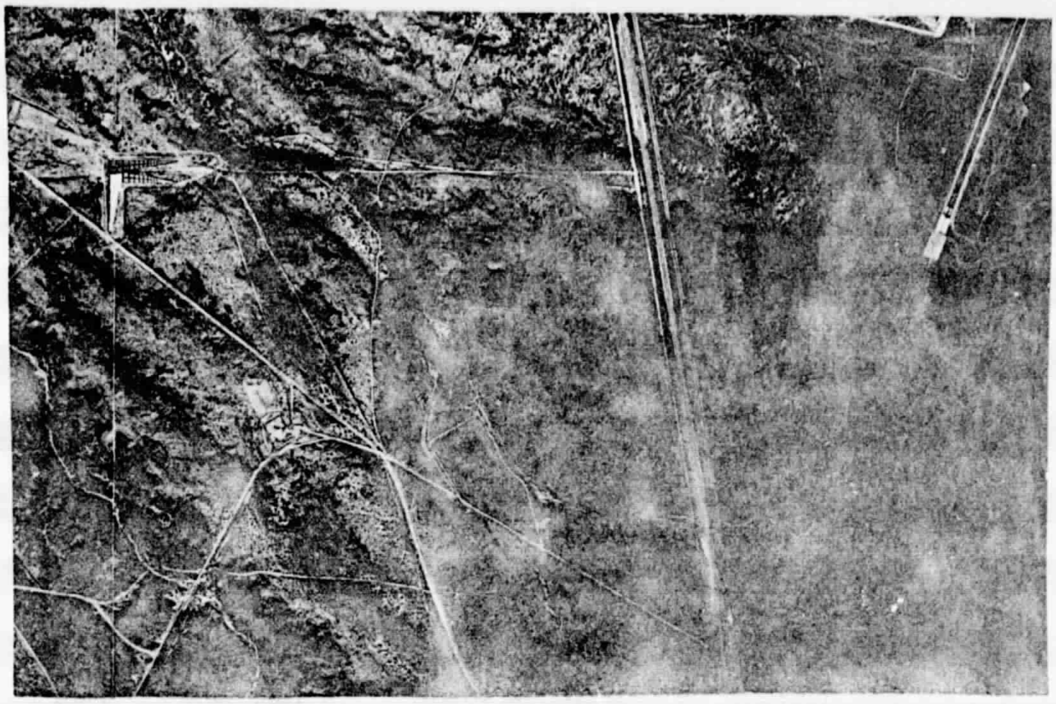


Second
Generation
(2447)

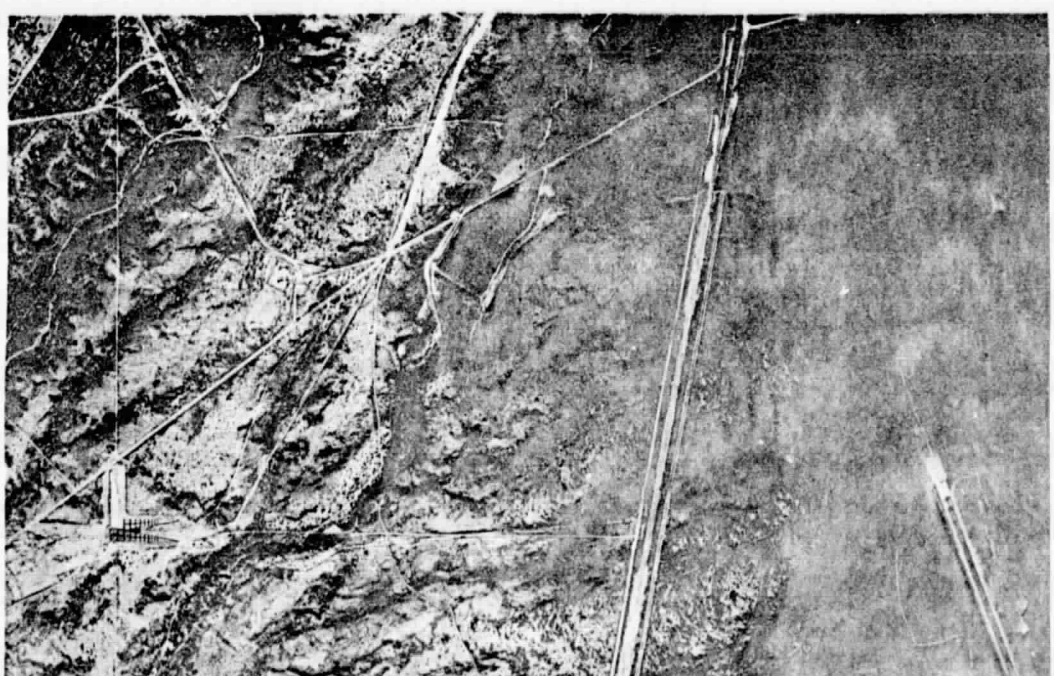
Third
Generation
(2447)

SET C

SO-356 Original Film
Duplicates on 2447



Second Generation Duplicate



Third Generation Duplicate