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NASA CR-
141551

INTERIM REPORT

Determination of Film Processing Specifications
for the Apollo 17
S-209 Lunar Sounder Experiment

(NASA-CR-141551) DETERMINATION OF FILM PROCESSING SPECIFICATIONS FOR THE APOLLO 17 S-209 LUNAR SOUNDER EXPERIMENT Interim Report (Technicolor Graphic Services, Inc.) 19 p HC $3.25 CSCL 14E G3/35

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17 April 1972

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National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas

Technicolor Graphic Services, Inc.

Determination of Film Processing Specifications
for the Apollo 17
S-209 Lunar Sounder Experiment

This report has been reviewed

and is approved.

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Photographic Technology Division

Noel T. Lamar

Noel T. Lamar
Technical Monitor

Determination of Film Processing Specifications
for the Apollo 17
S-209 Lunar Sounder Experiment

I. INTRODUCTION

The Apollo 17 Lunar Sounder is a chirped-pulse synthetic-aperture radar system operating at carrier frequencies of 5, 15, and 150 MHz. This instrument sends periodic electromagnetic pulses toward the lunar surface from the Command Service Module which are reflected by both surface and interior features of the moon. The radar echoes are then recorded onto Kodak Type SO-394 Film through the use of an optical recorder utilizing a Cathode Ray Tube as the exposing device.

The purpose of this project is to determine a processing configuration for the type SO-394 film which will result in an Amplitude Transmission (T_a) versus Recorder Input Voltage (V) curve having optimum characteristics with regard to linearity, dynamic range, and noise. As suggested by the Principal Investigator Photographic Committee, tests were initiated in two separate directions: one was aimed at attempting to match the Density versus Log_{10} Exposure (D-Log E) curve obtained by Goodyear Aerospace Corporation, the Lunar Sounder contractor; the second was directed toward arriving at a process which would produce a linear T_a vs. V curve.

II. PROCEDURES

Sensitometric testing of the type SO-394 film was conducted using both a Fultron and a Versamat processor. Kodak MX-641 and MX-819 developers were used in the Fultron Spray Processor, and Kodak MX-641 and Itek G4-L developers were used in the Versamat 11C-M processor. Both temperature and machine speed were varied over a broad range in order to adequately describe the sensitometric characteristics of the film/chemistry/processor configurations tested. Examples of the resultant D-Log E curves, along with the standard Goodyear D-Log E curve, are included in the Appendix.

A sensitometric crossover between the Goodyear and the Photographic Technology Division's (PTD) sensitometers was accomplished by processing a roll of type SO-394 film having exposures produced by both sensitometers. Both sets of exposures were read on a MacBeth densitometer, and each set was averaged. The average densities were then plotted on the same sheet of D-Log E graph paper. As can be seen in Figure 1, both curves have about the same shape and are merely displaced laterally along the Log E axis. This information allows a meaningful comparison to be made between the Goodyear Control Curve obtained by processing in a Versamat processor with Hunt Arcon chemistry, and the D-Log E curves obtained during the testing phase previously described. A review of the processor/chemistry test configurations showed that none of them produced a good match to the Goodyear Control Curve. The next logical step was to try

DATE 7 Jan 72 CONTROL # ______ TASK HT-35 PREPARED BY E. Weizer

FILM SO-394 EMULSION # 3-1 MFG E. K. Co. EXPIRATION DATE n/a

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER	PROCESSOR Fultron	INSTRUMENT MacBeth	SPEED ( )
ILLUMINANT °K	CHEMISTRY MX-641	TYPE TD217DR	D-MAX
TIME SEC.	SPEED Full TANKS 20 FPM	APERTURE SIZE 4 MM	GAMMA
FILTER	TEMP °F 80 TIME	FILTER Visual	BASE + FOG

CHEMICAL ANALYSIS

SP GR

pH

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TRP

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Technicolor

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

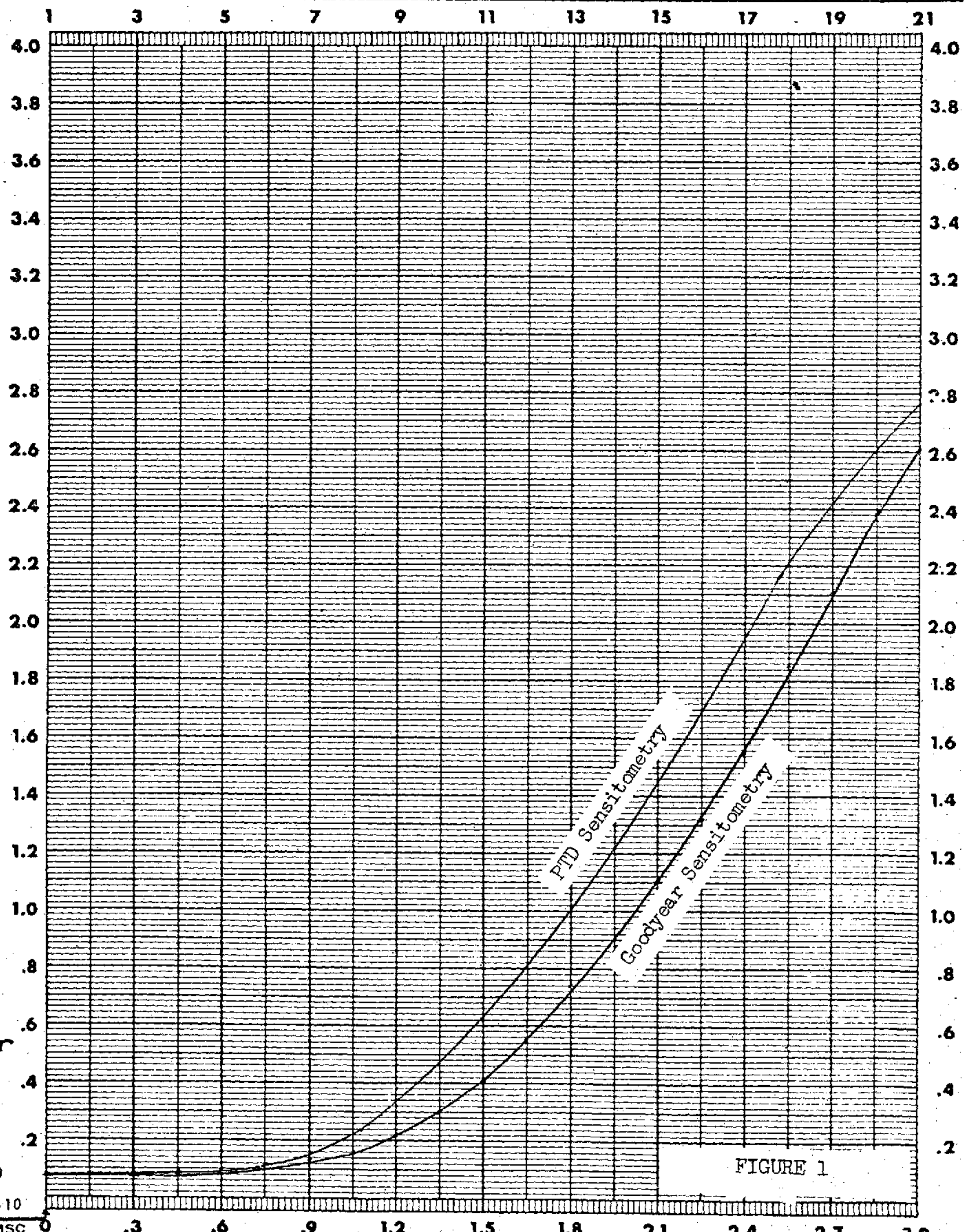


FIGURE 1

T71-21 NASA — MSC

to obtain the Hunt Arcon chemistry for processing tests in a Versamat processor. A representative of the Hunt Chemical Company was contacted, and the Photo Science Office was informed that Arcon chemistry was no longer being made; however, a limited quantity was available, if needed. He suggested that Hunt Aeroflo-Hi chemistry might give very similar results.

The problem of matching the Goodyear curve and obtaining the Hunt chemistry brought up the question of whether it was logical to continue on this route.

A parallel investigation was taking place to determine the optimum process to obtain a linear T_a vs. V curve. For these preliminary investigations diffuse density measurements were made using a MacBeth densitometer, and these values were converted to Amplitude Transmission through the use of the following formulas:

$$D = \text{Log} \frac{1}{\text{Transmittance}}$$

$$\therefore \quad \frac{1}{\text{Antilog } D} = \text{Transmittance } (T)$$

$$\sqrt{T} = T_a$$

The Optical Processor used by the University of Michigan operates with coherent light in a specular fashion, and in fact, T_a is defined as "the square root of the coherent specular energy transmission".* However, it was stated that "for initial preliminary experimental measurements, the difference between the diffuse and specular transmission may be ignored".*

The Lunar Recorder T_a vs. V response is a combination of the film T_a vs. E characteristics and the recorder E vs. V characteristics. This is shown graphically in Figure 2. The determination of T_a vs. V can be found by either of two methods. If the recorder E vs. V curve is known, then it is a simple matter to relate the film T_a vs. E curve with the recorder E vs. V curve to obtain the system T_a vs. V response. However, the best method of obtaining T_a vs. V characteristics would be to produce a series of exposures with the recorder onto film using known voltage levels. After processing, the densities could be read, converted to T_a, and plotted directly with respect to voltage. This type of test data was requested numerous times, but never received. Without having actual test film with exposures at various voltage levels, the only other method possible to obtain T_a vs. V information is to know the E vs. V characteristics of the recorder, and to use this information in conjunction with the film T_a vs. E curves to derive a T_a vs. V curve. This information was also requested, but never received. The only information available was that the recorder E vs. V response was nonlinear.

* Memorandum: "Recommended Procedure for Processing Prototype Recorder Test Films", from Gary Adams to Roger Phillips, December 6, 1971.

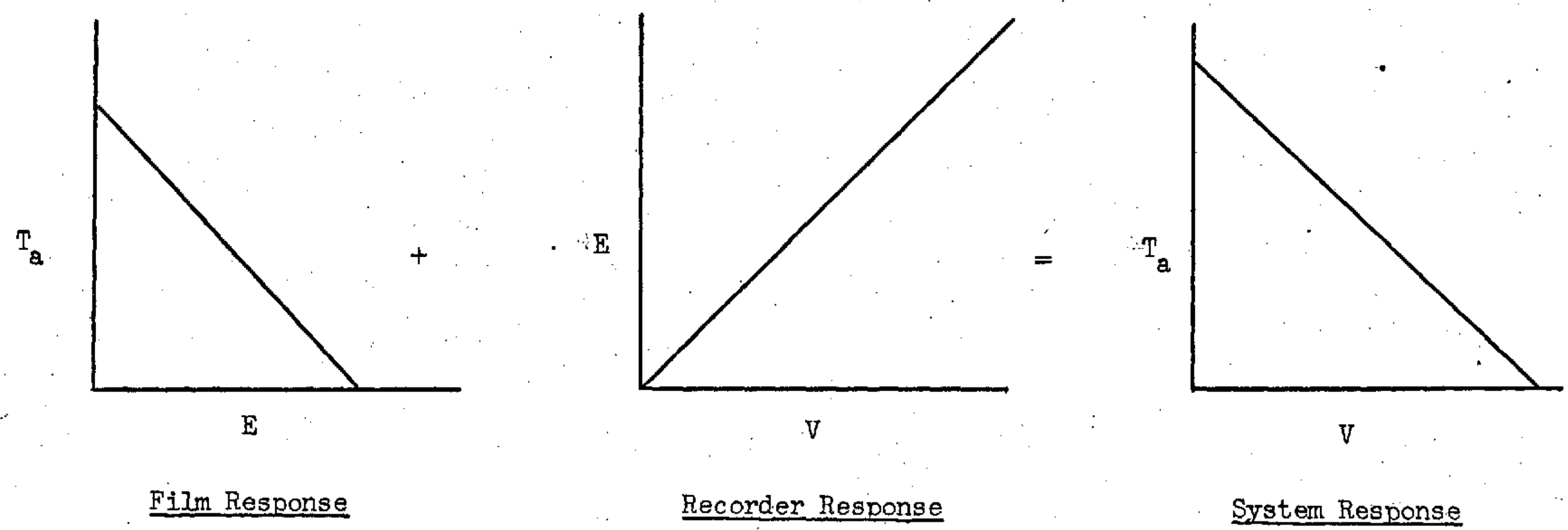

T_a
E
Film Response
+
E
V
Recorder Response
=
T_a
V
System Response

FIGURE 2

The inability to obtain the required information, or some suitable test film, severely hampered our ability to support the requirement of obtaining an optimum process.

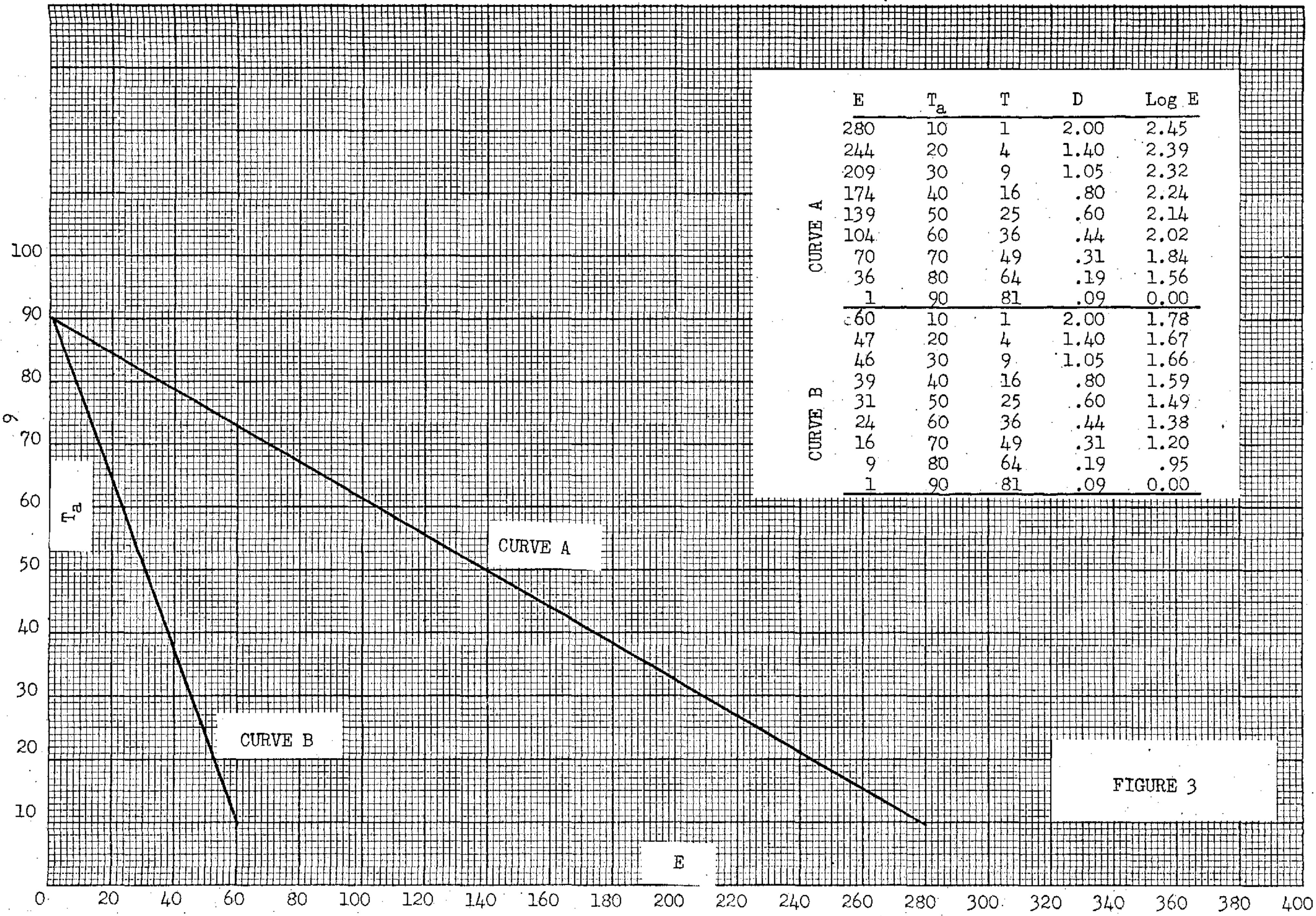
These problems, along with the difficulty in matching the Goodyear curve, prompted several meetings with the NASA representatives for the Lunar Recorder project, Mr. Vern Dauphine and Mr. Ron Kelly. It was hypothesized that the nonlinear response of the recorder was necessitated by the characteristics of the Goodyear film/process curve and the need to maintain a linear T_a vs. V system response. If the recorder response was linear, then a linear film T_a vs. E curve would result in a linear T_a vs. V system response (Figure 2). If this approach were adopted, preliminary sensitometric testing could easily be done without the Lunar Recorder.

Shortly thereafter, the PTD was informed by Mr. Kelly that the E vs. V response of the recorder was being changed from a nonlinear to a linear function, and that the PTD was to optimize the system for linear T_a vs. E film response. In addition, Mr. Kelly had prepared an instrument suitable for measuring coherent specular energy transmission and noise in the same manner as that employed by the University of Michigan.

Knowing now that the recorder response was to be linear, and therefore, that the T_a vs. E curve should be linear, it was a simple matter to derive a theoretical film/process D-Log E curve. This was done in the following manner. Two linear T_a vs. E plots were made with different slopes (Figure 3). Exposure values were tabulated at numerous T_a levels. Exposure was converted to Log Exposure, and T_a converted to Density, using the formulas given previously. These values were then used to plot the two resultant D-Log E curves (Figure 4). As can be seen from the graph, these curves have the same shape, but are displaced along the Log E axis. The PTD now had to attempt to match the general curve shape, and to position it on the Log E axis with respect to the recorder bias level.

III. EVALUATION OF RESULTS

An examination of the D-Log E curves resulting from processing with the equipment and chemistries normally used by the PTD showed that using the Fultron processor with MX-641 chemistry at 80° F. and a machine speed of 5 feet per minute gave the closest approximation to the theoretical D-Log E curve shape. In addition, the resultant toe speed was close to that found in the Goodyear control curve. This meant that whatever bias level the recorder had been set for when using the Goodyear processing technique would be sufficient to produce the proper exposure level with the proposed PTD processing scheme. It is also evident from an examination of the D-Log E curves that the Goodyear Control Curve does not produce a very good match to the theoretical D-Log E curve required to produce a linear T_a vs. E response. Although the Goodyear processing configuration probably produced good results in terms of linear T_a vs. V



	E	T_a	T	D	Log E
CURVE A	280	10	1	2.00	2.45
	244	20	4	1.40	2.39
	209	30	9	1.05	2.32
	174	40	16	.80	2.24
	139	50	25	.60	2.14
	104	60	36	.44	2.02
	70	70	49	.31	1.84
	36	80	64	.19	1.56
	1	90	81	.09	0.00
CURVE B	60	10	1	2.00	1.78
	47	20	4	1.40	1.67
	46	30	9	1.05	1.66
	39	40	16	.80	1.59
	31	50	25	.60	1.49
	24	60	36	.44	1.38
	16	70	49	.31	1.20
	9	80	64	.19	.95
	1	90	81	.09	0.00

FIGURE 3

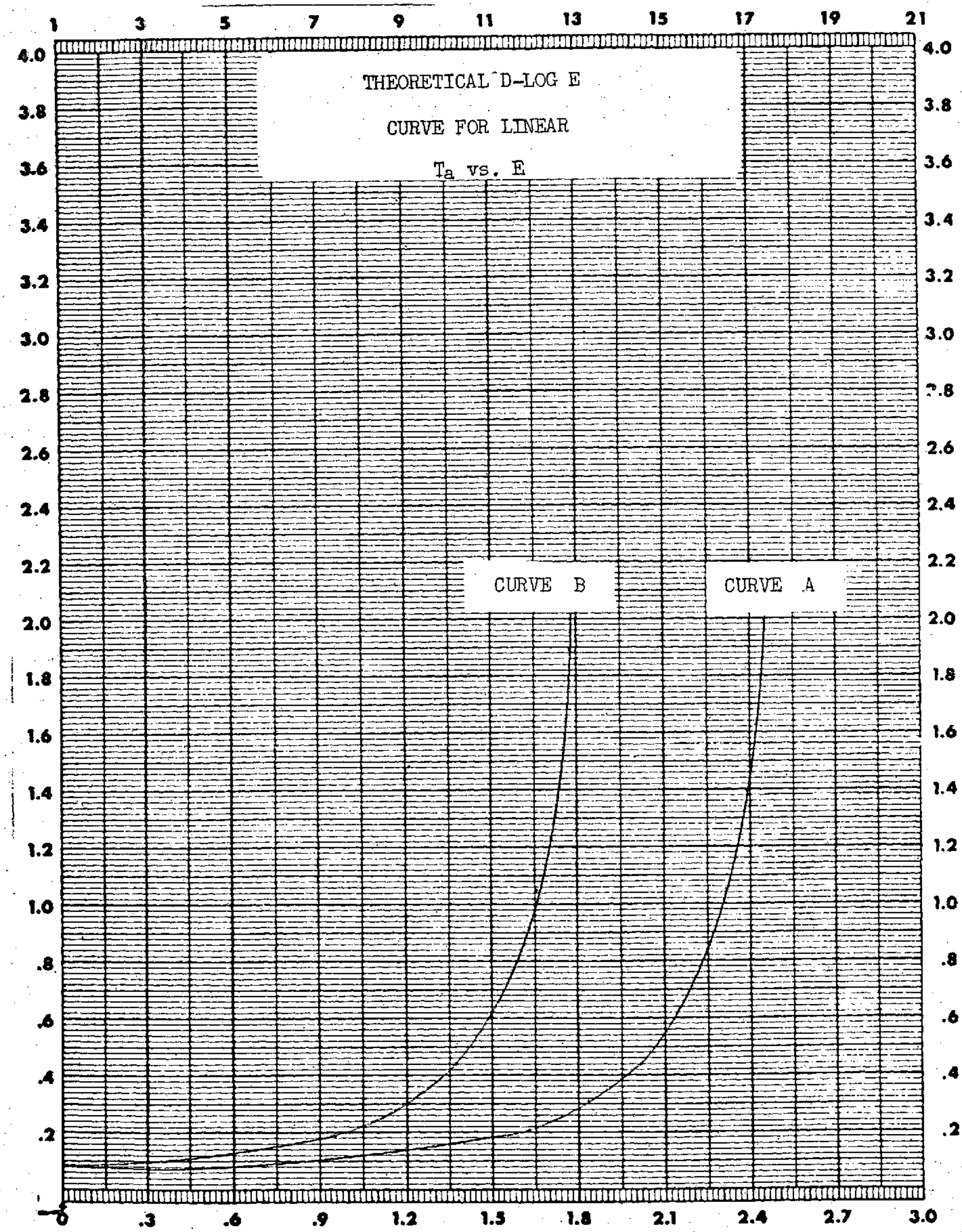

THEORETICAL D-LOG E
CURVE FOR LINEAR
T_a vs. E
CURVE B
CURVE A
1 3 5 7 9 11 13 15 17 19 21
4.0 3.8 3.6 3.4 3.2 3.0 2.8 2.6 2.4 2.2 2.0 1.8 1.6 1.4 1.2 1.0 .8 .6 .4 .2
0 .3 .6 .9 1.2 1.5 1.8 2.1 2.4 2.7 3.0

FIGURE 4

with a nonlinear recorder response, it appears futile to attempt to match their curve shape when considering the decision to change the recorder response to a linear function.

The PTD arrived at a preliminary processing configuration, based on the requirements for linear T_a vs. E response and the need for a film speed sufficient to provide suitable exposures, considering the inability to change the recorder bias level setting. This processing configuration was used to process all of the test films received at PTD to date. Considering the change from a nonlinear to a linear recorder response function, it does not seem useful to attempt to match the Goodyear processing configuration at this time. All density measurements in this report were made with a MacBeth diffuse densitometer and were converted to T_a using the formulas described. Mr. Kelly's device for making coherent specular energy transmission measurements was used to determine T_a and noise for some of of the sensitometric tests. The Photo Science Office is now in the process of correlating Mr. Kelly's measurements with the described density readings. This will undoubtedly lead to a refinement of the theoretical diffuse D-Log E curve yielding a linear T_a vs. E response.

IV. PROPOSED TESTS

Additional testing is planned using Kodak D-97 developer. The characteristics of this developer are such that it should produce a closer match to the theoretical D-Log E curve than those previously tested. This testing had been planned for the week of 3 April 1972. Mr. Kelly was informed that the PTD had no raw stock left, thus making it impossible to continue testing. The request for more raw stock was relayed to the appropriate people; however, to this date none has been received. The inability to obtain sufficient raw film stock has been a continuing problem throughout the course of this project.

As soon as new raw stock is received, testing will be continued with the goal of obtaining the most linear T_a vs. E with the lowest possible noise. The sensitometric strips from all of the film/process combinations tested will be sent to the University of Michigan for analysis. Their recommendations will be used to zero in on the optimum film/process specifications.

APPENDIX

DATE 27 Jan 72 CONTROL # NASA HOUSTON TASK HT-35 PREPARED BY E. Weizer

FILM SO-394 EMULSION # 3-1 MFG E.K. Co. EXPIRATION DATE N/A

772 EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER 1-B	PROCESSOR Fultron	INSTRUMENT Macbeth	SPEED ( )
ILLUMINANT 3000 °K	CHEMISTRY MX-641	TYPE TD 217 DR	D-MAX
TIME 1/10 SEC.	SPEED Full TANKS FPM	APERTURE SIZE 4 MM	GAMMA
FILTER P-11	TEMP °F 80 TIME	FILTER Visual	BASE + FOG 0.07

CHEMICAL ANALYSIS

SP GR

pH

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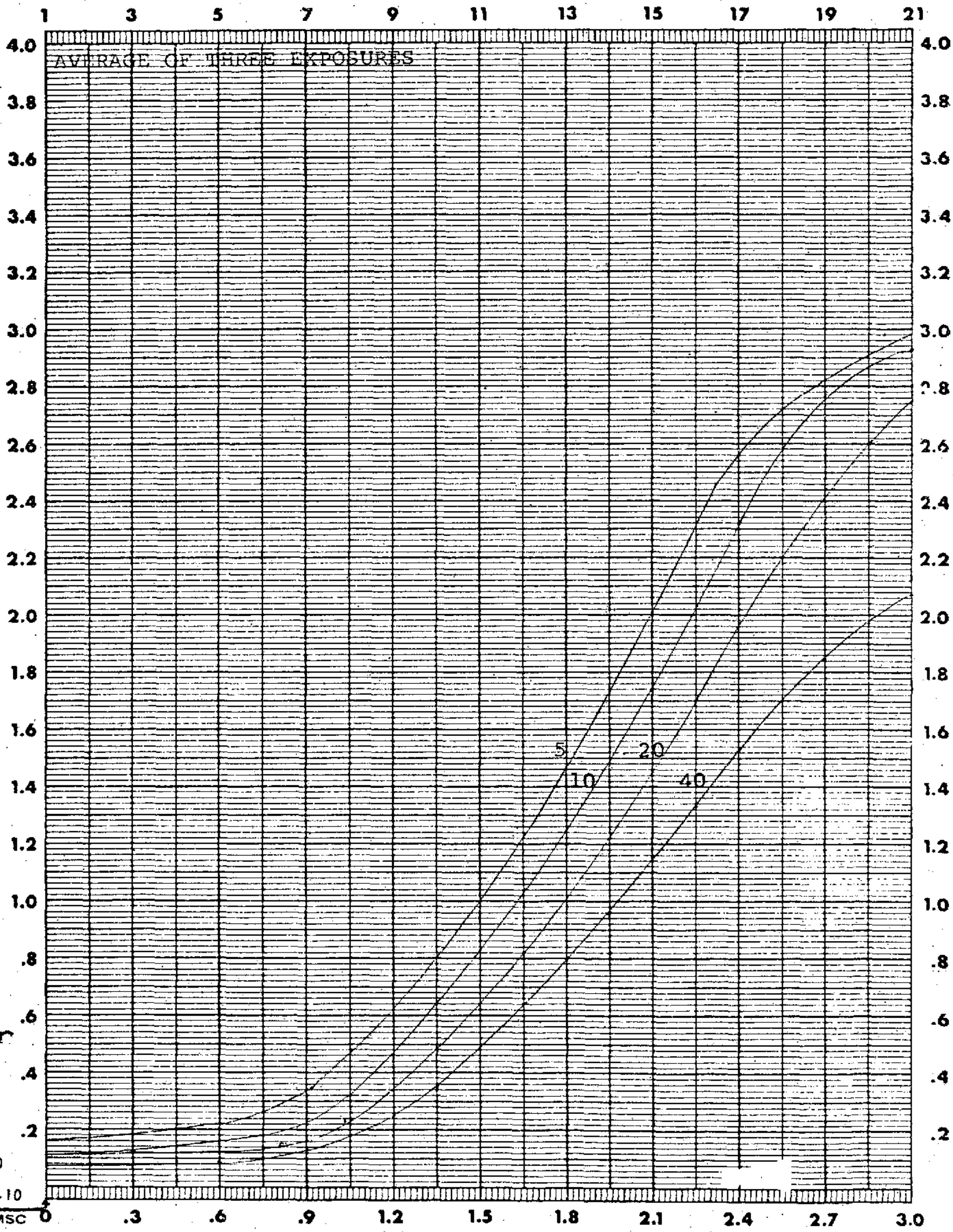

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ABSOLUTE LOG E AT R.L.E. - 0

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T71-21 NASA — MSC

DATE 1-14-72 CONTROL # ______ TASK HT-35 PREPARED BY E. Weizer

FILM SO-394 EMULSION # ______ MFG ______ EXPIRATION DATE ______

772-150 EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER I-B	PROCESSOR Fultron	INSTRUMENT MacBeth	SPEED ( )
ILLUMINANT 3000 °K	CHEMISTRY MX-641	TYPE TD 203	D-MAX
TIME 1/10 SEC.	SPEED ______ TANKS 5,10,20,40 FPM	APERTURE SIZE 4 MM	GAMMA
FILTER P 11	TEMP °F 85 TIME	FILTER Visual	BASE + FOG

CHEMICAL ANALYSIS

SP GR

pH

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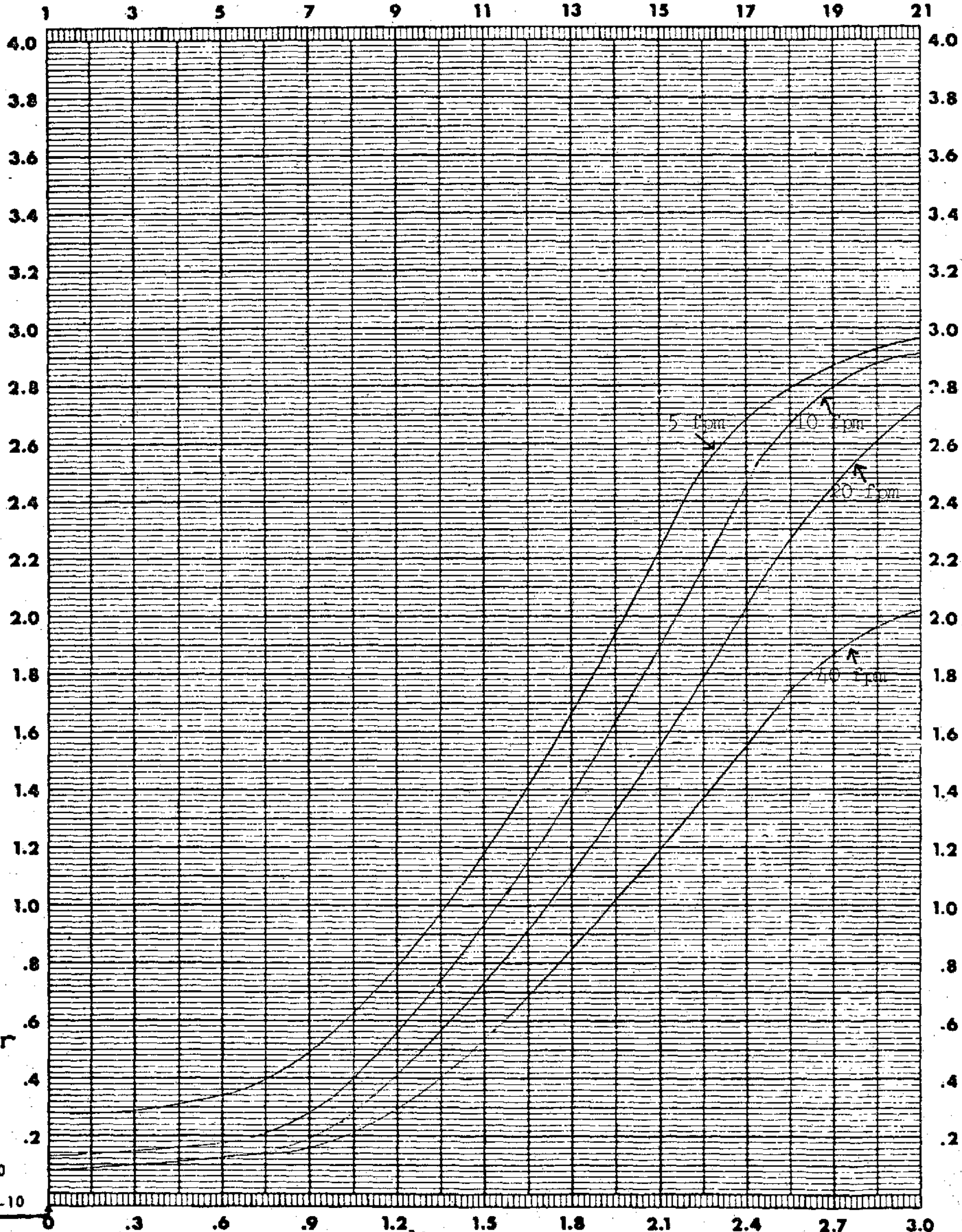

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DATE 18 Oct. 71 CONTROL # ______ TASK ______ PREPARED BY C. Moody

FILM SO 394 EMULSION # ______ MFG ______ EXPIRATION DATE ______

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER 1-B	PROCESSOR Fultron # 1	INSTRUMENT TD- 217	SPEED ( )
ILLUMINANT 3000 °K	CHEMISTRY MX 819-1	TYPE DD	D-MAX
TIME 1/10 SEC.	SPEED full TANKS 15-25 FPM	APERTURE SIZE 4 MM	GAMMA
FILTER P-11 pack	TEMP °F 80 TIME	FILTER Visual	BASE + FOG

CHEMICAL ANALYSIS

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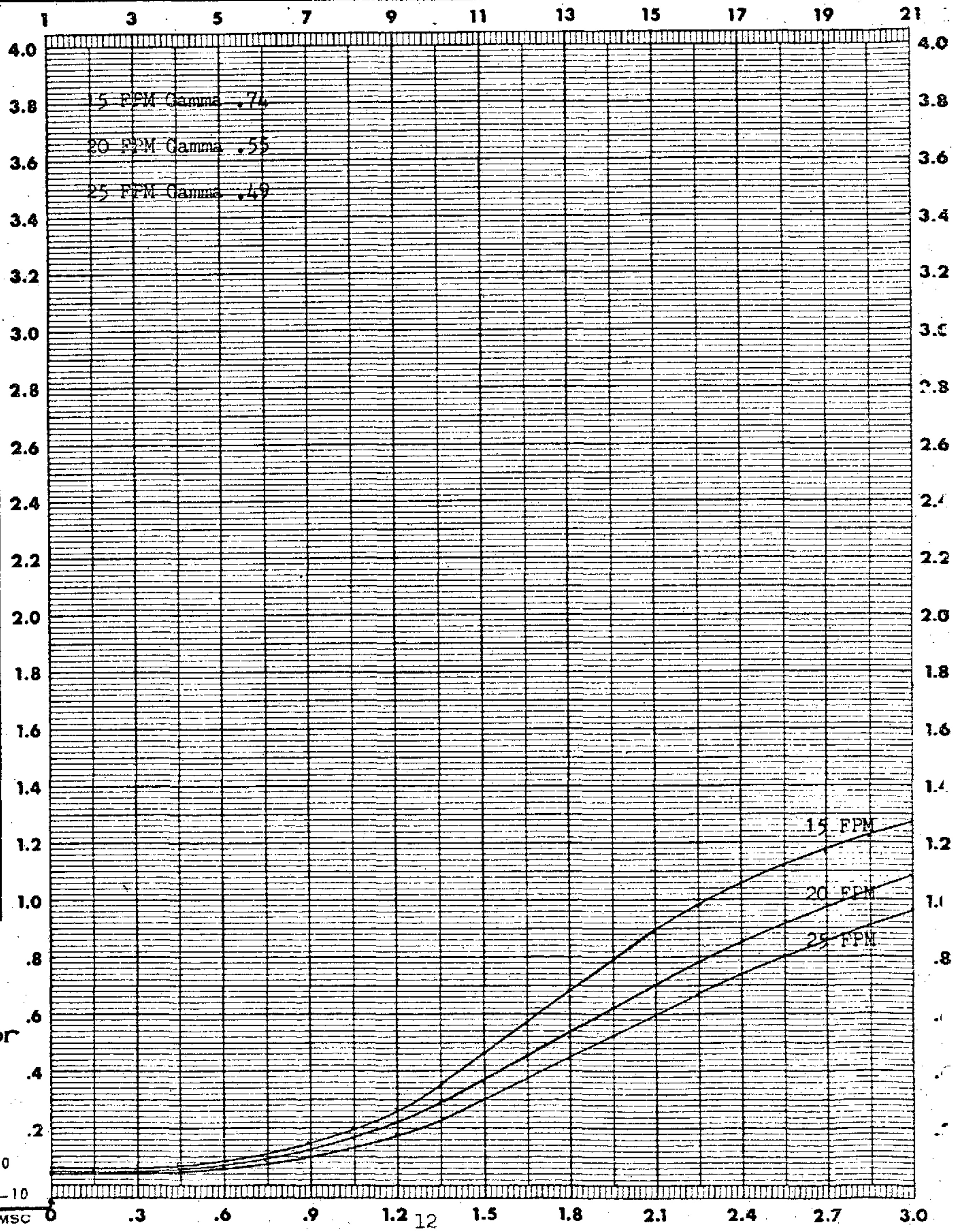

DATE 18 Oct. 71 CONTROL # ______ TASK Time Gamma PREPARED BY C. Moody

FILM SO 394 EMULSION # ______ MFG ______ EXPIRATION DATE ______

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER 1-B	PROCESSOR Fultron # 1	INSTRUMENT TD- 217	SPEED ( )
ILLUMINANT 3000 °K	CHEMISTRY MX 819-1	TYPE DD	D-MAX
TIME 1/10 SEC.	SPEED full TANKS 10-25 FPM	APERTURE SIZE 4 MM	GAMMA
FILTER P-11 pack	TEMP °F 85 TIME	FILTER Visual	BASE + FOG

CHEMICAL ANALYSIS

SP GR
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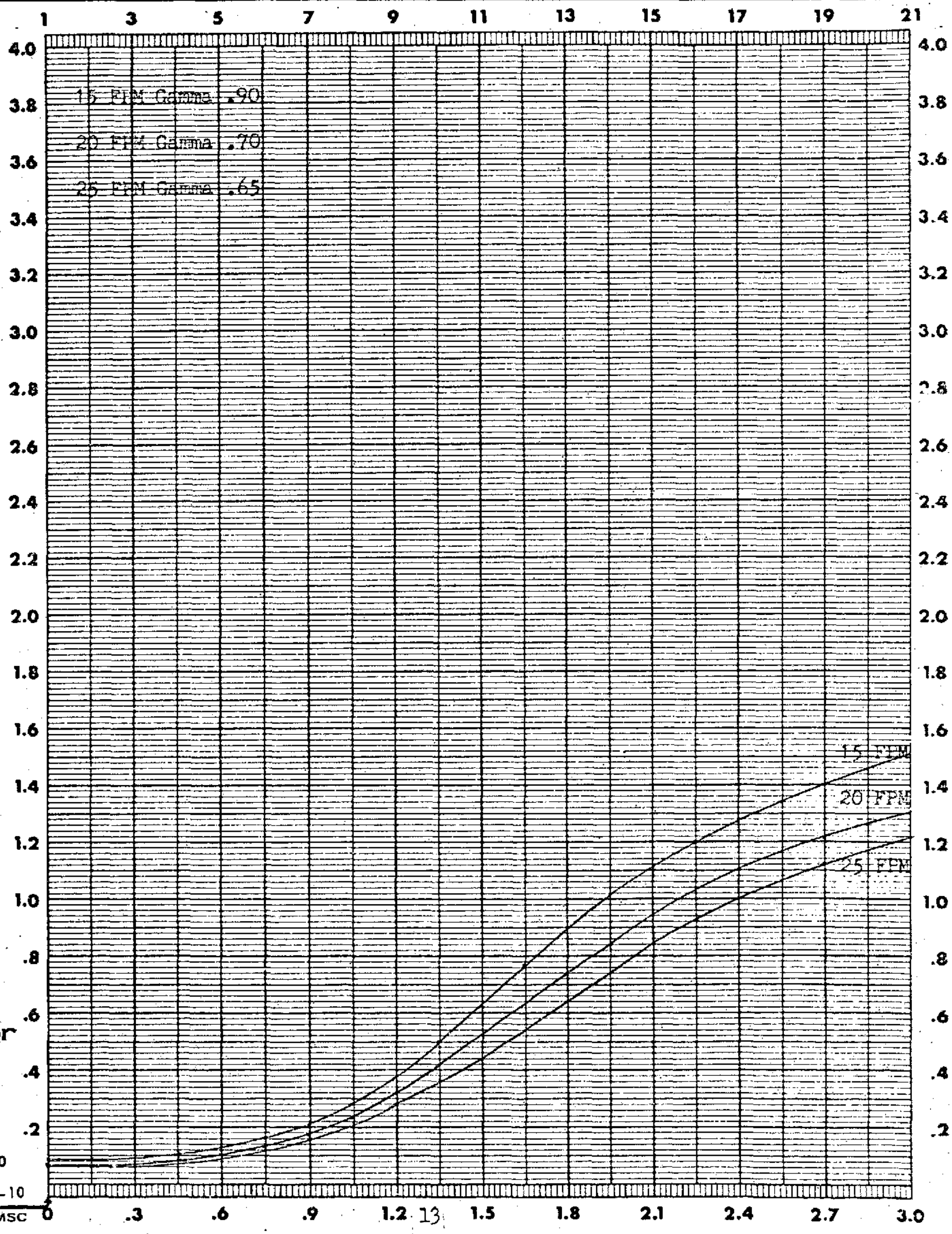

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T71-21 NASA — MSC

DATE 18 Oct. 71 CONTROL # ______ TASK Time Gamma PREPARED BY C. Moody

FILM SO 394 EMULSION # ______ MFG ______ EXPIRATION DATE ______

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER 1-B	PROCESSOR Fultron # 1	INSTRUMENT TD- 217	SPEED ( )
ILLUMINANT 3000 °K	CHEMISTRY MX 819-1	TYPE DD	D-MAX
TIME 1/10 SEC.	SPEED full TANKS 15-25 FPM	APERTURE SIZE 4 MM	GAMMA
FILTER P-11 pack	TEMP °F 90 TIME	FILTER Visual	BASE + FOG

CHEMICAL ANALYSIS

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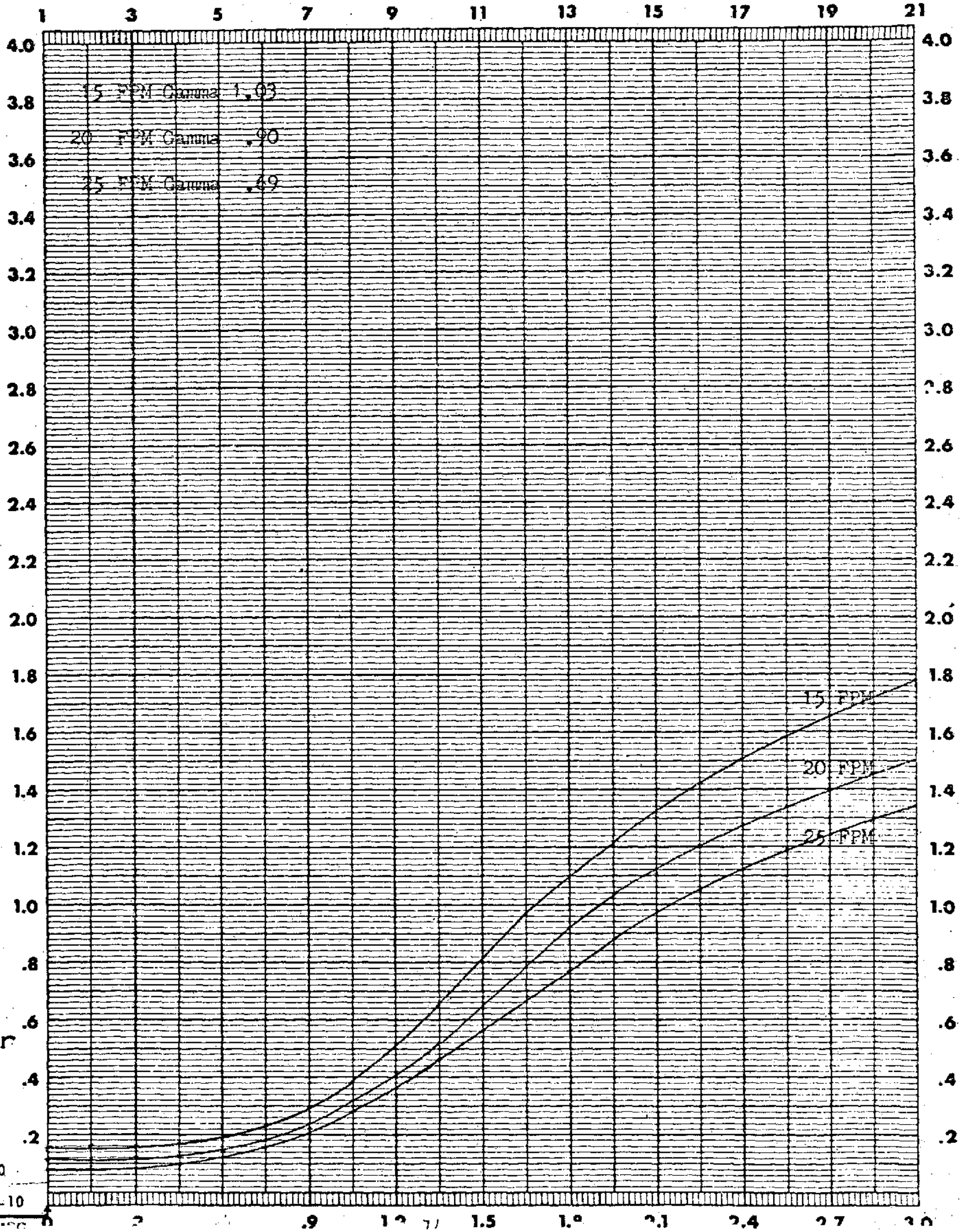

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ABSOLUTE LOG E AT R.L.E. - 0

DATE 14 June 71 CONTROL # (5in.) TASK PREPARED BY E. Weizer

FILM SO-394 EMULSION # MFG E.K. EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER 1-B	PROCESSOR V-Mat 11C	INSTRUMENT Macbeth	SPEED ( )
ILLUMINANT 3000 °K	CHEMISTRY G4L	TYPE TD 204	D-MAX
TIME Various SEC.	SPEED 2 TANKS 6.5 FPM	APERTURE SIZE 4 MM	GAMMA
FILTER P-11 pack	TEMP °F 85 TIME	FILTER Visual	BASE + FOG 0.04

CHEMICAL ANALYSIS

SP GR

pH

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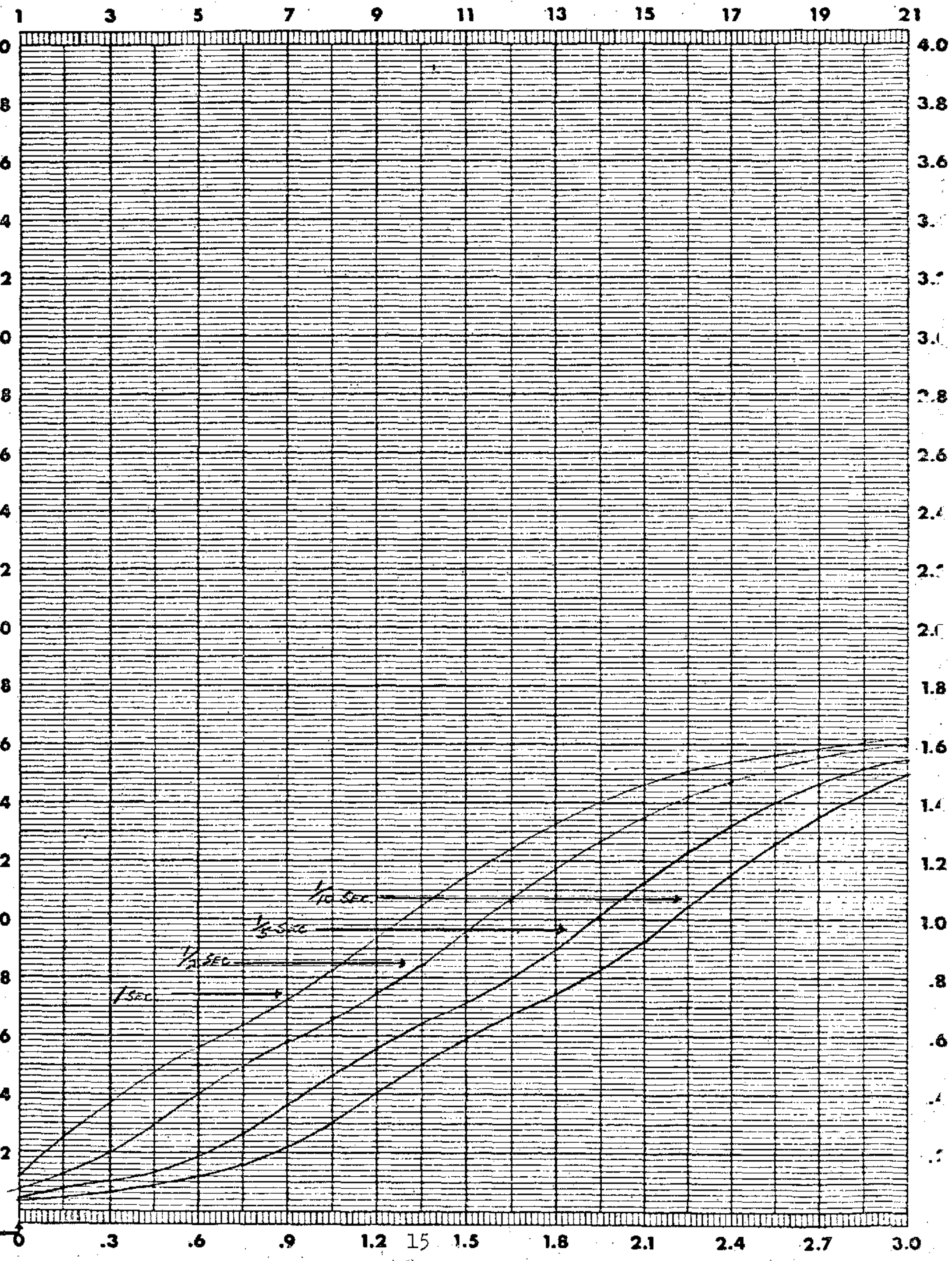

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T71-21 NASA — MSC

DATE Dec 7 71 CONTROL # 70mm TASK ______ PREPARED BY E. Weizer

FILM SO-394 EMULSION # 3-1 MFG E.K. Co. EXPIRATION DATE N/A

792 EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER 1-B	PROCESSOR V-Mat 11C	INSTRUMENT Macbeth	SPEED ( )
ILLUMINANT °K	CHEMISTRY MX-641	TYPE TD 217 DR	D-MAX
TIME SEC.	SPEED 2 TANKS 10 FPM	APERTURE SIZE 4 MM	GAMMA
FILTER	TEMP °F 85 TIME	FILTER Visual	BASE + FOG 0.12

CHEMICAL ANALYSIS

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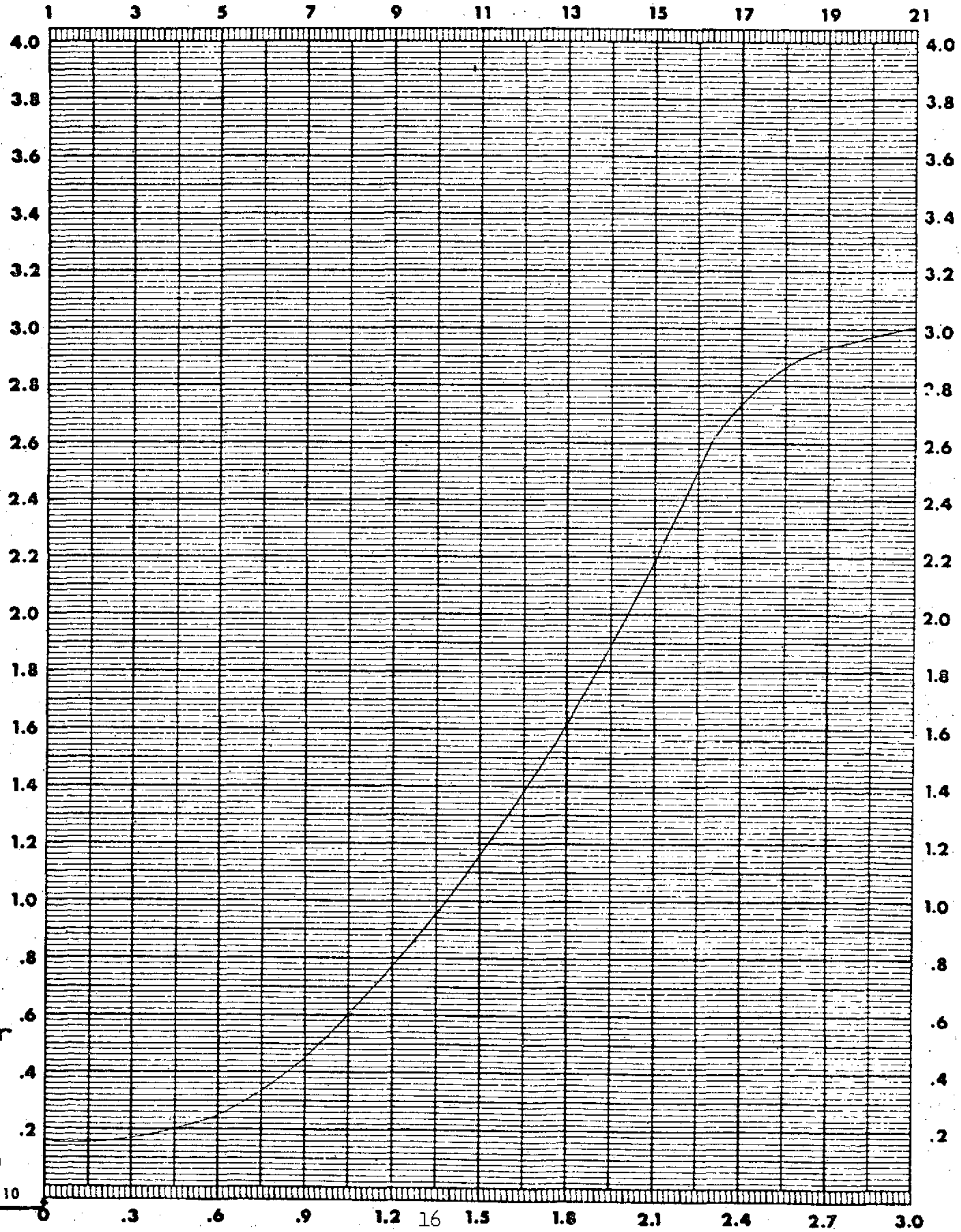

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T71-21

DATE Oct 71 CONTROL # GOODYEAR TASK HT-35 PREPARED BY E. Weizer

FILM SO-394 EMULSION # 3-1 MFG E.K. Co. EXPIRATION DATE N/A

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER E.G. & G.	PROCESSOR Versamat 411	INSTRUMENT	SPEED ( )
ILLUMINANT °K	CHEMISTRY Hunt Arcon	TYPE	D-MAX
TIME 10^{-2} 1/1000 SEC.	SPEED TANKS 12.5 FPM	APERTURE SIZE MM	GAMMA
FILTER Wratten 48	TEMP °F 95 TIME	FILTER	BASE + FOG

CHEMICAL ANALYSIS

SP GR

pH

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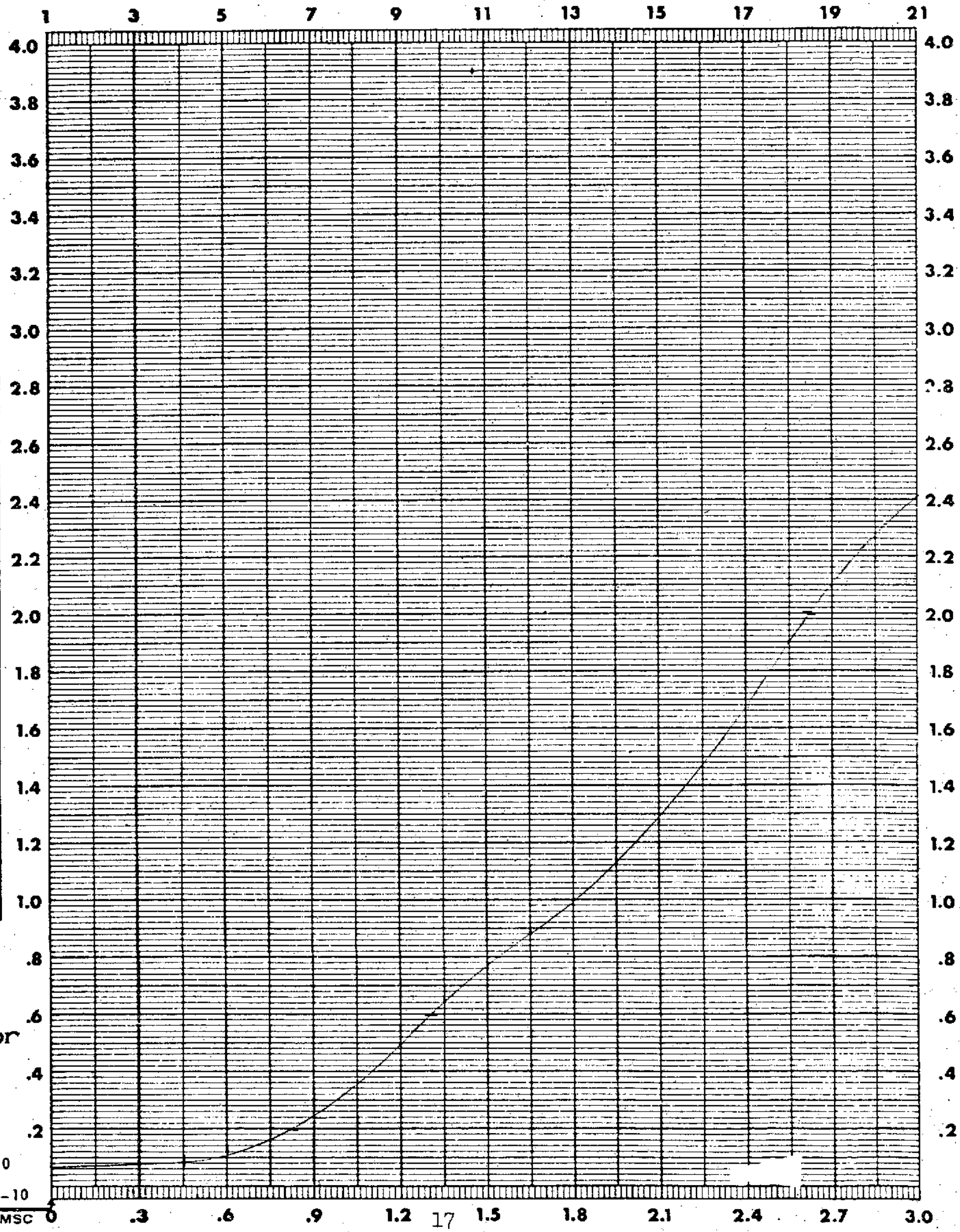

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ABSOLUTE LOG E AT R.L.E. – 0

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