(NASA-CR-141734) EVALUATION OF FILM TYPE QX 807 (SO-368, KODAK EKTACHROME MS, ESTAR THIN BASE, WITH AN EQUIVALENT WRATTEN 2A FILTER OVERCOAT) (Technicolor Graphic Services, Inc.) 31 p HC $3.75 CSCL 14E G3/35

N75-21598

Unclas 19221

EVALUATION OF FILM TYPE QX 807, (SO-368, Kodak Ektachrome MS, Estar Thin Base, with an Equivalent Wratten 2A Filter Overcoat)

Prepared Under
Contract NAS 9-11500
Task Order HT-114

Prepared By

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April 1975

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(SO-368, Kodak Ektachrome MS, Estar
Thin Base, with an Equivalent
Wratten 2A Filter Overcoat)

This report has been reviewed
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ABSTRACT

A color film with a sensitivity and color balance equal to SO-368, Kodak MS Ektachrome (Estar Thin Base) was required for use on the Apollo-Soyuz Test Project. A Wratten 2A filter was required for use with the film to reduce short wavelength effects which frequently produce a blue color balance in aerial photographs.

This report documents the background regarding a special emulsion which was produced with a 2A filter equivalent as an integral part of an SO-368 film manufactured by Eastman Kodak, the cost for production of the special film, and the results of a series of tests made within PTD to certify the film for ASTP use.

The tests conducted and documented were physical inspection, process compatibility, effective sensitivity, color balance, cross section analysis, resolution, spectral sensitivity, consistency of results, and picture sample analysis.

BACKGROUND

The Apollo-Soyuz Test Project (ASTP) scheduled for mid-year 1975 has requirements for photography of the Earth's surface from the Apollo-Soyuz spacecraft. Project MA-136, Earth Observations and Photography, requires the use of color photography with oblique looking 70mm Hasselblad cameras to support the observation program of Dr. Farouk El Baz.

Photography of the earth from very high altitudes necessitates considerations of the effects of the atmosphere on light travelling through it from the subject to the camera. These effects are well documented [1], [2] with perhaps the best description being in Color Science [3]. The net effect is a predominance of shorter wavelength radiation which causes a blue veiling in uncorrected color photographs. Correction of this problem is routinely accomplished through the addition of a camera filter such as the Kodak Wratten 2A (Figure 1).

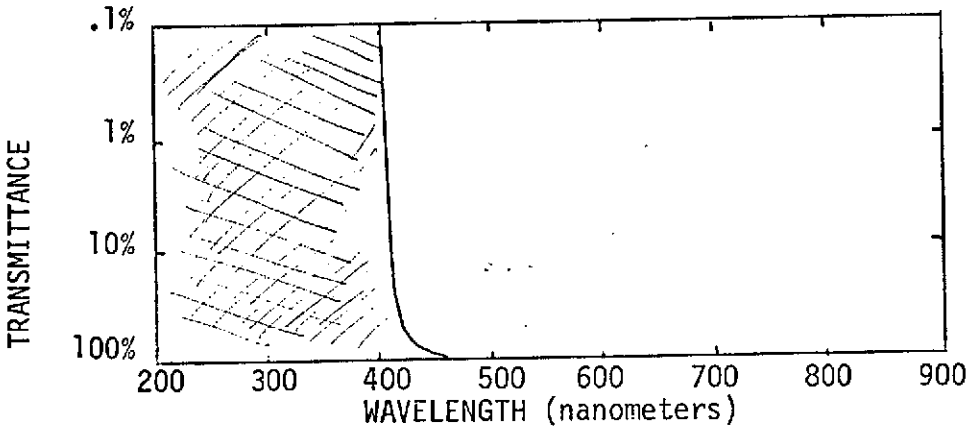


FIGURE 1. Wratten 2A Filter

It was determined during photographic planning for ASTP that Wratten 2A or short wavelength blocking filters for the Hasselblad cameras were not in the approved flight hardware inventory. It was also determined that procurement of the proper filters and check-out for approval as flight hardware would be difficult due to scheduling.

PTD proposed an alternative to the camera filter which would produce the same photographic effect in the imagery, this being to "coat" a filter directly on the film to be used. The decision was made to adopt this technique for providing proper filtration with the SO-368, Kodak Ektachrome MS (Estar Thin Base) Film to be used on ASTP.

This report is a review of available information regarding the filter coating technique, a comparison of cost information and documention of test results on the specially coated SO-368 film. The film has been designated QX807 emulsion 1-32 by Eastman Kodak.

TECHNIQUE

The available techniques for filter coating a photographic film include (1) a dye absorption coating added to the emulsion side surface of an existing film stock and (2) an absorption dye addition to the film overcoat during the film manufacturing process.

A normal photographic film, as manufactured, consists of numerous separate and distinct layers, each with a well defined use in the final product. Typical of these layers for a color film might be :

- the anti-curl coating
- an antihalation coating
- the film base
- a minimum of three light sensitive layers
- a yellow filter coating to correct dye characteristics
- a protective overcoat

Each layer incorporates different chemicals and materials. The technology for coating these layers is highly developed and routinely accomplished by photographic and thin film manufacturers.

Tech/Ops, Inc. of Burlington, Massachusetts was notified of the requirement for an ultraviolet absorption overcoat on SO-368 film for ASTP and responded with a brief proposal (4). This company had performed a similar service under Contract NAS 9-8240 completed in 1968. The Tech/Ops technique required the addition of dyes to the surface of an existing film type. Three dye types were cited in their letter of 14 November 1974, reference: proposal 5204550. These dyes were available from Ciba-Geigy, GAF and American Cyanamid.

Eastman Kodak, the film manufacturer for the scheduled ASTP SO-368 film, later agreed to provide the film with dyes added during manufacturing which would approximate the addition of a Wratten 2A filter. This alternative was selected by PTD representatives as the best for several reasons.

- Eastman technology for accomplishing this has been demonstrated and is in current use. SO-242, High Definition Ektachrome Aerial Film, also scheduled for use on ASTP is manufactured with a coated "yellow filter". SO-242 has been successfully used in space on

the Skylab program and has been used on the Earth Resources Aircraft Program in aircraft flown at altitudes from 20,000 to 60,000 feet. Previous experience resulted in high confidence by PTD in Eastman Kodak filter coating technology.

- The coating could be accomplished by technique number 2 as an integral part of the film manufacturing process necessitating no additional coatings.

- The cost was significantly less when accomplished at the manufacturing stage and no added time was necessary for an additional step in the ASTP film preparation.

The film with the filter overcoat was purchased from Eastman Kodak and subsequently delivered to NASA in March 1975.

COST

The costs incurred for producing the special SO-368 film for ASTP were a total of $11,296.38 (less 4% discount). This included 200 rolls of film 16mm x 158 feet, 22 rolls of film 35mm x 200 feet and 36 rolls of film 70mm x 400 feet in length. The charge for the coating process called a "set up charge" was $4000.00.

This cost is compared to a proposed Tech/Ops cost of $13,627.00 for coating 1000 feet of 70mm film. NASA was to provide the film for coating.

The quantity of film when it is a special order film (SO prefix) is somewhat determined by the fact that an entire coating or 4000 square feet minimum of film must be purchased. The width, length and perforation may be specified by the buyer with a plus or minus ten percent quantity guaranteed by Kodak. This is the reason for the excess quantities of film type QX807 (coated SO-368) ordered.

TESTS

Although PTD was highly confident in the process used for manufacturing the QX807 film, a series of tests were designed and implemented to check the new film both to determine its characteristics and to certify it for ASTP use.

These tests included:

- Physical inspection
- Process compatibility
- Effective sensitivity (Speed)
- Color Balance
- Cross Section Analysis
- Resolution
- Spectral sensitivity
- Consistency of Results
- Picture Sample Analysis

These tests were conducted using another SO-368 emulsion for cross reference where applicable.

The tests and results were as follows.

Physical Inspection

A physical inspection of randomly selected sample rolls of each roll width, 16mm, 35mm and 70mm, was made. The inspection is designed as a check for manufacturing anomalies including emulsion defects, dirt, scratches, edge smoothness and coating evenness.

The surface of all QX807 was completely clear of dirt and scratches. The edges were smooth and the base and emulsion surfaces appeared evenly coated. One emulsion defect was found near the end of a 400 foot roll of 70mm film. This defect was a pinhole less than 1 millimeter in length with dark streaks about 7.5 centimeters in length and 2.5 centimeters in width. Although objectionable, it is not uncommon to find such defects on photographic film. These defects represent some very small percent of the total surface coated.

Subsequent defects have not been found on any of the film.

Eastman Kodak was contacted regarding the occurrence of the anomaly and was requested to review its quality control results from the QX807 emulsion. The manufacturer's results indicated that this particular emulsion was exceptionally defect free and selected for NASA because of an awareness of its important space application.

The thickness of QX807 was determined to be 0.0035 inches which was the same as the thickness of 70mm SO-368 emulsion 18-32. The appearance of the two films was also identical. The film was considered physically acceptable.

Process Compatibility

The QX807 film was processed by PTD in its Houston Ektachrome Film Processor in Kodak ME-4 chemistry and in the 1811 Versamat Ektachrome RT Processor using Kodak EA-5 chemistry to evaluate process compatibility. Resultant sensitometric curves are attached here as Appendix A.

The film was found to be compatible with either process producing results which were acceptable when speed and color balance were evaluated.

The curves produced in the Versamat were superior to those produced in the Houston, therefore the 70mm ASTP QX807 flight film will be processed in EA-5 chemistry by the 1811 Versamat.

It was also found that machine speed control in either machine was easily achieved which would make it operationally easier to meet flight film processing control standards.

Effective Sensitivity

The effective speed of QX807 was evaluated by exposing the film with a calibrated sensitometric exposure using the PTD I-B sensitometer. Exposures were made using a 2850°K lamp filtered to a 5500°K color temperature and 1/50 second exposure.

The exposed films were processed in the Versamat and Houston processors, the densities were read using the MacBeth TD-504 densitometer and the results recorded. The curves are included in Appendix A.

Using the Southard Speed method which derives an equivalent ASA speed the results were as follows.

Versamat 1811		Houston	
Machine Speed (fpm)	Film Speed	Machine Speed (fpm)	Film Speed
7	101	9	82
9	71	10	66
11	57	11	61

Color Balance

The color balance or the relationship of the red-green-blue sensitive layers in the film was evaluated using the sensitometric results achieved above and shown in Appendix A.

Color balance with the Versamat operated at nine feet per minute and the Houston operated at ten feet per minute where the approximate proper equivalent ASA speed was achieved were compared. The Versamat results show the red and green sensitive layers with good balance from toe to shoulder and the blue layer sensitivity about one-half stop slower at points through the curve middle or straight line. The Houston curve shows a greater separation between the red and green layers, a slightly more dense toe area and a blue layer sensitivity one-half stop slower. The slower blue layer indicates that the dye additions are absorbing some of the shorter wavelength radiation before it exposes the blue layer as designed.

The Versamat curve is excellent. This curve or one very similar will be established as an ASTP control curve.

Cross Section Analysis

Cross sections of QX807 and a reference SO-368 emulsion 18-38 were cut using the PTD Leitz microtome and examined in a microscope. Photomicrographs are shown in Figure 2.

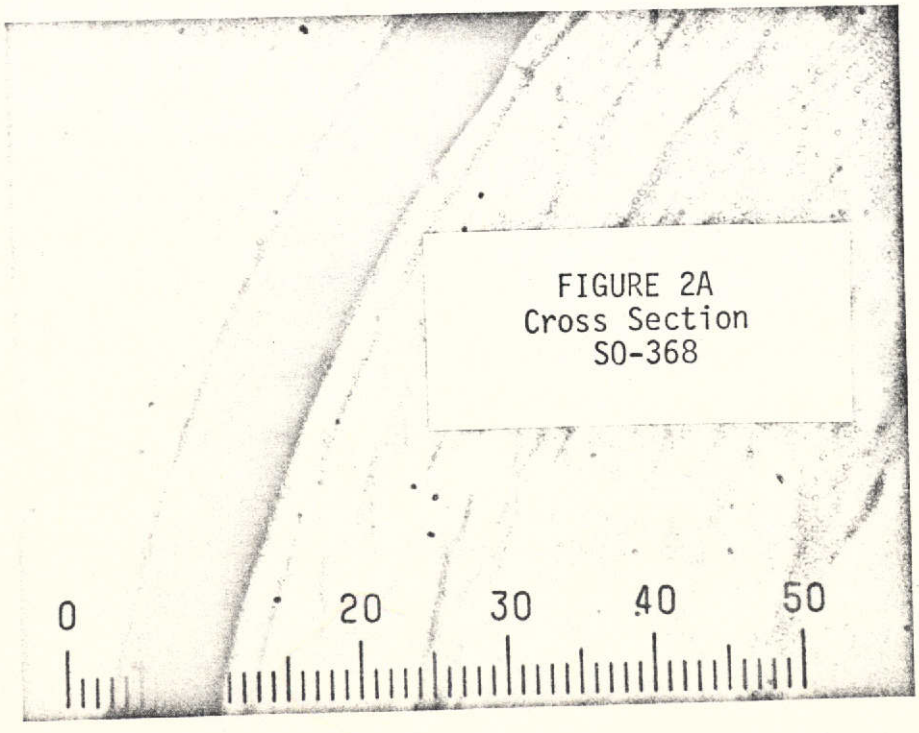


FIGURE 2A
Cross Section
SO-368

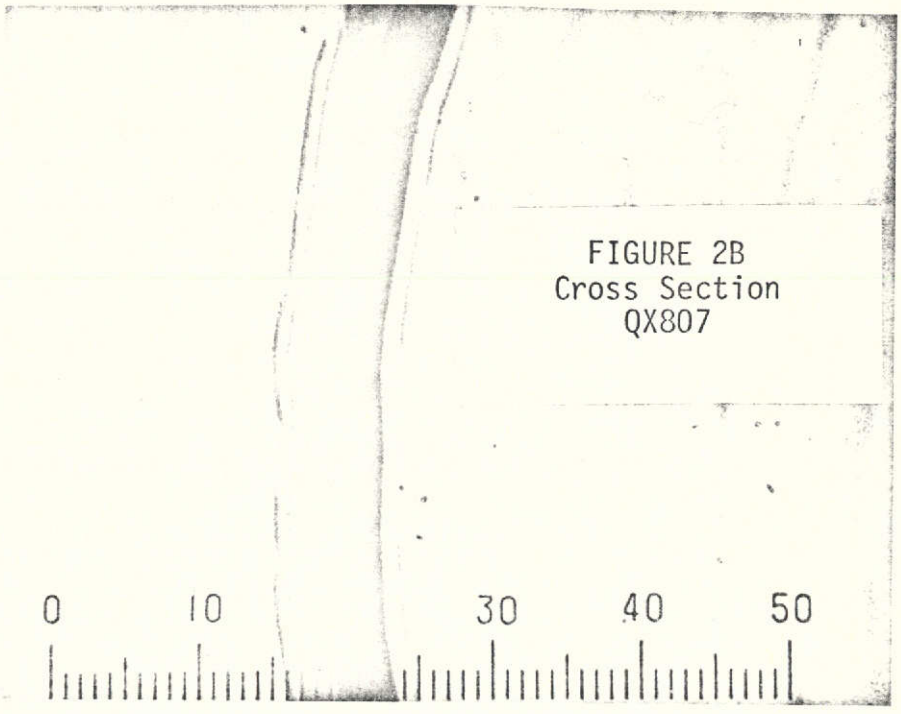


FIGURE 2B
Cross Section
QX807

Subjectively, the two films appear to be very similar. The cyan, magenta and yellow dye layers, the base, an adhesion layer and the overcoat layer (over the yellow layer) are all visible. A relative scale included for reference shows the thicknesses of the two films to be very similar.

The overcoat layer in the QX807 has better defined edges on the microtome than the reference emulsion, but this may be a function of either the microscope illumination relative to the sample position, or the filter characteristics of the dye additives in the QX807.

No significant differences were found between QX807 and the reference SO-368 films.

Resolution

Resolution of QX807 was checked by exposing a master USAF 1951 resolution target onto the new film and reference film using the PTD microcamera.

An exposure and camera focus series were conducted to determine optimum settings and the results were processed in the 1811 Versamat.

Results showed a resolution of 63 line pairs per millimeter for QX807 compared to 71 line pairs per millimeter for the reference. The QX807 was considered acceptable on the basis of resolution tests.

Spectral Sensitivity

Exposures were made on QX807 and a reference SO-368 emulsion using the PTD Mead Spectrum spectral sensitometer. This instrument places an exposure with wavelengths varying from 350 nanometers (nm) to 1000 nm with 11 levels of intensity attenuation at each wavelength.

Integral to analytical density conversion matrices for SO-368 are not available in PTD therefore the results were evaluated subjectively using the samples included as Figure 3.

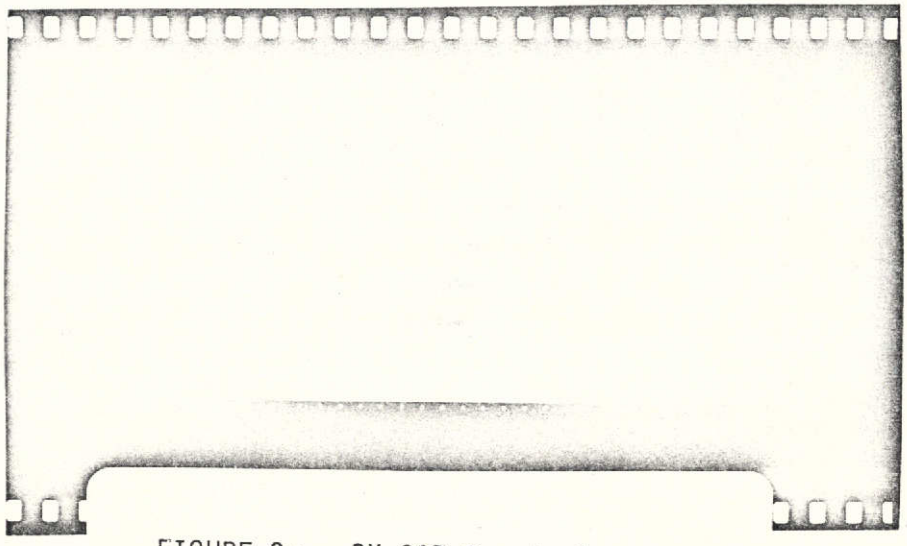


FIGURE 3a. QX-807 Spectral Sensitometry

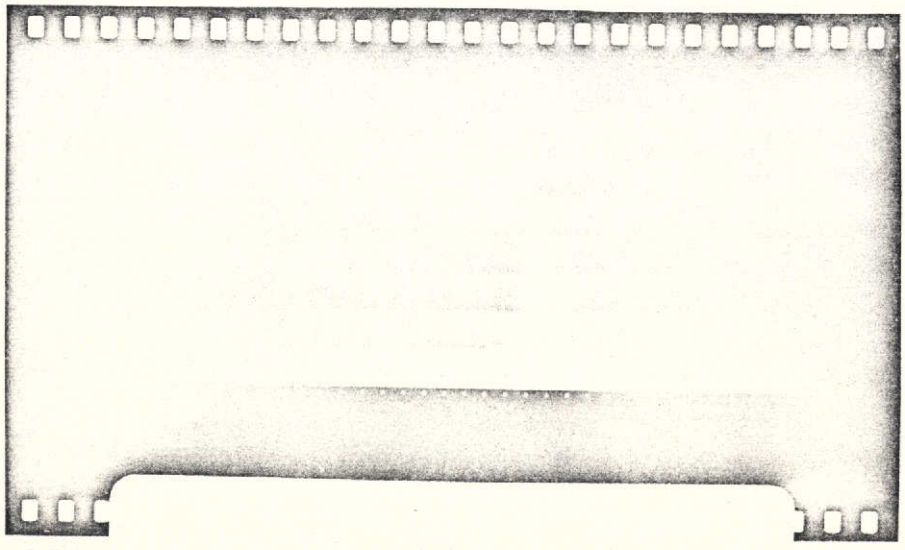


FIGURE 3b. SO-368 Spectral Sensitometry

The effect of the dye absorption in the QX807 emulsion may be noted by exposure attenuation below 400 nm compared to SO-368. This result may be compared to the transmission characteristics of a Wratten 2A filter shown in Figure 1.

Consistency of Results

Consistency of density and color produced by equal exposures was evaluated by making a series of 16 spectral sensitometric exposures on a 100-foot section of 70mm QX807, processing the film in the 1811 Versamat and reading the densities at three wavelengths using the MacBeth TD-217 densitometer with a visual filter.

The results, in density units:

500nm Level 1	650nm Level 1	570nm Level 4
0.54	0.89	0.97
0.53	0.89	0.97
0.53	0.89	0.95
0.53	0.89	0.97
0.53	0.89	0.98
0.53	0.89	0.96
0.53	0.88	0.95
0.53	0.88	0.97
0.52	0.88	0.96
0.53	0.89	0.98
0.53	0.88	0.94
0.53	0.89	0.97
0.53	0,89	0.95
0.53	0.88	0.95
0.52	0.88	0.95
0.53	0.88	0.94

The results were within plus or minus 0.02 density units (densitometric reading error) at the three levels read and recorded.

This data is consistent with the observations made in the physical examination, with sensitometric evaluations and with picture sample analysis.

Picture Sample Analysis

Perhaps the ultimate proof of any film is a subjective evaluation of sample photographs taken under conditions simulating actual anticipated use.

QX807 was exposed in Hasselblad cameras by astronauts on T-38 aircraft training flights and by PTD personnel on ground tests.

Based on sensitivity data generated above the film was exposed to a variety of targets and the results were examined. A slight yellow color balance was obvious on ground targets and less-than-normal blue was observed with aerial scenes.

PTD made tests to "print-out" the effect of the yellow filter (short wavelength dye absorption layer) should non-earth looking photographs be made where atmospheric effects would not be present. This was accomplished with routine laboratory color balancing techniques.

CONCLUSION

The QX807 film (SO-368, Kodak Ektachrome MS,(Estar Thin Base) with an equivalent Wratten 2A filter) was found to be acceptable for ASTP use and was certified for such use [5].

The sensitometric characteristics of this emulsion are superior and high quality space photographs should result if other influencing parameters are controlled.

QX807 is similar in many ways to either SO-242 and SO-356 with the exception of resolution and should be considered a reasonable replacement where greater film speed is important.

REFERENCES

(1) Electro-Optics Handbook; RCA; Harrison, New Jersey, 1968.

(2) Thomas, Woodlief, "SPSE Handbook of Photographic Science and Engineering", Wiley-Interscience, New York, 1973.

(3) Wyszecki, Gunter et al, "Color Science" Wiley & Sons, New York, 1967.

(4) Letter, James Harvey, Tech/Ops to John R. Brinkmann; reference: Proposal No. 5204550, 14 November 1974.

(5) Letter, Harold Lockwood, Technicolor Graphic Services to Noel T. Lamar, NASA, Certification for QX807-1-32C.

APPENDIX A

Sensitometric Curves

QX807-1-32

DATE _____ CONTROL # _____ TASK _____ PREPARED BY _____

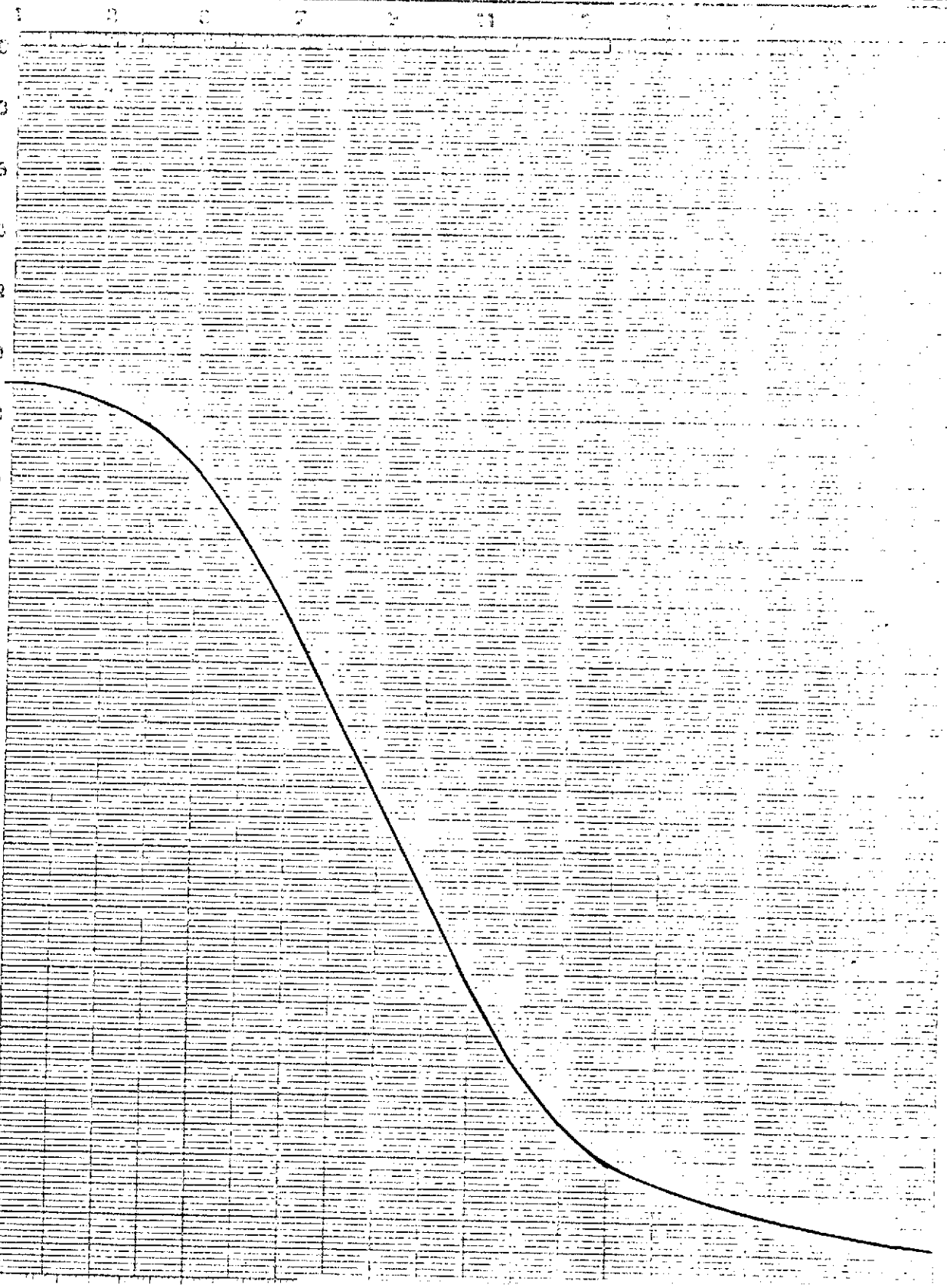
FILM QX 807 EMULSION # 1-32 MFG _____ EXPIRATION DATE _____

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY
SENSITOMETER 1B	PROCESSOR Versamat 1811	INSTRUMENT MacBeth SPEED 101
ILLUMINANT 2850 K	CHEMISTRY EA-5	TYPE TD504 DMAX _____
TIME 1/50 SEC.	SPEED _____ TANKS 7 FPM	APERTURE SIZE 3 DMIN _____
FILTER 5500	TEMP °F 115 TIME _____	FILTER Visual

CHEMICAL ANALYSIS

_____ SP GR	3.0
_____ pH	2.8
_____ TA	2.6
_____ TRP	2.4
_____ KBr	2.2

21	3.0
20	
19	2.8
18	
17	2.6
16	
15	2.4
14	
13	2.2
12	
11	2.0
10	
9	1.8
8	
7	1.6
6	
5	1.4
4	
3	1.2
2	
1	1.0



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FILM QX 807 EMULSION # 1-32 MFG _____ EXPIRATION DATE _____

EXPOSURE DATA	PROCESSING DATA	
SENSITOMETER _____	PROCESSOR 1811	INSTRUMENT MacBeth 101
ILLUMINANT _____ °K	CHEMISTRY EA-5	TYPE TD504
TIME _____ SEC.	SPEED 18 7	APERTURE SIZE 3
FILTER _____	TEMP °F 115	FILTER Status A

CHEMICAL ANALYSIS

SP GR

pH

TA

TRP

KB_r

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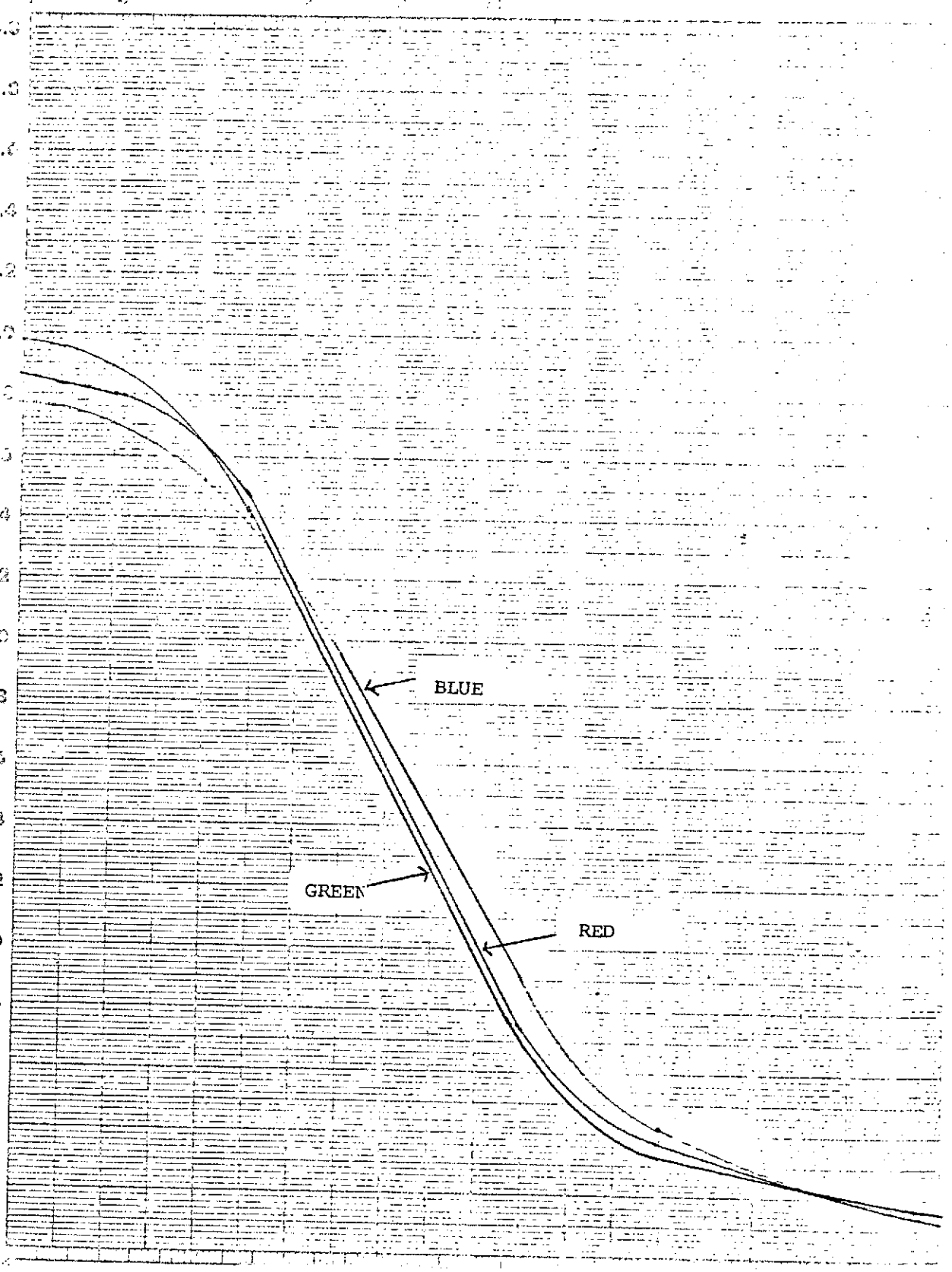

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DATE _____ CONTROL # _____ TASK _____ PREPARED BY _____

FILM QX 807 EMULSION # 1-32 MFG _____ EXPIRATION DATE _____

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY
SENSITOMETER 1B	PROCESSOR Versamat 1811	MAKE MacBeth
ILLUMINANT 2850 °K	CHEMISTRY EA-5	TYPE TD504
TIME 1/50 SEC.	SPEED _____ TANKS 9 TEMP	APERTURE SIZE 3
FILTER 5500°K	TEMP °F 115 TIME _____	FILTER Visual

CHEMICAL ANALYSIS

_____ SP GR

_____ pH

_____ TA

_____ TRP

_____ KB_r

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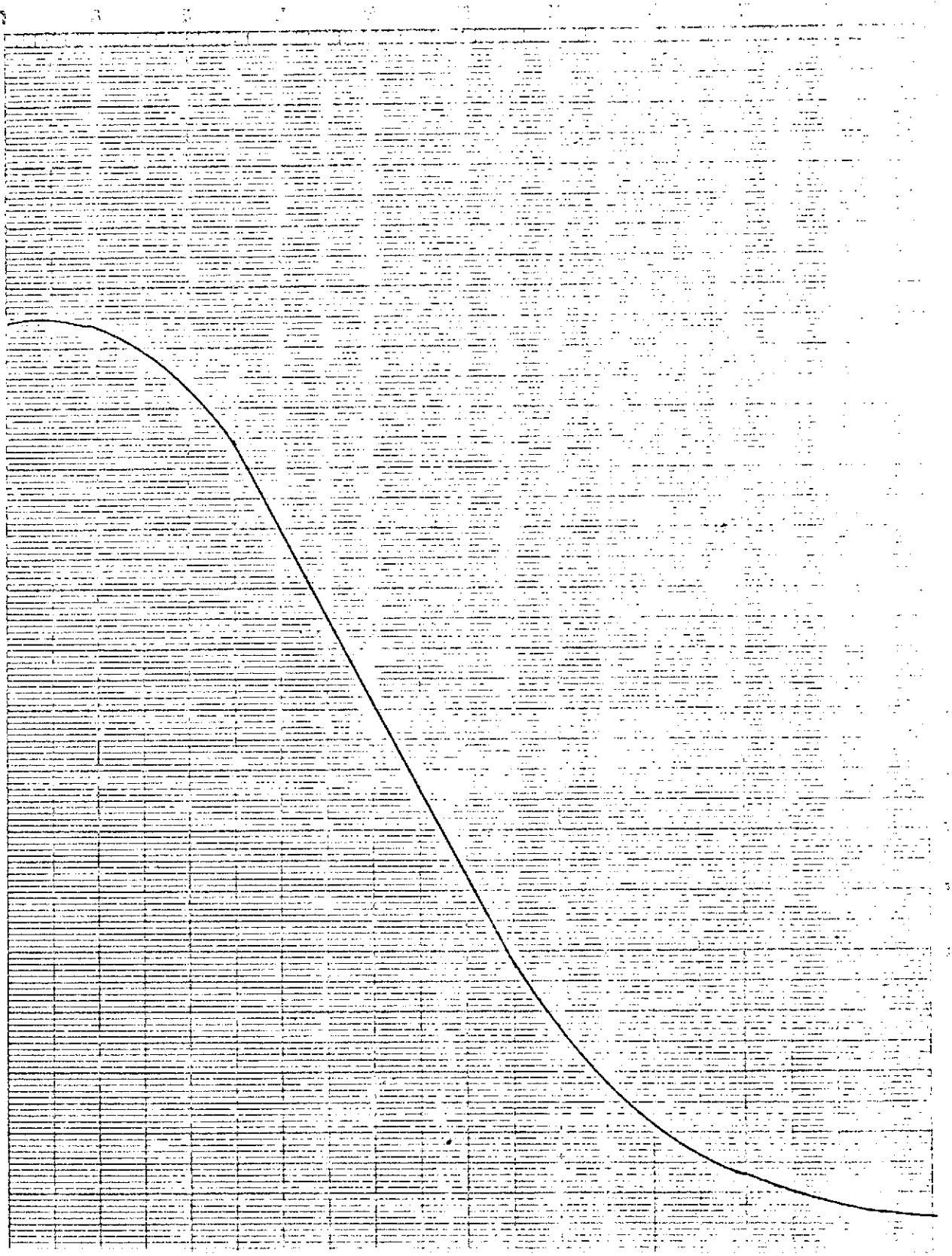

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FILM QX 807 EMULSION # 1-32 MFG _____ EXPIRATION DATE _____

EXPOSURE DATA		PROCESSING DATA		DENSITOMETRY	
SENSITOMETER	1B	PROCESSOR	1811	INSTRUMENT	MacBeth
ILLUMINANT	2850 °K	CHEMISTRY	EA-5	TYPE	TD504
TIME	1/50 SEC.	SPEED	TANKS 9 FPM	APERTURE	3
FILTER	5500°K	TEMP °F		FILTER	Status A

CHEMICAL ANALYSIS

SP GR

pH

TA

TRP

KBr

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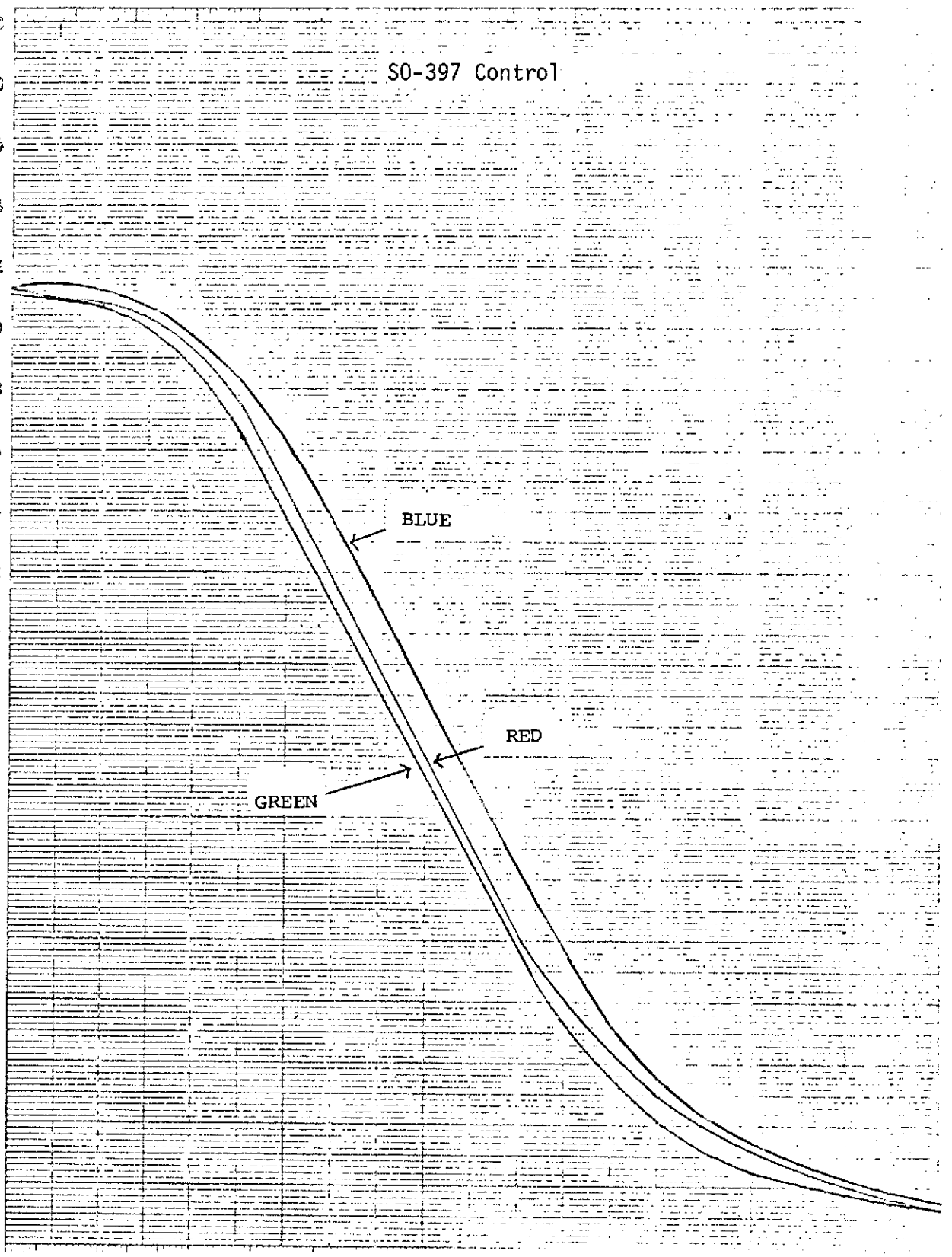

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FILM QX 807 EMULSION # 1-32 MFG _____ EXPIRATION DATE _____

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY
SENSITOMETER 1B	PROCESSOR 1811	INSTRUMENT MacBeth SPEED 57
ILLUMINANT 2850 K	CHEMISTRY EA-5	TYPE TD504 STATUS _____
TIME 1/50 SEC.	SPEED 18 TANKS 11	APERTURE SIZE 3 GAMMA _____
FILTER 5500	TEMP °F 115	FILTER Visual BASE + FOG _____

CHEMICAL ANALYSIS

_____ SP GR

_____ pH

_____ TA

_____ TRP

_____ KBr

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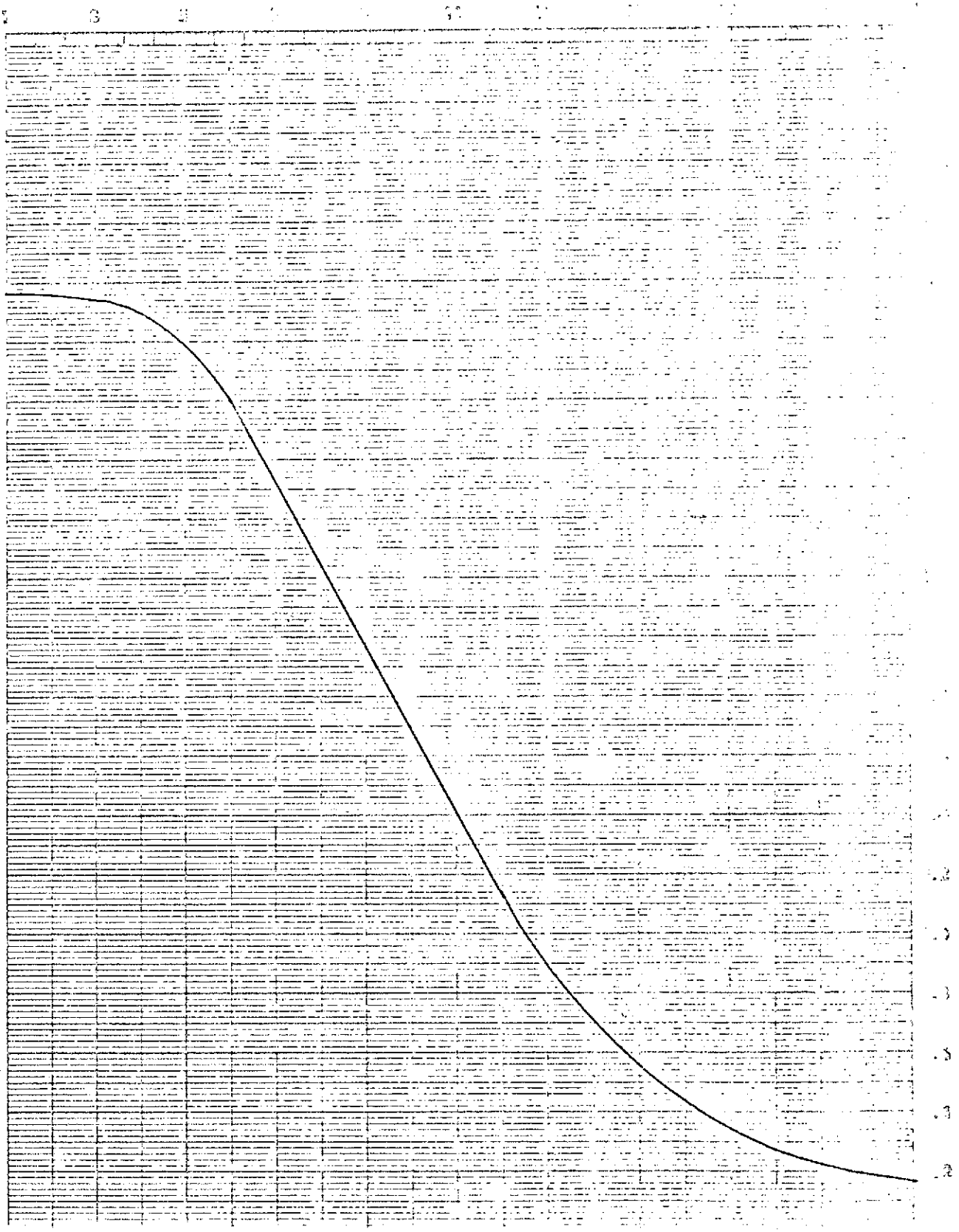

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FILM QX 807 EMULSION # 1-32 MFG _____ EXPIRATION DATE _____

EXPOSURE DATA		PROCESSING DATA			
SENSITOMETER	1B	PROCESSOR	1811	INSTRUMENT	MacBeth
ILLUMINANT	2850 K	CHEMISTRY	EA-5	TYPE	TD504
TIME	1/50 SEC.	SPEED	TANKS 11 RPM	APERTURE SIZE	3
FILTER	5500	TEMP °F	115	FILTER	Status A

CHEMICAL ANALYSIS

SP GR

pH

TA

TRP

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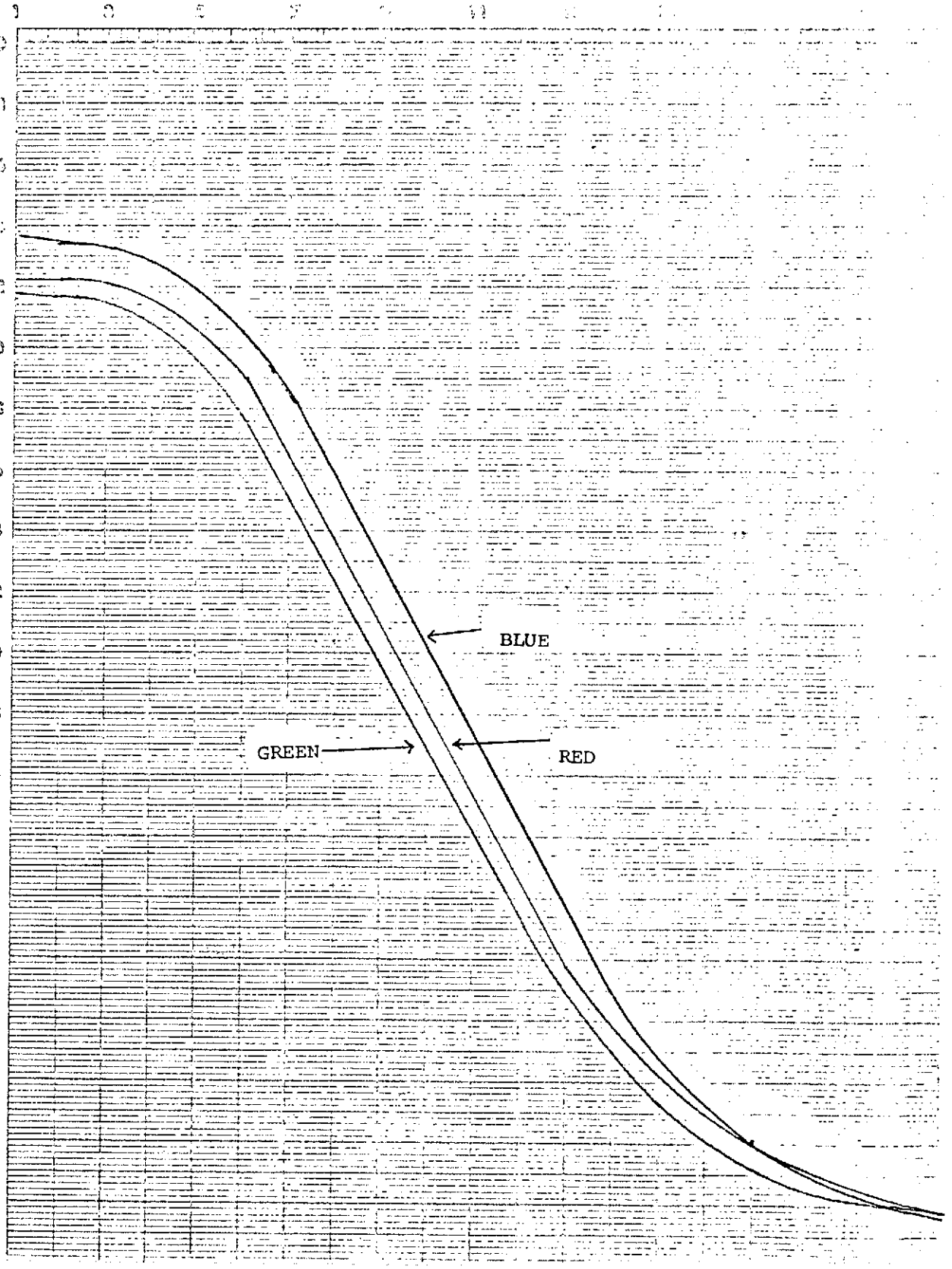

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FILM QX 807 EMULSION # 1-32 MFG EK EXPIRATION DATE _____

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY
SENSITOMETER 1B	PROCESSOR Houston	INSTRUMENT MacBeth
ILLUMINANT 2850 K	CHEMISTRY ME-4	TYPE TD504
TIME 1/50 SEC.	SPEED - TANKS 9	APERTURE SIZE -
FILTER 5500	TEMP °F 98	FILTER Visual

CHEMICAL ANALYSIS

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pH _____

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TRP _____

KB_r _____

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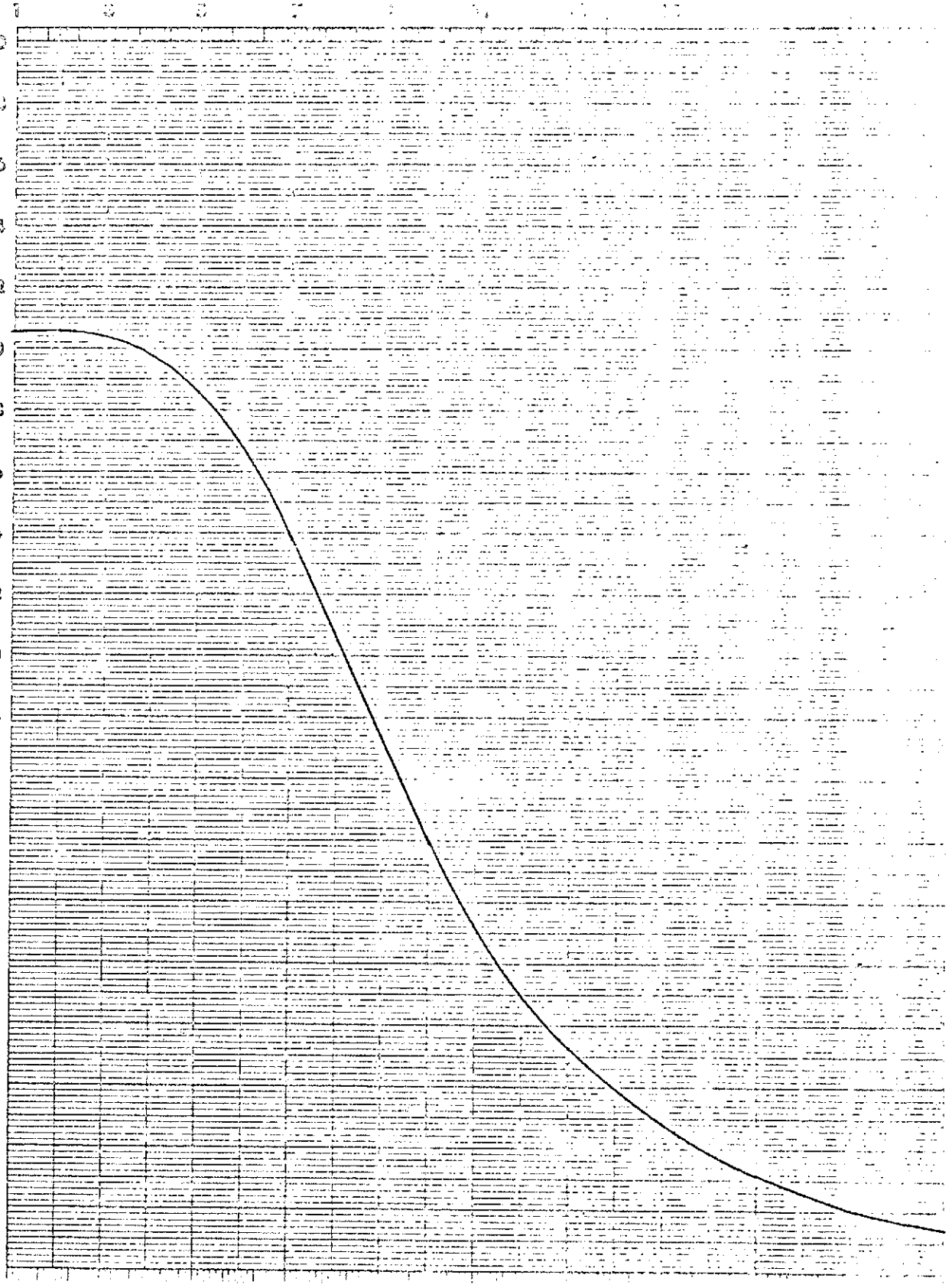

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FILM QX 807 EMULSION # 1-32 MFG EK EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY
SENSITOMETER 1B	PROCESSOR Houston	INSTRUMENT MacBeth
ILLUMINANT 2850	CHEMISTRY ME-4	TYPE TD504
TIME 1/50 SEC.	SPEED - TANK 9 RPM	APERTURE SIZE 3
FILTER 5500	TEMP °F 98 °C	FILTER Status A

CHEMICAL ANALYSIS

SP GR

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TRP

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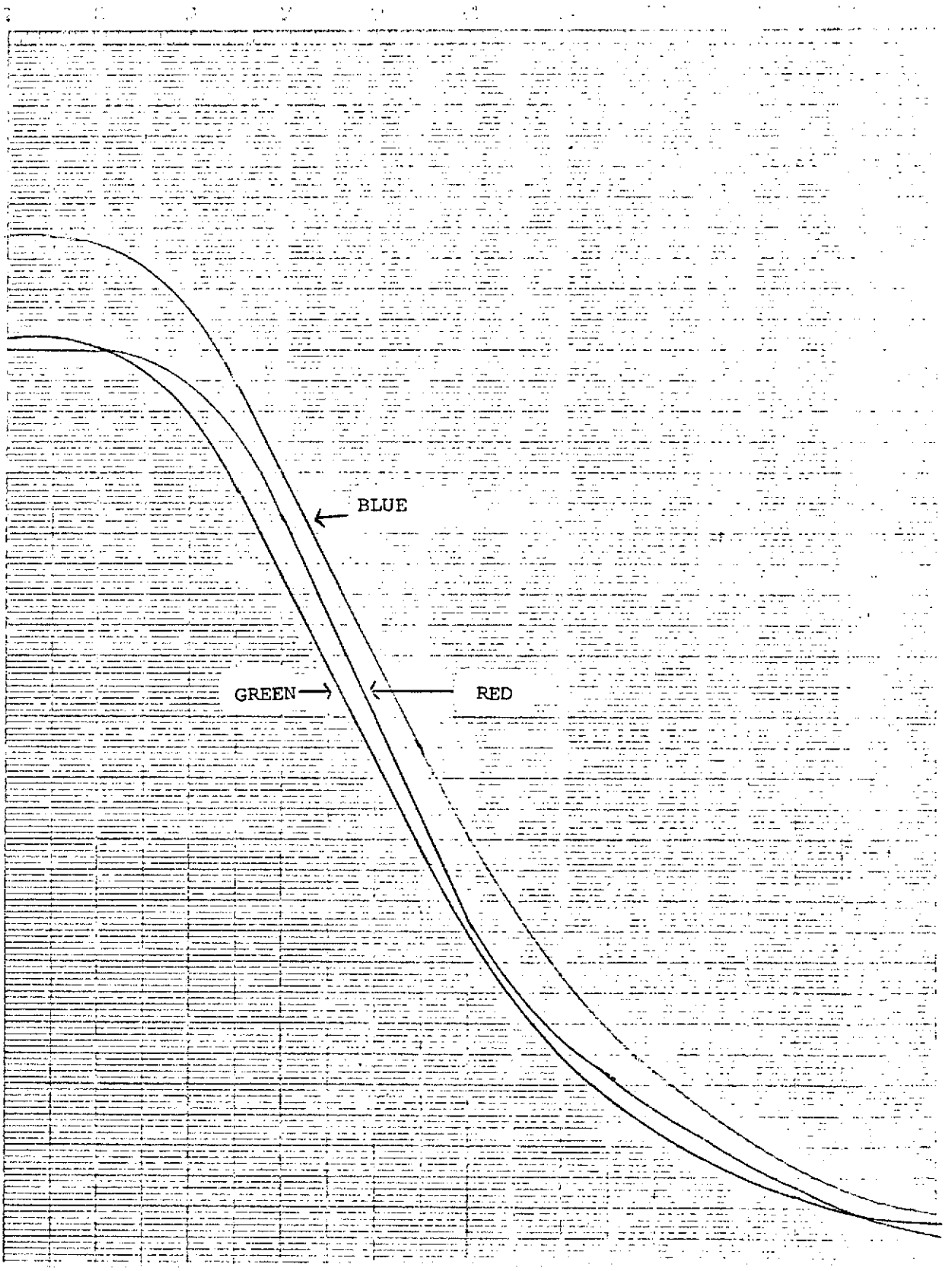

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DATE _____ CONTROL # _____ TASK _____ PREPARED BY _____

FILM QX 807 EMULSION # 1-32 MFG _____ EXPIRATION DATE _____

EXPOSURE DATA	PROCESSING DATA	[illegible]
SENSITOMETER 1B	PROCESSOR Houston	INSTRUMENT MacBeth
ILLUMINANT 2850 °K	CHEMISTRY ME-4	TYPE TD504
TIME 1/50 SEC.	SPEED _____ TANKS 10	APERTURE SIZE 3
FILTER 5500	TEMP °F 98 TIME _____	FILTER Visual

CHEMICAL ANALYSIS

_____ SP GR

_____ pH

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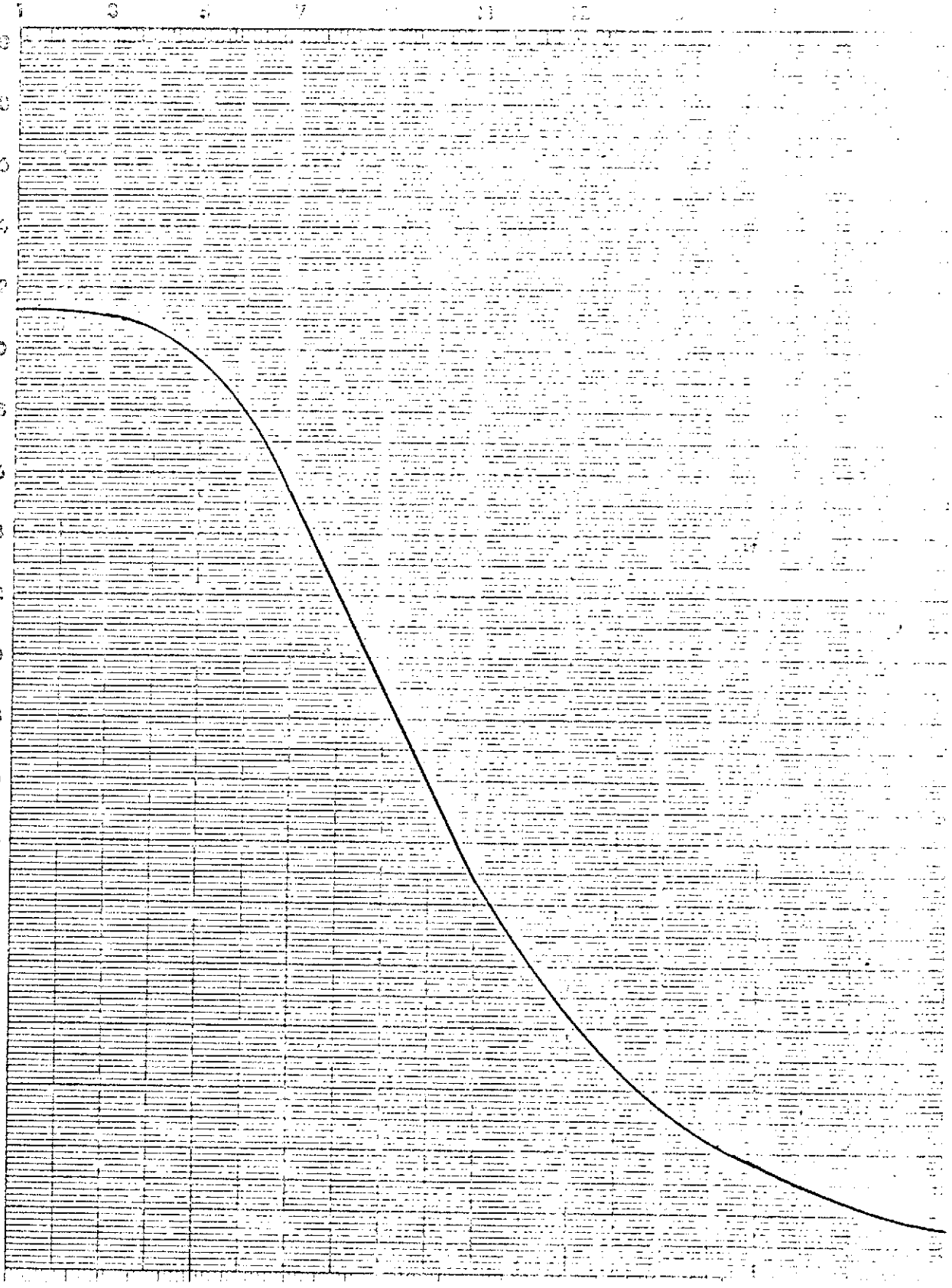

echnicolor

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

DATE _____ CONTROL # _____ TASK _____ PREPARED BY _____

FILM QX 807 EMULSION # 1-32 MFG _____ EXPIRATION DATE _____

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY
SENSITOMETER 1B	PROCESSOR Houston	INSTRUMENT MacBeth 66
ILLUMINANT 2850	CHEMISTRY ME-4	TYPE TD504
TIME 1/50 sec.	SPEED _____ TANKS 10	APERTURE SIZE 3
FILTER 5500	TEMP °F 98 TIME _____	FILTER Status A

CHEMICAL ANALYSIS

SP GR

pH

TA

TRP

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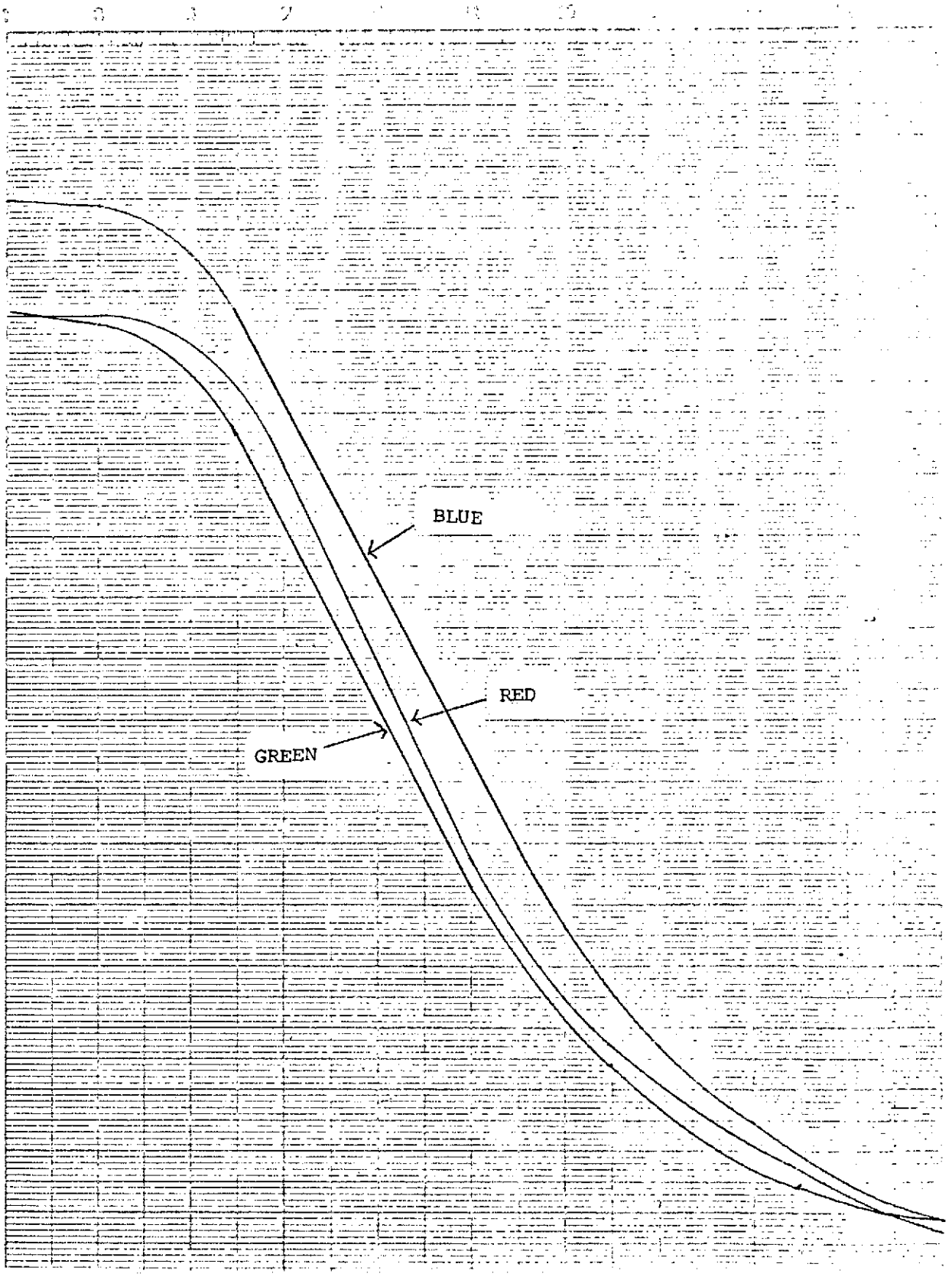

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+R *G ·B

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

DATE 3-11-75 CONTROL # _____ TASK _____ PREPARED BY _____

FILM SO-368 EMULSION # _____ MFG _____ EXPIRATION DATE _____

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY
SENSITOMETER 1B	PROCESSOR Houston	INSTRUMENT MacBeth
ILLUMINANT 2850 K	CHEMISTRY ME-4	TYPE TD504
TIME 1/50 SEC.	SPEED _____ TANKS 11	APERTURE SIZE 3
FILTER 5500	TEMP F 98 TIME 1450	Visual

CHEMICAL ANALYSIS

SP GR

pH

TA

TRP

KBr

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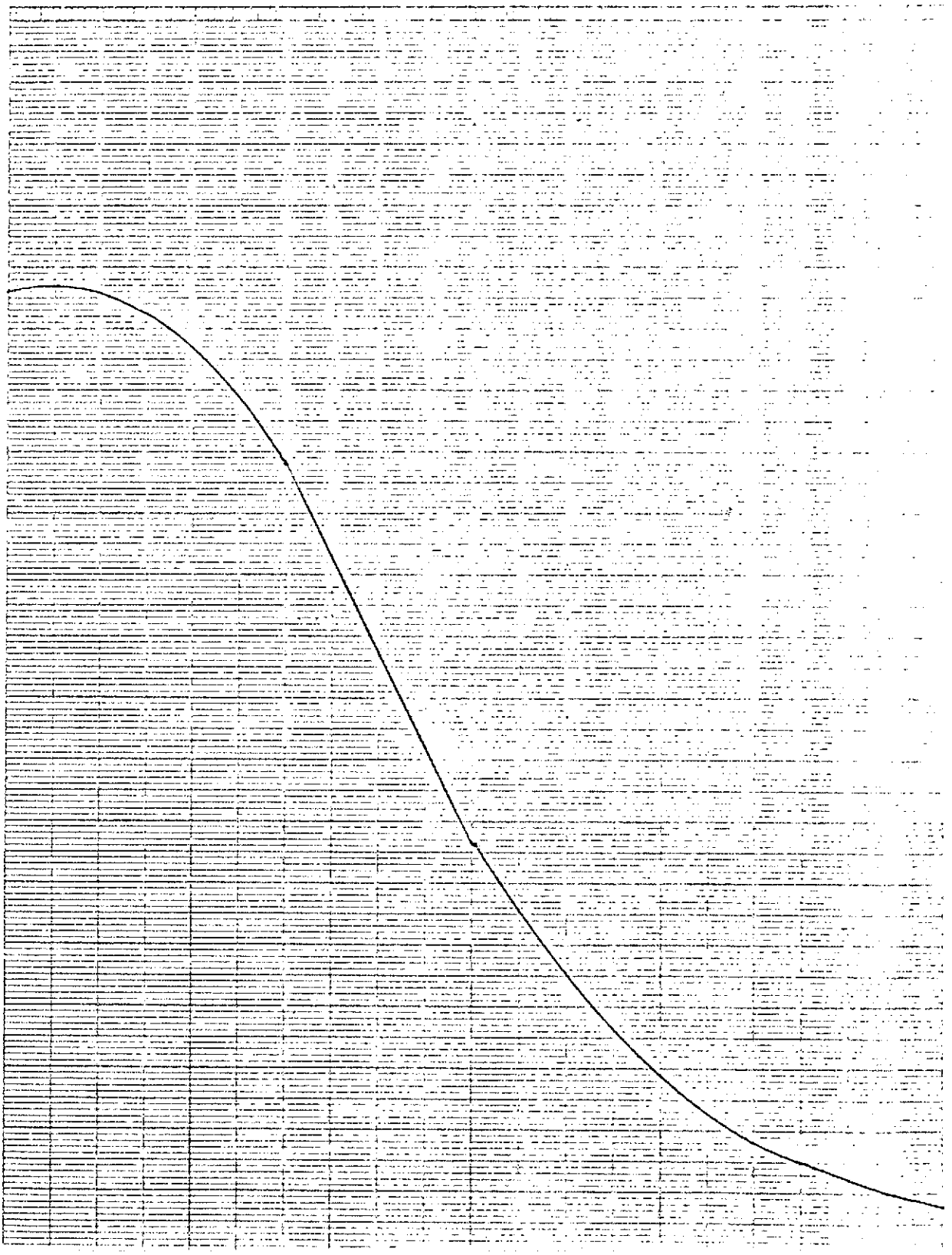

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ABSOLUTE LOG E AT R.L.E. = 0

DATE _____ CONTROL # E TASK _____ PREPARED BY _____

FILM QX 807 EMULSION # 1-32 MFG _____ EXPIRATION DATE _____

EXPOSURE DATA	PROCESSING DATA	SENSITOMETRY
SENSITOMETER 1B	PROCESSOR Houston	INSTRUMENT MacBeth
ILLUMINANT 2850 °K	CHEMISTRY ME-4	TYPE TD504
TIME 1/50 SEC.	SPEED _____ TANKS 11	APERTURE SIZE 3
FILTER 5500°K	TEMP °F 98 TIME _____	FILTER Status A

CHEMICAL ANALYSIS

_____ SP GR

_____ pH

_____ TA

_____ TRP

_____ KBr

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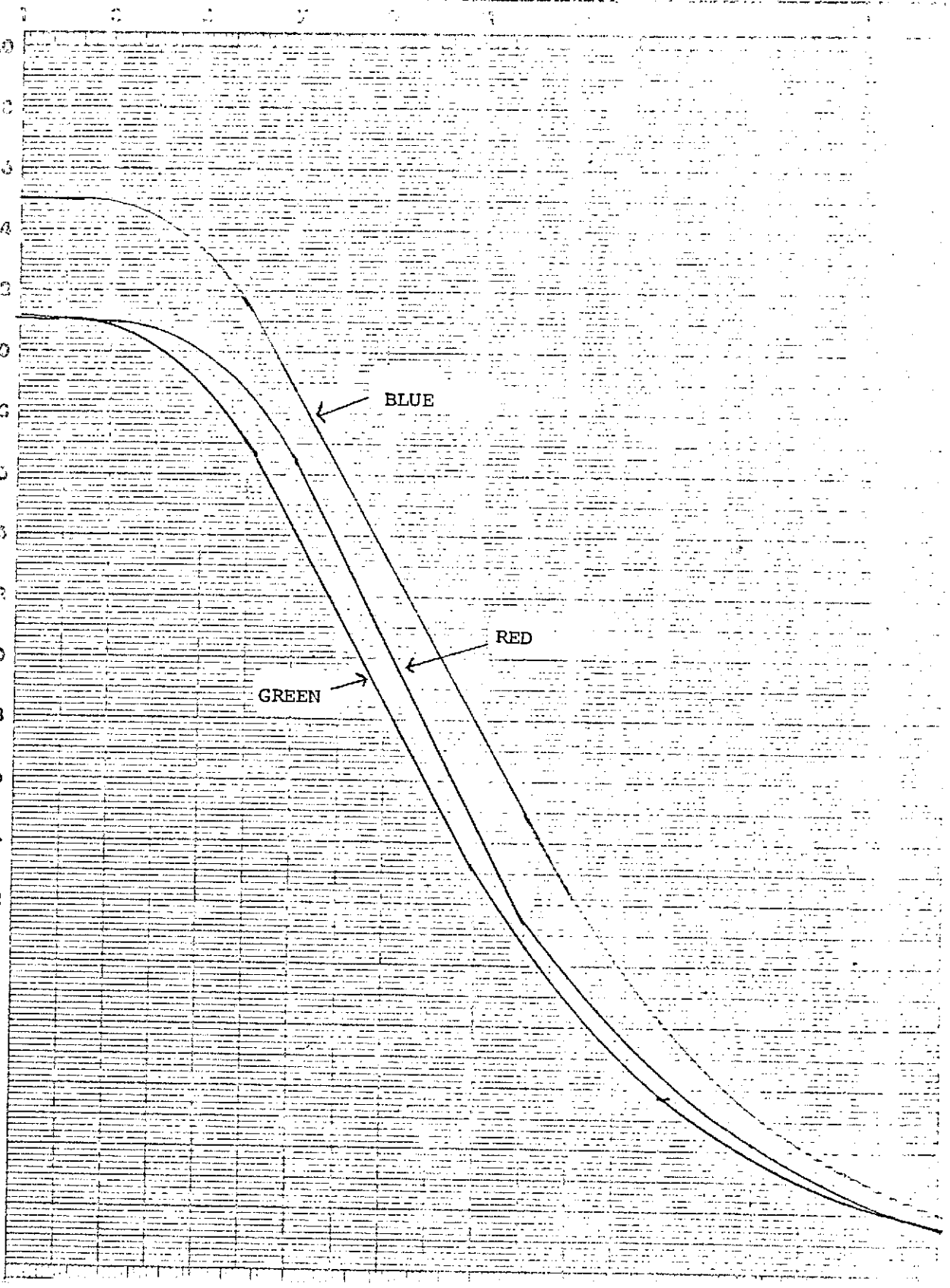

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*G *B

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

7 415 -10