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INFORMATION RECOVERY FROM HIGH-SPEED SILVER HALIDE EMULSIONS CONTAINING CRT TRACES AFTER EXPOSURE TO NUCLEAR GAMMA RADIATION

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INFORMATION RECOVERY FROM HIGH-SPEED SILVER HALIDE EMULSIONS CONTAINING CRT TRACES AFTER EXPOSURE TO NUCLEAR GAMMA RADIATION

ABSTRACT

A data recovery problem often occurs in nuclear tests when photographic film used to record CRT traces is unavoidably exposed to gamma rays before it can be retrieved for developing. This report describes studies made to improve recovery of the CRT data from such film. Best results were obtained with a procedure involving reversal processing, silver intensification, dye-coupling development, and duplication.

INTRODUCTION

Much of the data from a nuclear test is recorded by making photographic records of cathode-ray-tube traces. Because the CRT transients are extremely fast, a highly sensitive photographic film (in our case Kodak Royal-X Pan Recording film) is used for recording.* Occasionally the films containing the CRT traces are unavoidably subjected to a dose of gamma radiation which fogs the film. The gamma rays fog the film with a grainier fogging than that resulting from light exposures. In addition, the gamma-ray fog alters the speed and contrast of the film.

Although Royal-X Pan has an exposure range of approximately 1 to 10,000, after analyzing several CRT traces on a microdensitometer I found that an exposure range of only about 1 to 100 is being utilized. The 1-to-100 range is at the threshold end of the exposure and is the first to go with gamma-ray fogging. In this report I describe studies made at LLL by the Technical Photography Group to improve the processing of gamma-ray-fogged film so as to recover the maximum amount of CRT data from it.

PREVIOUS LLL INVESTIGATIONS

In the past several years our group has tried many methods to reduce the effects of nuclear radiation on photographic emulsions. These are described briefly below.

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*Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Atomic Energy Commission to the exclusion of others that may be suitable.

Herschel Effect

This is latent image destruction by infrared postexposure. It is believed that the latent image from the gamma ray exposure is more sensitive to the infrared exposure than the latent image from the light exposure. This technique was tried on films in the past but did not prove practical because it was very time-consuming and thus quite impractical for any quantity of film. Also, the gain in signal-to-background ratio was of a very small percentage (Ref. 1, p. 25).

Surface Development

Many people in photography research are of the opinion that the latent image caused by light is a surface image on the silver crystal while the latent image caused by gamma radiation is of smaller silver specks which penetrate deep through the crystal. If this is true, then processing the surface image should increase the ratio of the light image to the gamma-ray image.[2] In work done by W. T. Jordan and myself, we were able to increase the light-to-gamma-ray ratio slightly but with a loss of speed and contrast.

Developer Dilution

The initiation of development is known to be a function of both the degree and type of exposure received by a photographic emulsion. According to the literature the induction period is expected to be greater for a latent image caused by gamma radiation than for one caused by light exposure due to the supposedly smaller size of the gamma ray image.[3] Since the induction period is also a function of the concentration of the developing agent, various developer dilutions were tested and employed on some of the shot films in the past with some degree of success.

THE PRESENT STUDY

After receiving a copy of a report titled "Reduction of the Effects of Nuclear Gamma Radiation on Photographic Silver Halide Emulsions," which described work undertaken by Nepela and Nitka,[1] I felt further research on reducing the effects of gamma radiation on silver emulsions would be of great benefit to the Laboratory. Nepela and Nitka's investigations were aimed at the development of gamma-ray-insensitive emulsions for use by the Armed Forces. They did not deal with films as

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[1] D. A. Nepela and H. F. Nitka, Reduction of the Effects of Nuclear Gamma Radiation on Photographic Silver Halide Emulsions, Ansco Division, General Aniline and Film Corp., Binghamton, N. Y., Rept. NP-6935 (1958). Final report for period Jan. 1, 1956-June 30, 1958.

[2] Ref. 1, p. 18.

[3] Ref. 1, p. 21.

fast as those our Laboratory uses for recording high-speed CRT transients; therefore, I decided to take the one film we use most widely for CRT photography, Kodak Royal-X Pan Recording 35 mm, and investigate it as thoroughly as possible.

Experimental Equipment

First of all, a calibration curve for the film's response to gamma rays was necessary. Since the response of silver halide emulsions is essentially constant beyond 0.3 MeV (Fig. 1), a ^{60}Co source (1.3 MeV) was employed to simulate the gamma radiation from a nuclear explosion, which is believed to have its most intense radiation energies at 0.3 and 1.7 MeV.

For the light exposures to simulate a P-11 phosphor, an EG&G Mark VI Sensitometer, which pulses a G. E. FT-118 xenon flashtube, was pulsed at a 10^{-4}-sec flash duration. The approximate spectral distribution is shown in Fig. 2. The flashtube was filtered with a Kodak Wratten No. 48 filter (Fig. 3). Figure 4 shows the flashtube and Wratten 48 filter curves folded and plotted against the P-11 phosphor curve. Although the filter curve is narrower, it comes fairly close to reproducing the P-11 phosphor. Figure 5 shows the spectral sensitivity of Kodak Royal-X Pan Recording film. The test films were exposed through a Kodak calibrated step tablet having a 0.0 to 5.0 density range in 18 steps of approximately a factor of two attenuation each.

Response of Royal-X Pan Film to Light and Gamma Rays

Figure 6 shows the characteristic curve of density vs log exposure for Royal-X Pan film exposed to the simulated P-11 phosphor using processing normally used on operations in the field. Figure 7 shows the response of the Royal-X Pan film to gamma exposure from a ^{60}Co source. The gamma-exposed film seems to develop to a higher gradient than the film exposed with the sensitometer. Part of the gradient difference could be caused by the reciprocity low failure for an exposure as short as 10^{-4} sec. Figure 8 shows the effect of gamma radiation on the density-vs-log-exposure curve.

Because of the higher density backgrounds encountered with the gamma fogging, a method of evenly processing the film was necessary. Several methods of agitation were tested; i. e., Nikor tank with hand agitation, nitrogen burst at varying pressures, and continually wiping the emulsion with a camel's hair brush. The wiping with a camel's hair brush proved to be the most successful. We also found that due to the contrast loss with gamma radiation, the Royal-X Pan should be processed to the highest contrast possible.

Reversal Processing vs Negative Processing

Nepela and Nitka's report stated that the best method found to date to minimize the degradation caused by fogging gamma-ray exposures is the use of the photographic reversal process.[1] The reason that reversal development should offer several advantages over the conventional photographic negative development is that a

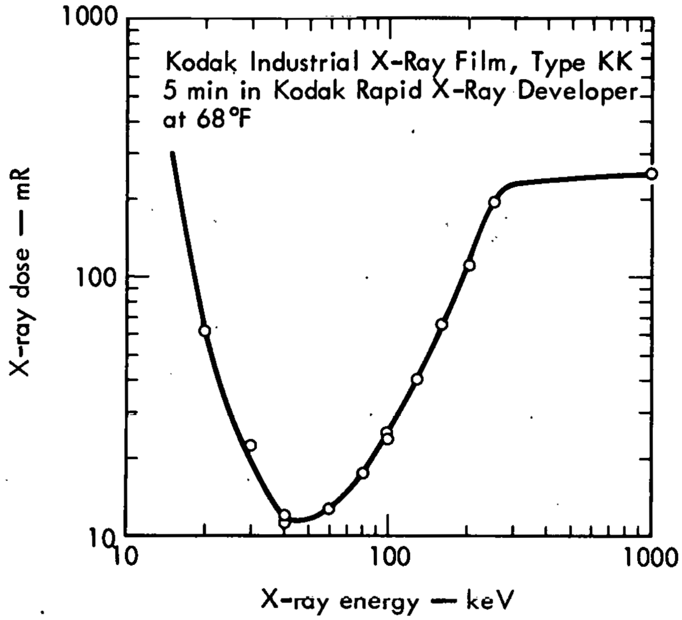

Fig. 1. X-ray dose required to produce density D = 1.0 above fog as a function of x-ray energy. Heavily filtered x rays (Eastman Kodak Co. data).

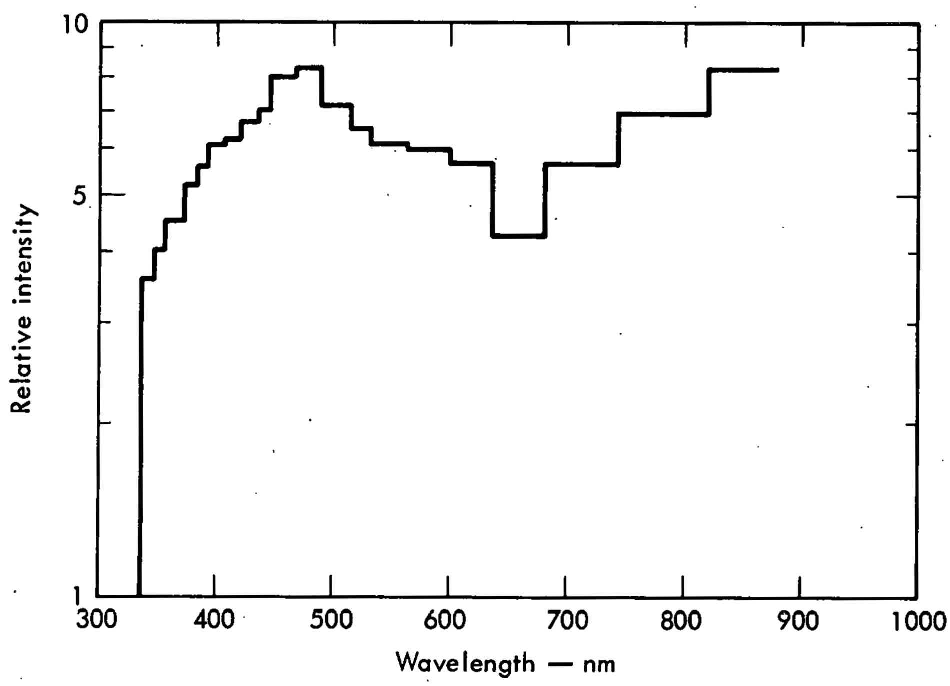

Fig. 2. Spectral distribution of xenon flashtube at 450 V (from General Electric Flashtube Data Manual).

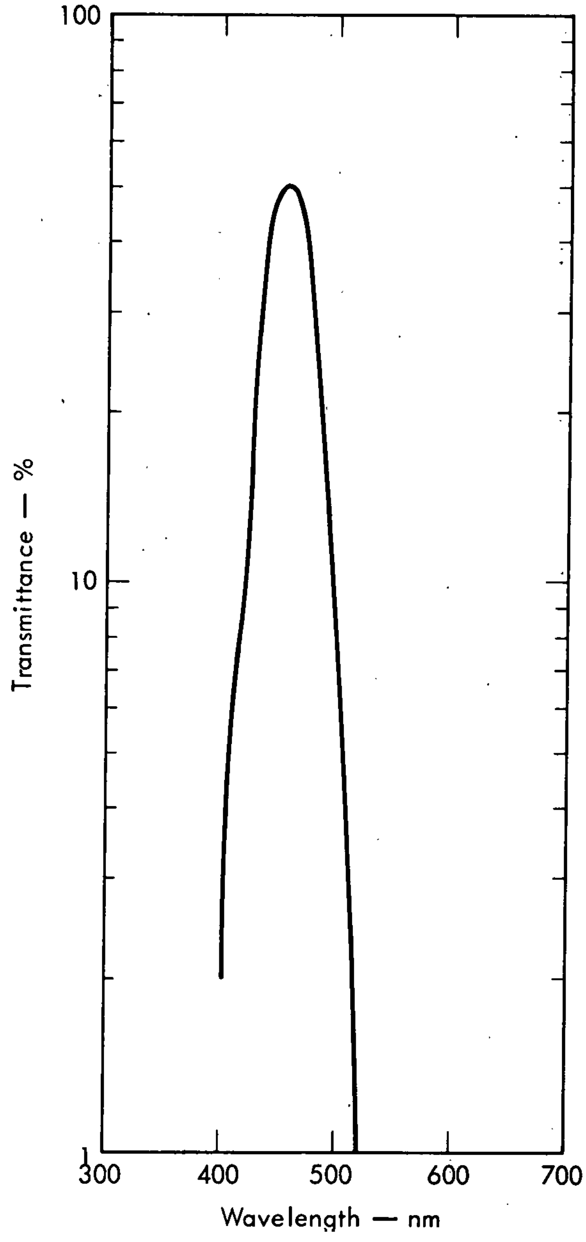

Fig. 3. Spectral transmittance of Kodak Wratten 48 filter (from Kodak Wratten Filter Book).

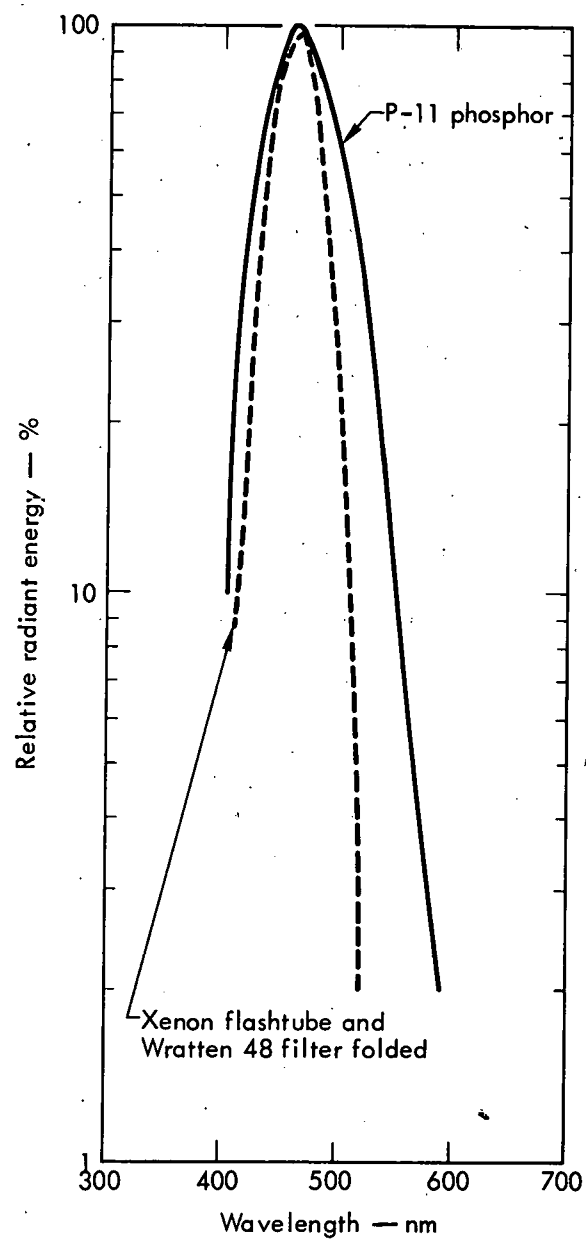

Fig. 4. Spectral comparison of simulated P-11 phosphor (xenon flashtube filtered through Wratten 48 filter) and actual P-11 phosphor.

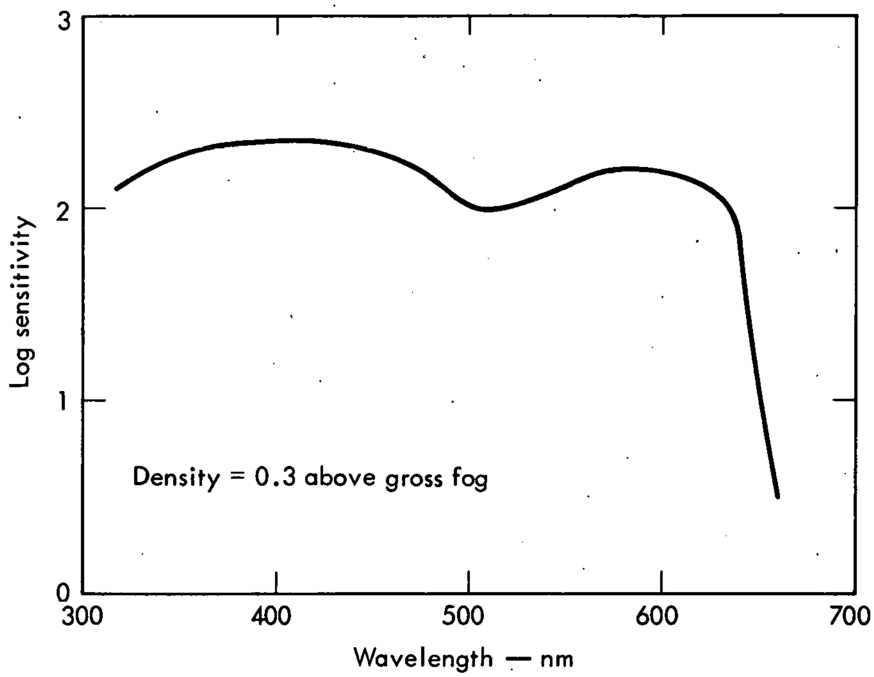

Fig. 5. Spectral sensitivity of Kodak Royal-X Pan Recording film, developed 8 min at 68°F in DK-50 (Eastman Kodak Co. data).

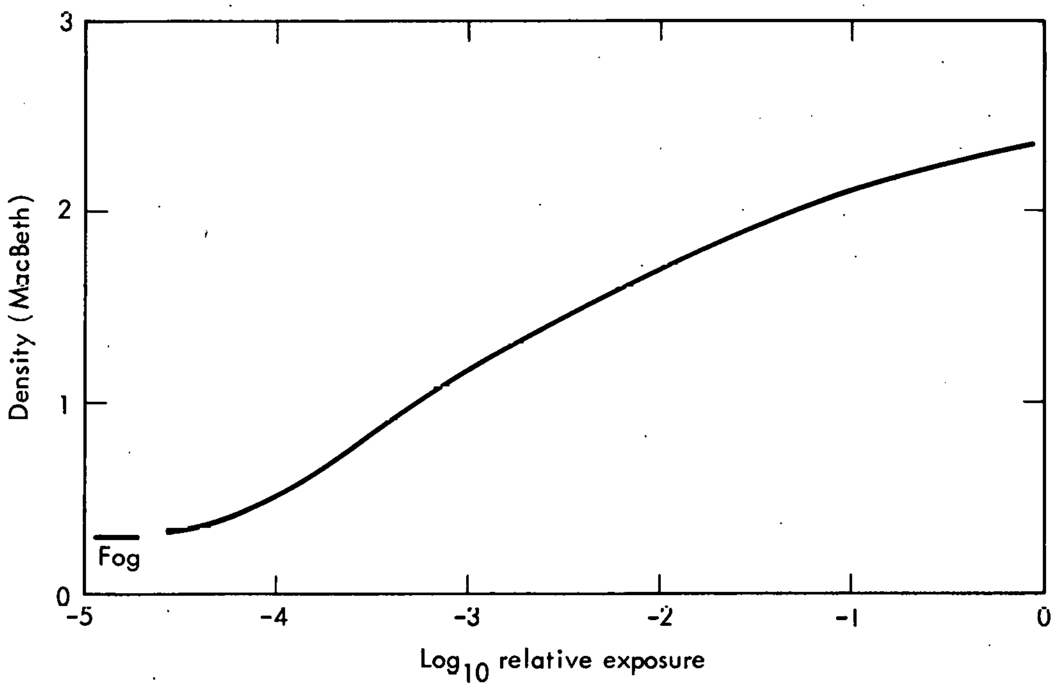

Fig. 6. Density vs log exposure for Royal-X Pan film exposed to the simulated P-11 phosphor and given LLL normal negative processing (developed in DK-50 at 72°F for 8 min with agitation 5 sec/30 sec).

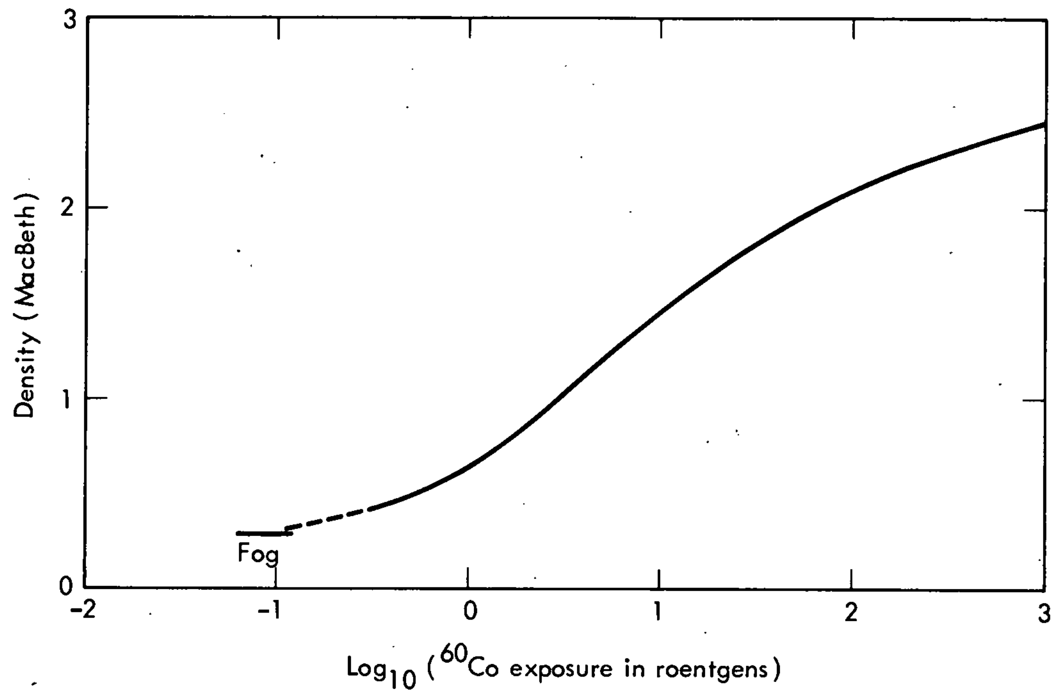

Fig. 7. Response of Royal-X Pan film to gamma rays from ^{60}Co exposure. Same processing as in Fig. 6.

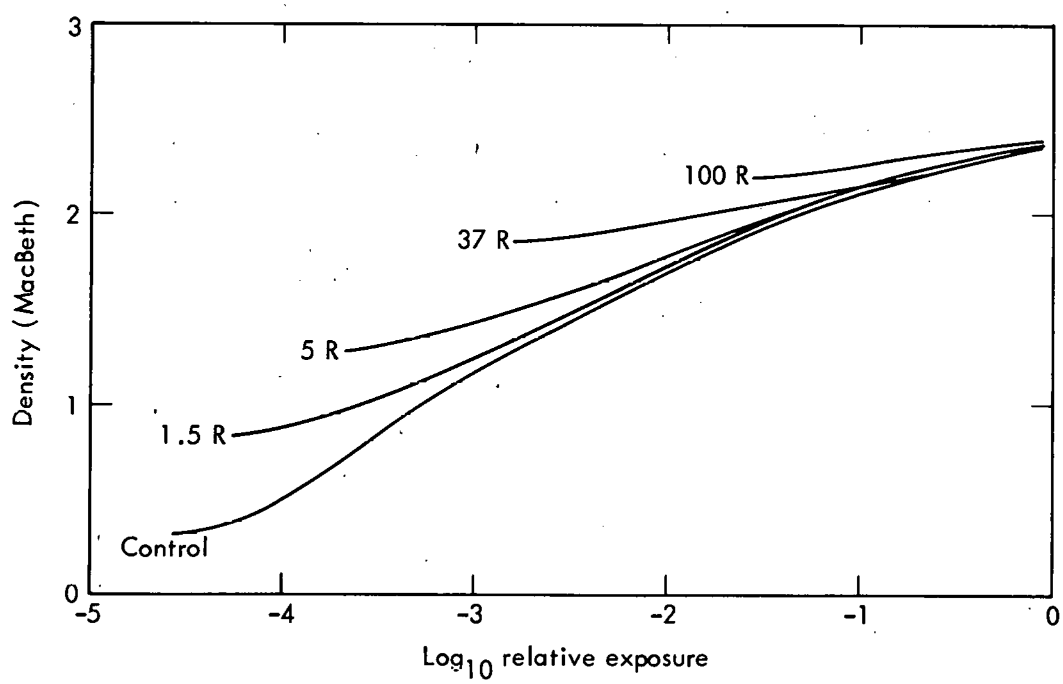

Fig. 8. Effect of various levels of gamma radiation on the curve of density vs log exposure for Royal-X Pan film. The film was exposed to ^{60}Co after light exposure through sensitometric tablet. Same processing as in Fig. 6.

gamma-ray-exposed negative has a high fog value and therefore a high overall opacity; films processed by photographic reversal on the other hand will show no increase in fog upon gamma-ray irradiation but will show loss in contrast and maximum density. We should bear in mind that any methods for intensifying the photographic record will be based on improving image quality. In the case of a CRT trace, if processed to a negative the trace would be above the fog background which would be quite high if the gamma exposure was of the order of a few roentgens. If the same film is processed reversally, the radiation fog would become the feature of maximum density and the trace would fall below it in density, and any intensification would enhance the image.

The negative-processed gamma-fogged film was found to be considerably grainier than the same film processed reversally. Tests were run using Nepela and Nitka's reversal formulas on Royal-X Pan without much success (Fig. 9), and from past experience I have found Royal-X Pan compatible with very few developers. Numerous tests were run using several developers and developer concentrations. Kodak DK-50 mixed to a double strength solution with the addition of 20 cc/1000 cc 0.2% solution of benzotriazole (antifog No. 1) gave the best results. Figure 10 is a plot of the normal 8-min DK-50 curve, the double strength DK-50 with benzotriazole, and the reversal curve obtained using the latter. As can be seen, the gradient has been increased considerably by using the concentrated developer.

Figure 11 shows granularity traces as a function of exposure on both the double strength DK-50 and the reversal curves. The granularity traces were obtained by scanning the step tablets at 4 mm/min with a 63-μm-diam aperture on an Ansco microdensitometer. It can plainly be seen that if one is operating in a medium-to-high-density region on the negative film, the noise level could be lowered considerably by reversal processing.

Figure 12 illustrates the density gain achieved when the reversal-processed Royal-X Pan is silver-intensified and redeveloped in the magenta-dye coupling developer. In Fig. 13, which is a spread function plot, there is some image spread with the reversal process, but, due to the finer grain of the reversal image, the image seems sharper on a viewer than the normally processed negative image.

For the final series of tests a 70-μm-wide slit backed by a photographic step tablet to give a range of exposures was contact-printed on the test film. The filtered xenon flashtube was used for the light source just as in the previous experiments. After measuring several CRT traces, I felt 70 μm was a good average trace width. Figures 14 through 17 are enlargements of the 70-μm-wide step tablet. Figure 14 was made from Royal-X Pan processed to a negative. Figure 15 was Royal-X Pan with reversal processing only. Figure 16 was Royal-X Pan with a 10-R (roentgen) gamma-ray exposure and negative processing only (note the high degree of granularity), and Fig. 17 was Royal-X Pan with 10-R gamma-ray exposure processed reversally, silver-intensified, and redeveloped in the magenta-dye coupling developer. The films in Figs. 16 and 17 were duplicated on high-contrast copy film to eliminate the high density backgrounds from the radiation exposure and for a further contrast buildup.

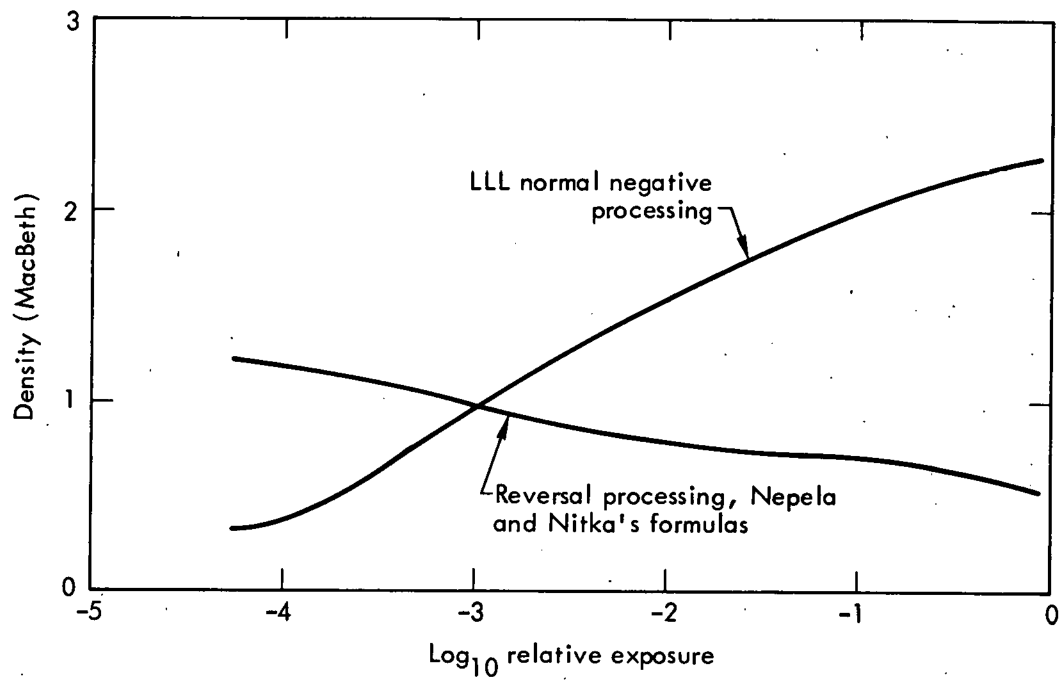

Fig. 9. Comparison of Nepela and Nitka's reversal processing formulas with LLL normal negative processing for Royal-X film.

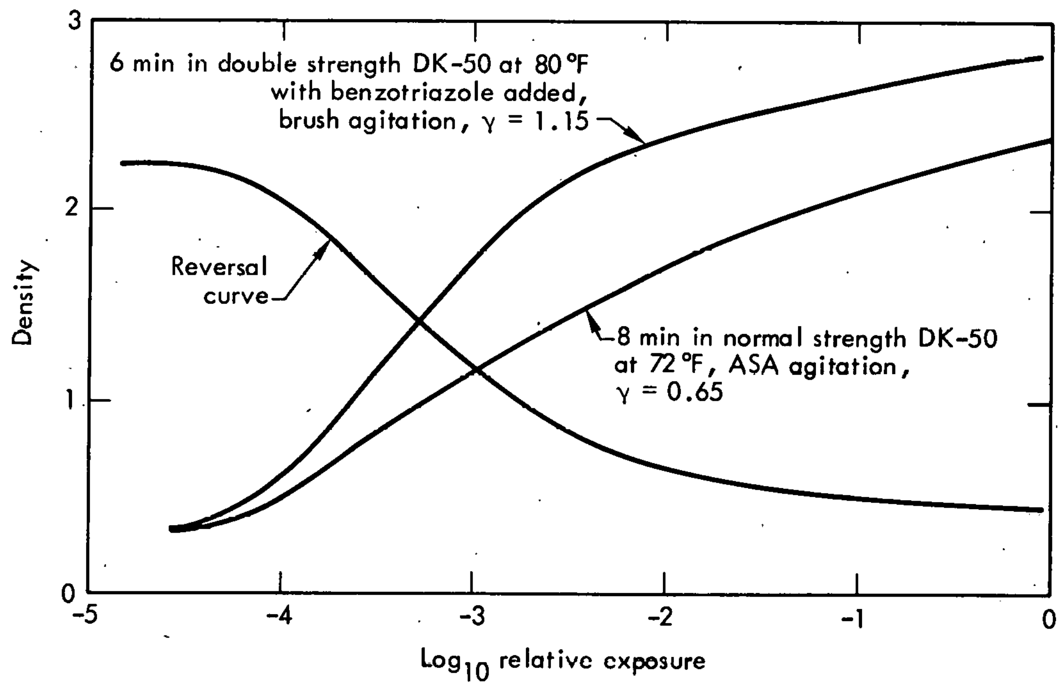

Fig. 10. Comparison of LLL normal negative processing (DK-50, 8 min), negative processing with double strength DK-50 plus antifog No. 2, and the reversal curve obtained with the latter.

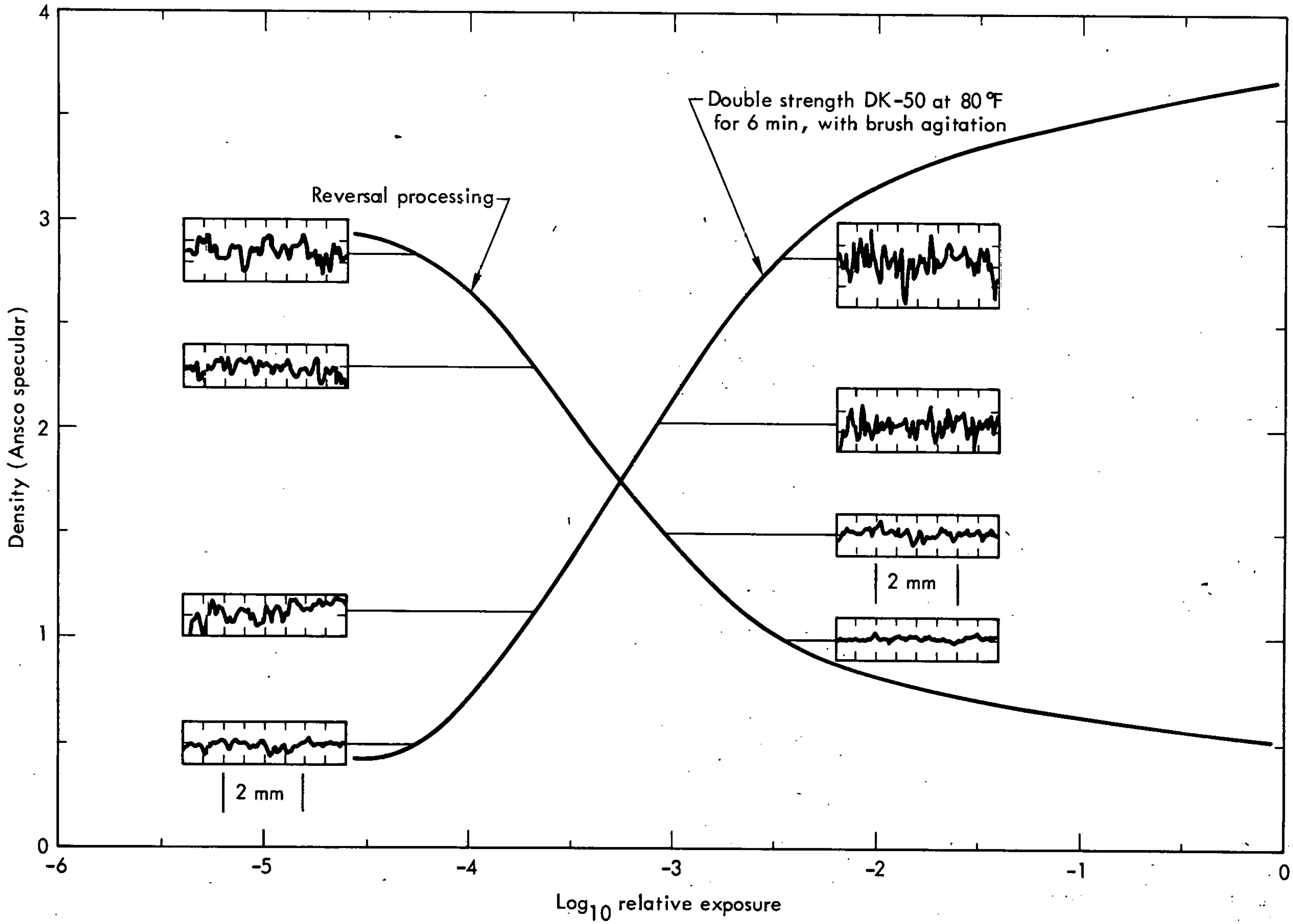

Fig. 11. Granularity traces as a function of exposure for double strength DK-50 negative processing and reversal processing.

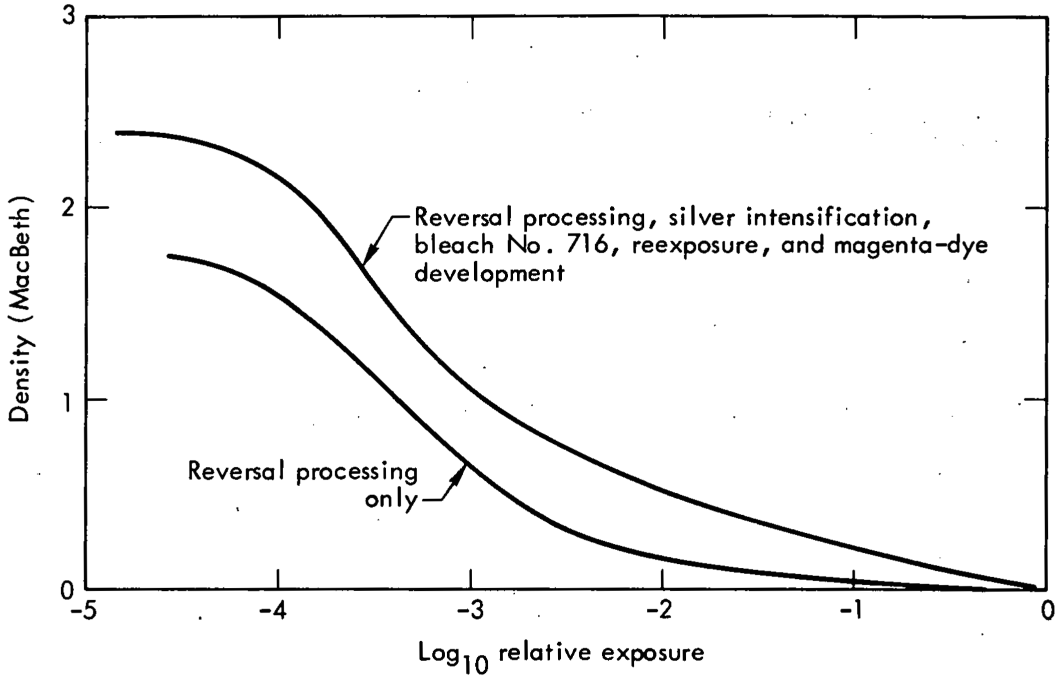

Fig. 12. Reversal processing of Royal-X Pan plus silver-intensifying and redeveloping in magenta-dye coupling developer, as compared with reversal processing only.

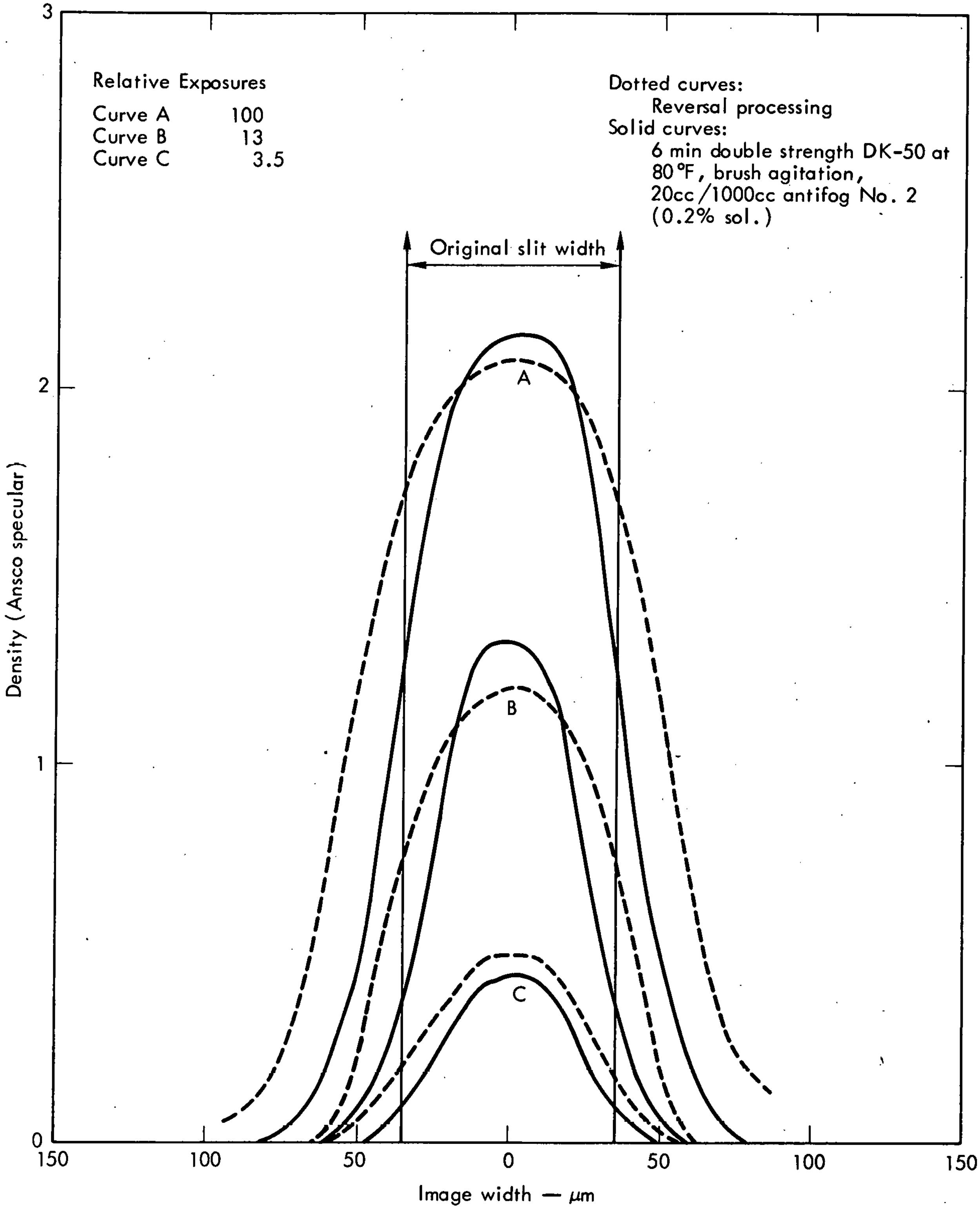

Fig. 13. Spread function plots for three different relative exposures of Royal-X pan, for reversal processing and for negative processing with double strength DK-50 plus antifog No. 2.

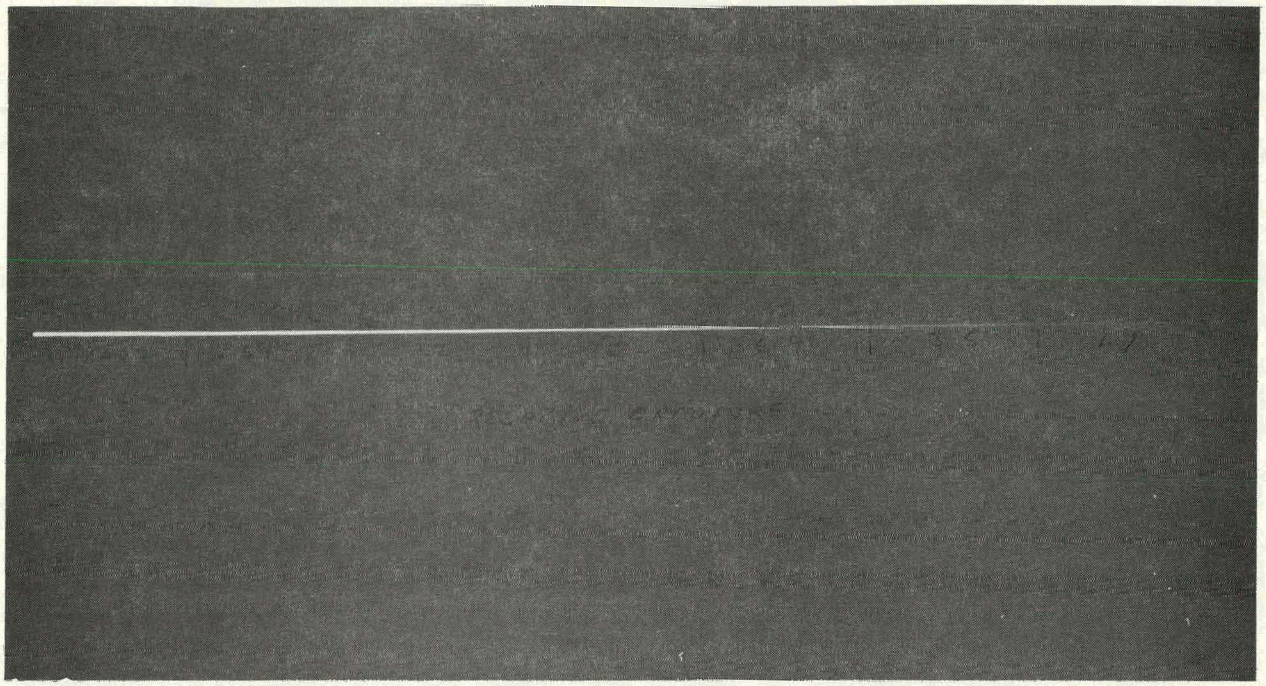

Fig. 14. Slit exposure with simulated P-11 phosphor on Royal-X Pan processed to a negative. (Magnification about 6X.)

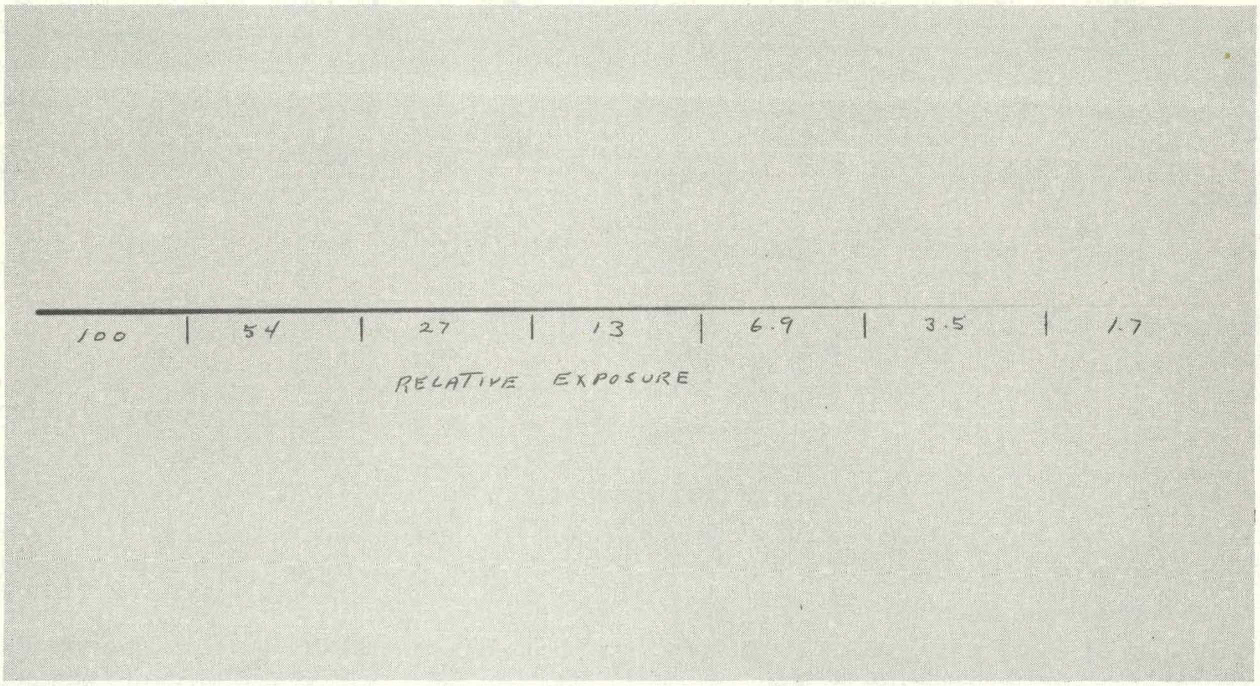

Fig. 15. Slit exposure with simulated P-11 phosphor on Royal-X Pan with reversal processing only. (Magnification about 6X.)

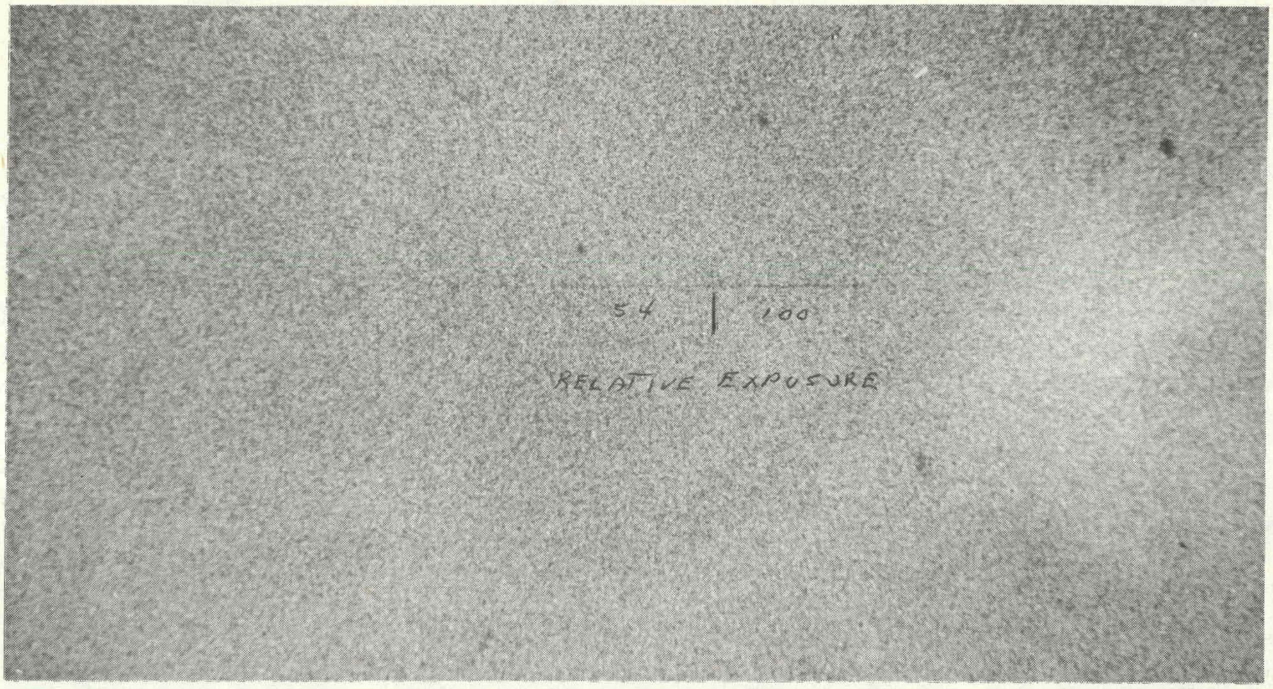

Fig. 16. Slit exposure with simulated P-11 phosphor on Royal-X Pan plus 10-R gamma ray exposure, processed to a negative. (Magnification about 6X.)

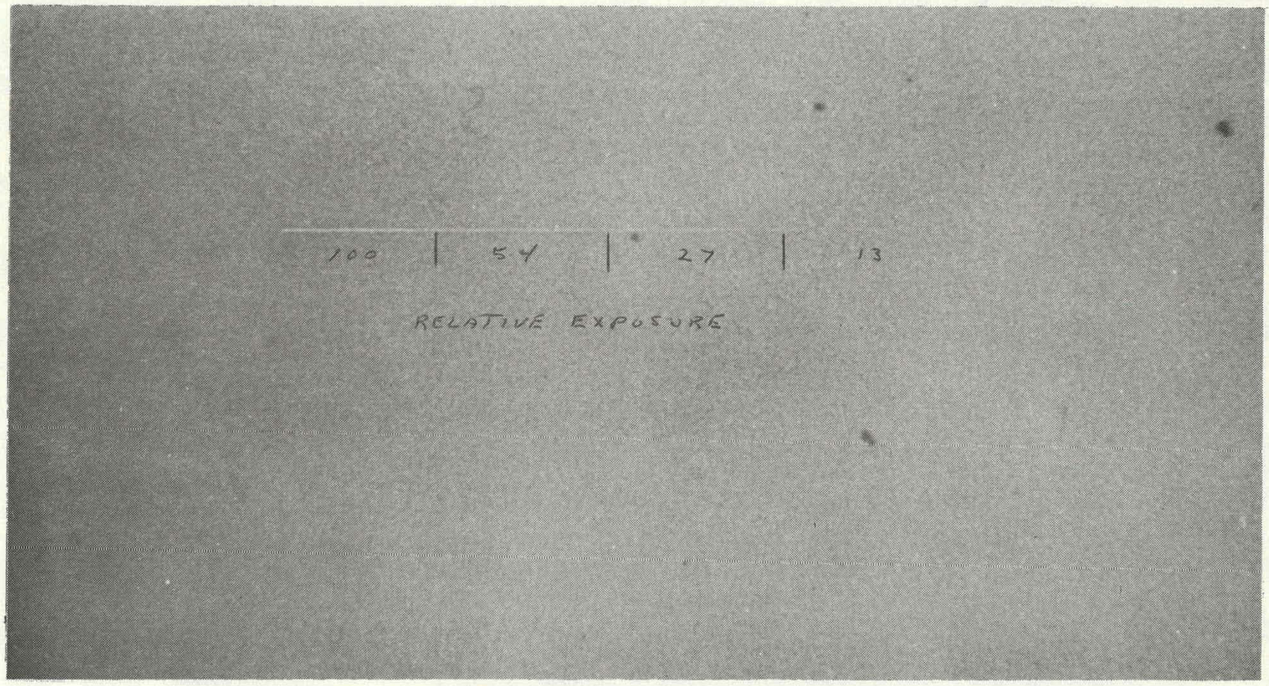

Fig. 17. Slit exposure with simulated P-11 phosphor on Royal-X Pan plus 10-R gamma ray exposure, with reversal processing plus silver-intensifying and redeveloping in magenta-dye coupling developer. (Magnification about 6X.)

RECOMMENDED PROCESSING FOR GAMMA-RAY-IRRADIATED ROYAL-X PAN FILM

On the basis of the work reported here, I recommend the following processing procedure for Royal-X Pan Recording film that has been exposed to gamma radiation.

I. Processing temperature: 80 ± 1/2°F.

II. Agitation: continuous.

  1. Camel's hair brush in developers only.

III. Processing times:

1.	First developer	6 min	In dark (steps 1–6)
2.	Acid stop bath	30 sec	
3.	Water rinse	30 sec	
4.	Bleach	1 min	
5.	Water rinsc	30 sec	
6.	Clearing bath	30 sec	
7.	Water rinse	30 sec	
8.	Second exposure	100-W lamp 30 sec each side	
9.	Second developer	3.5 min	
10.	Kodak rapid fixer	1 min	
11.	Wash	10 min	
12.	Copenhafer's silver intensifier	15 min	
13.	Wash	20 min	
14.	No. 716 bleach	3 min	In dark (steps 14–17)
15.	Wash	3 min	
16.	Bisulfite rinse	3 min	
17.	Wash	3 min	
18.	Third exposure	100-W lamp 30 sec each side	
19.	Magenta dye developer	3 min	
20.	Wash	20 min	

21. If necessary, steps 12, 13, 19, and 20 can be repeated for further intensification.

ACKNOWLEDGMENT

I am indebted to D. A. Nepela and H. F. Nitká for many of the ideas pursued in this work. Although their studies, as reported in "Reduction of the Effects of Nuclear Gamma Radiation on Photographic Silver Halide Emulsions," dealt with slower films than the Royal-X Pan treated here, the principles they developed were often applicable to the case of fast film as well.

APPENDIX

FORMULAS FOR THE PROCESSING SOLUTIONS USED IN THIS STUDY

FIRST DEVELOPER

Elom	5 g
Sodium sulfite (desiccated)	60 g
Hydroquinone	5 g
Kodalk	20 g
Potassium bromide	1.0 g
Water to	500 ml

BLEACH

Potassium dichromate	9.6 g
Sulfuric acid (conc.)	10.7 ml
Water to	1 liter

CLEARING BATH

Sodium sulfite	71.4 g
Water to	1 liter

SECOND DEVELOPER

Metol	0.5 g
Sodium sulfite	50 g
Hydroquinone	20 g
Potassium bromide	2.5 g
Sodium hydroxide	2.5 g
Water to	1 liter

MAGENTA DYE DEVELOPER

Quadrofos	1.5 g
Sodium bromide	0.54 g
Potassium iodide (0.10% sol.)	10 ml
6-nitrobenzimidazole (1%) in 1% sodium hydroxide sol.	1.0 ml
Sodium sulfite	8.7 g
Sodium sulfate	70 g
Ethylene glycol	17 ml
Sodium hydroxide	1.7 g
Kodak CD-2 developing agent	2.25 g
Kodak magenta coupler M-31	2.06 g
Butylamine	7.25 ml
Water to	1 liter

No. 716 BLEACH

Potassium ferricyanide	100 g
Potassium bromide	15 g
Sodium bisulfate	25 g
Water to	1 liter

BISULFITE RINSE

Sodium bisulfite	50 g
Water to	1 liter

COPENHAFER'S SILVER INTENSIFIER

Solution A

Silver nitrate	40 g
Water to	1 liter

Solution B

Sodium sulfite	40 g
Water to	1 liter

Solution C

Sodium thiosulfate	70 g
Water to	1 liter

Solution D

Sodium sulfite	15 g
Metol	24 g
Water to	1 liter

Use of Copenhafer's Silver Intensifier

Add one part solution A to one part solution B with constant stirring. The white precipitate is dissolved by the addition of one part solution C. Continue stirring and add three parts solution D and stir to insure complete mixing. Solution A should be stored in an amber bottle. The stability of mixed physical developer is approximately 30 minutes.

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