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AUTORADIOGRAPHIC ENHANCEMENT OF POLAROID FILMS

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By: R. G. Manning and R. R. Pettijohn

Prepared for:

Lawrence Livermore Laboratory

P.O. Box 808

Livermore, California 94550

Attn: Dr. R. C. Weingart

Order No. 1263309

MASTER

SRI Project PYD-7420

**SRI International
333 Ravenswood Avenue
Menlo Park, California 94025
(415) 326-6200
Cable: SRI INTL MNP
TWX: 910-373-1246**

International

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Approved:

G. R. Abrahamson, Director
Poulter Laboratory

P. J. Jorgensen, Vice President
Physical and Life Sciences

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INTRODUCTION AND BACKGROUND

Under a six-month contract to Lawrence Livermore Laboratory (LLL), SRI International has investigated the application of radiotracer photographic image enhancement (PIE) techniques to increase the photographic speed of three Polaroid Films. SRI has a state-of-the art capability in the field of nondestructive photographic image enhancement of original negatives. With these procedures, we have successfully increased optical density, contrast, and resolution of photographic imagery, and thereby increased the information derivable from original negatives. The present LLL contract represents our first attempt at PIE treatment of Polaroid films.

Polaroid films pose unique experimental difficulties, principally because of their paper negatives, which contain many chemicals not found in conventional photographic negatives. These chemicals are necessary for the unique Polaroid development process. Radiotracer PIE techniques are currently the only method of enhancing Polaroid imagery because other methods, such as digital processing or increased contrast printing, depend on light transmission through the negative. Since the Polaroid negative is opaque, these other methods are not applicable.

Current difficulties with Polaroid films include the recording of transient oscilloscope traces, which are too fast for the film. In many cases these traces can be the output signal from an expensive, hard-to-reproduce experiment. If the trace image is not severely underexposed, radiotracer PIE methods may recover the invisible but existing image. This research is directed toward increasing the effective Polaroid film speeds to allow recovery of such imagery.

The completed research included the following tasks:

- Preparation of controlled calibration imagery on Polaroid film types 47 (ASA 3000), 57 (ASA 3000), and 410 (ASA 10,000), developed using the Polaroid developer, Eastman Kodak (EK) D-19, or POTA.
- PIE processing of the controlled calibration imagery, using a variety of toning techniques and isotopes to determine the best procedure.
- Evaluation of the enhancement capabilities and effective speed increase achievable using PIE techniques.

This report contains a general discussion of the experimental methods used and results obtained on SRI-prepared controlled imagery. The final section includes a summary and suggestions for continued research.

EXPERIMENTAL PROCEDURES

Preliminary Experiments

Preliminary experiments focused on the feasibility of simply applying PIE techniques to Polaroid paper negatives that had been developed according to standard Polaroid procedures. This approach resulted in autoradiographs with unacceptably high fog levels. These high fog levels were caused by the chemicals used in the Polaroid developing method. The fog levels were lowered by immediately fixing the paper negative in EK Rapid Fixer after developing the film, as described below. However, alternative developers gave even lower fog levels and consequently better image enhancement. Procedures were developed to bypass the normal Polaroid development procedure, develop the Polaroid negative using darkroom chemical processing, and autoradiographically enhance the resulting image.

Development of Polaroid Paper Negatives

Besides the Polaroid developer, two other developers were investigated: EK D-19 and POTA. EK D-19 was chosen because it is a frequently used high-contrast, clean-working developer. It is recommended by Kodak for continuous tone work that requires higher-than-normal contrast. POTA was originally formulated to provide a developer that yielded low fog and an extended toe region in a plot of log exposure versus optical density. An extended toe region in the Polaroid paper negative should allow greater autoradiographic enhancement since intensification of this region of image results in an effective speed increase.

Three film sets were prepared. Film set 1 consisted of films that were exposed and developed according to Polaroid instructions. The film packets were then opened in a darkened room, and the paper negatives were immersed in EK Rapid Fix for 5 minutes and washed in running deionized water for 30 minutes.

Film set 2 consisted of film developed in EK D-19. The holder for Polaroid type 57 film was modified by removing the steel and rubber rollers. This removal prevented the breaking of the chemical pod in the film packet and thereby prevented the film from being conventionally Polaroid developed. After the exposures were made, the packets were opened in total darkness. The pod was detached from the paper negative, and the negative was processed in EK D-19 for 3 minutes, in 1% acetic acid stop bath for 30 seconds, in EK Rapid Fix for 3 minutes, and then washed in running water for 30 minutes. For Polaroid types 47 and 410, 4 x 5 Graflex film holders were modified by inserting a piece of clear plastic to hold the Polaroid negatives flat. This was necessary because the paper negatives had a tendency to curl. The paper negative was then cut into sections of the correct size and inserted behind plastic. After exposure, the negatives were processed in D-19 for 3 minutes, acetic acid stop bath for 30 sec, EK Rapid Fix for 3 minutes, and then washed in running water for 30 minutes.

For film set 3, the various types of Polaroid film were handled in the same manner as set 2, except that POTA was used as the developer. POTA consists of 3% Na_2SO_3 + 0.15% phenidone. Development time was 15 minutes. Fresh POTA was prepared daily because it oxidizes quickly and cannot be stored without special precautions.

Oscilloscope Imagery

Precise evaluation of image enhancement and film speed increases requires controlled imagery. We wanted a test image that would simulate an oscilloscope trace that might be received during an actual experiment and that would also allow quantitative speed increase evaluation.

To satisfy these conditions, we developed a system for placing multiple traces of variable optical density on an oscilloscope. Since the optical density of any trace on an oscilloscope is a function of the scan speed, the system was designed to sequentially induce different waveforms with the same period and at diverse amplitudes in a retrace mode on the oscilloscope. A block diagram of this circuit is shown in Figure 1. The square wave generator produces a wave train with a period of 1 ms (1 kHz frequency). The frequency (f) is determined by

$$f = \frac{1.44}{(R_1 + 2R_2) C_1}$$

where R_1 and R_2 are resistances and C_1 is the capacitance. In our application $R_1 = 3.0K$, $R_2 = 5.7K$ and $C_1 = 0.01 \mu F$. This wave train is transferred to an integrator where voltage out (e_o) is determined by:

$$e_o = \frac{1}{R_3 C_2} \int_0^t v_{in} dt$$

where $R_3 = 10K$, $C_2 = 1 \text{ mfd}$, v_{in} is the input voltage and t the time. Thus the output waveform from a square wave input is a triangular waveform.

The output of the square wave generator is also sent to the sequentially operated analog switch. When analog switch 1 is active, the square wave appears on the output and the proportional gain amplifier is disabled. When analog switch 2 is active, the triangular waveform appears at the output and the proportional gain amplifier is set for unity gain. When analog switches 3, 4, and 5 are activated, the proportional gain amplifier is set at X2, X10, and X1000 gain, respectively, in sequence. Thus, the writing speed is varied from 1 volt/ms

MA-7420-1

FIGURE 1 SCHEMATIC OF CIRCUIT USED TO GENERATE STANDARD OSCILLOSCOPE TRACE

to the maximum slew rate of the proportional gain amplifier, or approximately 50 volts/ μ s. The function of the clipper is to contain all the waveforms within a fixed maximum amplitude.

The scale is triggered each time the positive slope of the square wave appears. Thus, with the proper setting of the time base on the oscilloscope, all the waveforms can be superimposed. We used a Tektronix type 555 dual-beam oscilloscope with Tektronix type 53/54K plug ins, Tektronix type 21A or type 22A time base units, and a Tektronix Model C-27 oscilloscope camera equipped with a Wollensak 75mm f/1.9 Oscilloscope 1:0.7x lens. A typical oscilloscope trace is shown in Figure 1. A single exposure such as that in Figure 2 contains imagery with an intensity dynamic range of several thousand-fold.

Operation of Controlled Exposure Imager

To provide quantitative results, we made an exposure sequence for each film type. The exposure was varied throughout the sequence by changing the aperture and/or the exposure duration. Exposures were made over a range of about a thousand. The resulting exposure sequence thus allowed a direct visual determination of the effective film speed increase. This visual comparison method, using reflected light, is analogous to using a step wedge to provide sensitometric evaluation of a transparent film's speed, using transmitted light.

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FIGURE 2 STANDARD OSCILLOSCOPE TRACE USED IN QUANTITATIVE
IMAGE ENHANCEMENT EXPERIMENTS

RESULTS

Preliminary Results

During the initial qualitative phase of this investigation, all three film types were evaluated for each of the three development procedures. Radiotoning procedures involving the radioisotopes nickel-63, iodine-125, and sulfur-35 were used. Although type 410 film exhibited significant enhancement regardless of the developer formulation, these early experiments showed that the best image enhancement was obtained with the POTA developer, regardless of film type. Accordingly, we decided to concentrate on the three film types developed in POTA.

POTA Results

Figure 3 compares the Polaroid exposure sequence for type 47 film and an autoradiograph resulting from the sulfur-35 toning of an original paper negative having a relative exposure value of 1. The autoradiograph corresponds to an original negative having a relative exposure value of more than 2 but less than 4. We have thus increased the effective photographic speed of Polaroid type 47 film by a factor of 2 to 4. Autoradiographs were prepared using EK type SR or type AA x-ray film as the receiving film.

Figure 4 shows similar results for type 57 film. Once again we toned an original negative having a relative exposure of 1. The resulting autoradiograph is shown in the upper right in Figure 4. The photographic speed has again been increased 2 to 4 times that of the original.

RELATIVE
EXPOSURE

ORIGINAL NEGATIVE

AUTORADIOGRAPH

1

PIE

2

4

8

MP-7420-3

FIGURE 3 COMPARISON OF POLAROID EXPOSURE SEQUENCE AND PIE AUTORADIOGRAPHIC ENHANCEMENT OF POLAROID TYPE 47 FILM

RELATIVE
EXPOSURE

ORIGINAL NEGATIVE

AUTORADIOGRAPH

1

PIE

2

4

8

MP-7420-4

FIGURE 4 COMPARISON OF POLAROID EXPOSURE SEQUENCE AND PIE AUTORADIOGRAPHIC ENHANCEMENT OF POLAROID TYPE 57 FILM

Figure 5 contains film type 410 results. A speed increase of more than 2 is again realized. Although we also toned duplicate original negatives with Ni-63 and I-125, S-35 yielded similar results in this preliminary study. Standard toning methods were used, and no attempt was made to optimize them for these particular film types.

The S-35 procedure is as follows: The negatives were first washed in deionized water for 10-20 minutes. They were then radiotoned by agitation in a S-35 labeled thiourea aqueous solution for 2 hours. The pH of the solution was 11.5 and was adjusted with 1% K_2CO_3 . The thiourea was present at a concentration of 0.13 mCi%. S-35 labeled thiourea was purchased from New England Nuclear at a specific activity of 4×10^4 Ci/g. Following the radiotoning, the negative was washed in deionized water for 10 minutes, in 30% methanol for 10 minutes, and in deionized water for 10 minutes. The negative was then air dried.

Autoradiographs were prepared by placing the x-ray-sensitive receiving film in contact with the toned paper negative in a vacuum cassette. Autoradiographic exposures varied from a few hours to a few days depending on the level of radioactivity in the toned negative.

RELATIVE
EXPOSURE

ORIGINAL NEGATIVE

AUTORADIOGRAPH

1

2

4

8

MP-7420-6

FIGURE 5 COMPARISON OF POLAROID EXPOSURE SEQUENCE AND PIE AUTORADIOGRAPHIC ENHANCEMENT OF POLAROID TYPE 410 FILM

SUMMARY AND SUGGESTIONS FOR CONTINUED RESEARCH

SRI International has completed a preliminary study to experimentally evaluate the effective speed increases achievable with Polaroid film types by the application of autoradiographic methods. The procedures developed for Polaroid film types 47, 57, and 410 increased their effective speeds 2 to 4 times that obtained using conventional Polaroid procedures, as summarized below.

Table 1

<u>Polaroid Film Type</u>	<u>Polaroid Film Speed (ASA)</u>	<u>Effective Polaroid Film Speed Using Autoradiographic Methods</u>
47	3,000	6000 to 12,000
57	3,000	6000 to 12,000
410	10,000	20,000 to 40,000

Type 410 film is currently the fastest commercially available photographic recording medium. However, applying autotradiographic technology to type 410 photographic applications extends the film's capability so that it can record events that occur 2 to 4 times faster or in which the light intensity is 2 to 4 times less than was previously possible.

Additional research and development in the following areas should be undertaken to obtain further increases in effective film speed of Polaroid films:

- (1) Negative pretoning treatments need to be formulated to allow direct treatment of conventionally developed Polaroid negatives.
- (2) Radiotoning methods should be optimized for Polaroid films.
- (3) An optimum procedure should be developed to aid in implementing this new capability.