Photographic & Optical Systems Analysis 75

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PHOTOGRAPHIC & OPTICAL SYSTEMS ANALYSIS

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The purposes of this endeavor are to evaluate photo-optical systems currently in use and to implement new materials or techniques which will lead to overall improvement of the systems. The emphasis of the present report is upon the film-chemistry system currently being used in the Development Division firing sites.

ABSTRACT

Initial studies have been started of the film developer combinations currently in use at the firing sites in the Development Division. Kodak Plus-X film and Diafine and Kodak Dektol developers were selected for study from among the combinations being used along with Kodak developers, D-76, D-19, Polydol, DK-50 (1:1) and full strength. Analysis of sensitometric and image quality results indicate that the use of Diafine and Dektol be discontinued for processing streak camera shadowgraphic records and D-76 be used in its place.

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DISCUSSION

One of the first tasks undertaken was the evaluation of the film-developer combination being used in the recording and processing of streak camera records of shock front propagation. Three basic criteria were used to evaluate the overall quality of the film-developer pair.

The first of these was graininess and grain size. This aspect of image evaluation describes the apparent non-uniformity in the developed image. A uniform appearing image is desirable to assist the operator in accurately determining distance-time coordinates of the shock front. The apparent graininess is a function of at least the following:

1. Magnification
2. Density level
3. Film type
4. Developer type

The second criterion comes under the general heading of sensitometry, but includes several individual parameters. A properly exposed and developed sensitometric strip will provide several useful pieces of information. These include the relative fog levels, contrast levels, and relative speed differences among the various film-developer combinations. The film speed on which these analyses were made was based upon the exposure required to produce a density of 0.70.

The third criterion used for evaluation is edge sharpness or its objective correlate, acutance. Acutance is an important factor for the simple reason that the higher the acutance or sharpness the better defined an image of an edge will be. Since an operator must visually locate the shock front on the negative (with the assistance of a comparator), an image with a higher acutance allows a more accurate determination of the coordinates of the shock front than will one with less acutance.

Acutance values are calculated from an edge trace such as the one shown below:

A trace such as this is made by exposing a piece of film which is partially shielded by a knife edge. The developed image is then scanned by a microdensitometer and a direct distance (x) versus density (D) plot is obtained. The acutance is computed by dividing the trace into a large number of small increments (n) and applying the following relationship:

$$A_c = \frac{\sum (\Delta D / \Delta x)^2 / n}{D_A - D_B}$$

Fig. 1. Same test object photographed by two different systems.

(a) Low sharpness and high resolving power

(b) High sharpness and low resolving power

Resolving power was not chosen as an evaluative aid for this particular system because the negative consists of images of edges and not of fine detail. Resolving power is an indication of how well a system records such fine detail and while in general resolving power and acutance correlate quite well, there are cases where they do not correlate at all. Fig. 1 illustrates this case (1). Fig. 1a shows a photograph of a test object that exhibits high resolving power and low sharpness. Fig. 1-b shows just the opposite—low resolving power and higher sharpness.

It is necessary to consider a basic concept called the line spread function to explain this phenomenon. This function is simply the distribution of energy in the image of a line. A knife edge exposure may be considered as a series of narrow, closely packed bright line exposures, each of which has its own line spread function. The edge trace or the energy distribution in the image of the knife edge is simply the integral of the many line spread functions. The spread functions of two theoretical film materials and their respective edge traces are illustrated in Fig. 2. It is obvious from the curves in Fig. 2 that spread function 1 yields a sharper image than does spread function 2.

If these same two films with their respective spread functions are used to image two parallel lines, such as in a resolving power target, the energy distributions will appear as shown in Fig. 3. It is obvious that the two lines will not be resolved with spread function 1 even though that spread function will produce a sharper image. On the other hand, spread function 2 will easily resolve the lines, but present a "fuzzy" image of the edges, i.e. less sharp.

(a) Spread functions

(b) Edge traces

Fig. 2. Two hypothetical spread functions and their edge traces

Fig. 3. Summation of two spread functions of type 1 in Fig. 2a and of type 2 in Fig. 2b.

The ability of a system to achieve maximum acutance is influenced by many factors, a few of which are listed below:

1. Optics
2. Film type
3. Developer
4. Density level
5. Geometry of lighting
6. Processing technique (time, temperature, agitation, etc.)

The factors currently being considered are 2, 3, 4, and 6: film type, developer type, density level, and processing technique. Optics and lighting will be studied in detail at another time. Argon candle lighting characteristics were approximated by using a high intensity, short duration sensitometer manufactured by E.G. & G., Inc. This sensitometer provides a reasonable approximation to the geometry, intensity, and duration of the argon candles. This system should enable one to observe relative differences among the various combinations tested.

A wide disparity exists in the types of films and developers being used at the present time. For example, one firing site uses Kodak Plus-X and Tri-X sheet film, and processes the negatives in Kodak Dektol developer or Diafine developer (at the Photo Lab.), while another firing site uses Kodak recording film, Type 2475. Since one of the requirements of the system is increased effective speed of the film, a series of sensitometric tests were run for Plus-X film developed in Diafine, Kodak developers D-76, D-19, Polydol, Dektol, DK-50 (1:1) and full strength. A time development series was run to determine if increased speed could be had in processing with a minimal increase in fog level. The applicable results are tabulated in Table I. The results indicate that all developers tested were capable of providing equally increased speed without adversely

affecting fog. Since speed is not the sole criterion, the other factors previously mentioned will have to be evaluated to determine whether the cost of the increased speed is too great in terms of image quality.

Table I
Effects of Developer Types on Speed and Fog Levels
for Kodak Plus-X Film

<u>Developer</u>	<u>Time (min.)</u>	<u>Fog</u>	<u>Relative^a Speed Gain</u>
Diafine	3 ^b	0.10	-
D-76	9	0.12	1
Polydol	9	0.09	1
Polydol	12	0.11	2
D-19	3	0.11	1
Dektol	5	0.22	3
DK-50 (F.S.)	4	0.10	2/3
DK-50 (1:1)	8	0.13	Nil

^aSpeed was based on a fixed density of 0.7 and used the Diafine process as a standard. The gain is given in terms of the usable number of f/stops gained.

^bTime is given for each part of the developer separately. The total development time for the two-part developer is 6 min.

Additional work was done with the Diafine developer and Plus-X to evaluate the effects of time, temperature and agitation on the sensitometric results and image quality. A time series was run for 3, 6, and 9 minutes in each part of the two-solution developer system. At 9 minutes yellow stains appeared on the processed film. No significant gain in speed was obtained beyond 7-8 minutes. The effect of agitation on the process was significant: the introduction of vigorous agitation increased the speed, contrast and fog level and in general improved the curve shape. Sensitometric exposures were made on Plus-X and were processed for 3 minutes (each part) using Kodak-recommended tank agitation of one cycle per minute. In addition agitation cycles of once every 15, 30, and 0 seconds were tested. Virtually no significant change in the sensitometric data was observed. However, the same process, when done in a Nikkor tank using the recommended agitation, produced significantly different results. The curves in Fig. 4 illustrate the differences.

The effects of temperature upon the sensitometric results obtained using the Kodak-recommended tank agitation were more pronounced. Results were obtained for temperatures of 58, 70 and 80°F and are tabulated in Table II. The data show that 10° temperature shifts can seriously affect results. Interpolation of the data indicated that a temperature control of $\pm 3^\circ\text{F}$ must be adhered to in order to achieve consistent results. Fig. 5 shows the sensitometric curves for the three processing temperatures.

Film: Kodak Plus-X
Developer: Diafine
Time: 3 min. each part
Temperature: 70°F

Fig. 4

Fig. 5

Table II
Effect of Temperature on Sensitometric Results
(Plus-X in Diafine, 3 min. each solution)

<u>Temperature</u> (°F)	<u>Fog</u>	<u>Gamma</u>	<u>Speed</u> ^a
58	0.09	0.44	-2
70	0.13	0.58	0
80	0.17	0.86	+2/3

^aExpressed in terms of f/stops of speed lost or gained, i.e. exposure at density = 0.7.

As of this writing, Plus-X film has been evaluated for image quality when processed with three of the above mentioned developers. Graininess and acutance values have been determined for Diafine (3-minute processing time), D-76 (7-1/2 minutes) and Dektol (5 minutes). Visual examination of a uniform density level of 0.7 ± 0.05 indicate that Dektol produces graininess considerably greater than either D-76 or Diafine. Diafine had a slight improvement in graininess over D-76, but they both were quite good.

Acutance values were obtained from edge traces read on an Ansco Model 4 Micro-densitometer located at the Lawrence Radiation Laboratory. Fig. 6 shows the edge traces for the three developers. Here again, the density level was 0.70 ± 0.05 . The values are tabulated below:

<u>Developer</u>	<u>Acutance</u>
Diafine	37
D-76	87
Dektol	17

Fig. 6. Edge traces for Kodak Plus-X film

These values will appear considerably lower than those published by the film manufacturer due to the nature of the processes used, and the geometry of the lighting. They do serve as a useful guideline to establish relative capability to produce a sharp edge.

The results given above—acutance, grain, and speed—indicate that Kodak D-76 developer is preferred over Dektol and Diafine for Plus-X film in streak camera recording of shock front propagation.

FUTURE WORK; COMMENTS; CONCLUSIONS

On the basis of the above data it is suggested that the use of both Diafine and Dektol developers on Plus-X film be discontinued as soon as is practicable, and D-76 used instead for streak camera shadowgraphic recordings. Prior experience with Tri-X film indicates that the above findings will equally apply to this type of film also. As an interim measure it is suggested that Kodak D-76 developer also be used to process Tri-X when used for streak shadowgraphics.

Efforts will continue toward improving the film-developer combination for streak camera records. Currently being evaluated are Kodak Tri-X Film and Kodak Linagraph Shellburst Film, 2476. In addition, there are several other types of recording films that seem to offer promise for improving the overall image quality.

Also under way is the setting up of an optics bench which will be capable of testing and evaluating optical components used throughout the plant.

The use of a suitable negative material to supplement and/or replace the Polaroid material now being used on some CRT records is being considered because Polaroid print material does not provide as much image detail as a negative material does. Processes have been developed which allow quite rapid access to the scope record with adequate image content.

Improved methods and some control equipment are needed to insure consistent and adequate image quality in the photographic records produced by the firing sites.

REFERENCES

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