Factors Affecting the Quality of Black-and-White Reflexion Prints

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ABSTRACT. Reflexion-print quality has been shown to be predictable from a knowledge of objective tone-reproduction characteristics for black-and-white reflexion prints. Based on a mathematical relationship between print quality and tone-reproduction data, quantitative data have been derived to show the dependence of print quality on several of the sensitometric variables in negative-positive reproduction systems.

INTRODUCTION

THE quality of a photographic reproduction is dependent on several factors, such as tone-reproduction characteristics, image-structure characteristics, viewing conditions, and type of scene. The following discussions are concerned with the dependence of the quality of black-and-white reflexion prints on tone-reproduction characteristics, the other factors being held invariant.

Tone-reproduction studies involve determination of the manner in which the luminances of an original scene are reproduced photographically. A common representation of tone-reproduction characteristics is a curve in which print densities are plotted as a function of logarithms of the luminances of corresponding areas in the original scene. A typical tone-reproduction curve is shown in Fig. 1. In general, these curves are "S"-shaped, indicating lower contrast in the highlight and shadow regions than in the middle tone areas. The exact shape of the curve for a given system is a function of the sensitometric properties of the negative and print materials as well as the exposure levels of these materials and the optical transfer characteristics of the cameras and enlargers used. From a knowledge of these characteristics, the tone-reproduction curve can be derived graphically or digitally. This curve can also be determined by making direct measurements of corresponding areas in both the original scene and in the reproduction.

A wide variety of tone reproductions can be realized from combinations of commercially available materials and equipment. Among these are a number of different tone reproductions which correspond to high print quality. The problem of the manufacturer and of the user of photographic materials is to determine the materials and the conditions which can produce the *optimum* print quality from among the many possible high-quality tone reproductions. To achieve the optimum solution, it is necessary that the relations between print quality and tone-reproduction characteristics be known.

In a recent study[1], a mathematical relationship was derived, in which reflexion-print quality was related to a numerical description of associated tone-reproduction characteristics. The relationship was based on psychophysical quality judgments of a wide variety of reproductions of several types of scene. Numerous tests of the validity of the relationship have confirmed its ability to predict the relative quality appraisal which would be assigned to a given reproduction by a panel of observers.

The relationship makes possible the evaluation of print quality by purely digital operations that are well suited to high-speed computing equipment; no further print-making is required—only a knowledge

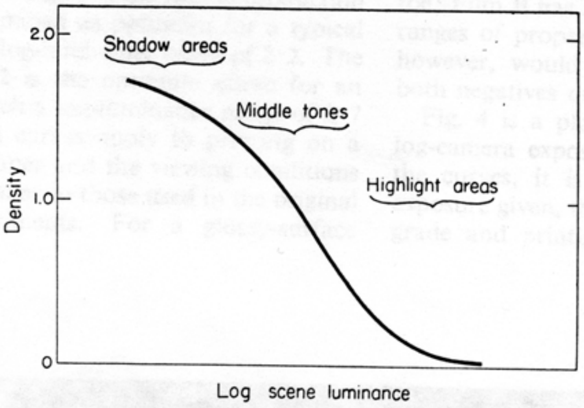

Fig. 1. A typical tone-reproduction curve.

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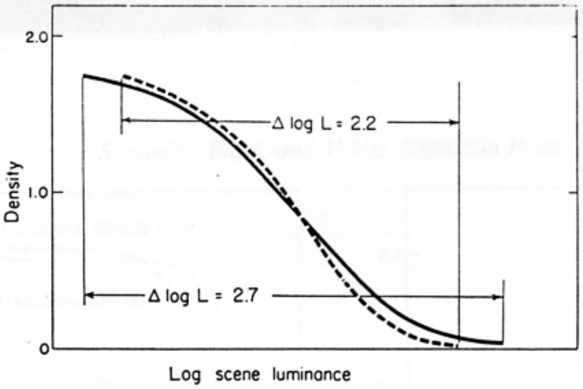

Fig. 2. Optimum tone-reproduction curves for (solid curve) outdoor scene and (dashed curve) studio portrait scene.

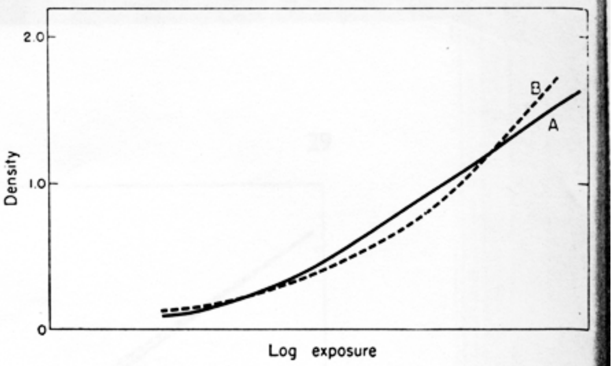

Fig. 3. Characteristic curves of two negative films. Film A has a long, straight line, short-toe curve; Film B has a long-toe curve.

of such factors as the *D*-log *E* curves of the negative and print materials, the exposures of these materials, the flare characteristics of the camera and printing systems employed, and the type of scene being reproduced. From these input specifications, tone-reproduction data are computed, numerically characterized, and a prediction of print quality is made by inserting the numerical data in the predetermined regression equation. In general, the computational program offers a simple means of determining the effects on print quality of varying each of the factors which influence the shape of the objective tone-reproduction curve.

Many thousands of hypothetical and actual reproduction systems have been evaluated by this technique. A few of the results of these computations are given in the next section.

RESULTS

Print-quality ratings are expressed on a scale from zero to 100. A quality index of 100 represents the optimum print quality that can be achieved for the particular type of scene being studied. Approximately ten units on the Q-scale represent a quality change which would be discerned and similarly ranked by at least 85 per cent of the observers.

The dashed curve in Fig. 2 is the tone-reproduction curve that was determined as optimum for a typical portrait scene with a log-luminance range of 2·2. The solid curve in Fig. 2 is the optimum curve for an outdoor scene in which a log-luminance range of 2·7 was measured. Both curves apply to printing on a semi-matte surface paper and the viewing conditions are assumed to be similar to those used in the original psychophysical experiments. For a glossy-surface paper, the curves bear a similar relationship to one another, but the maximum density is higher on both. An interesting fact is that the optimum curve for the shorter-range portrait scene can be made to coincide almost exactly with the curve for the outdoor scene by a simple stretching along the log-luminance axis.

The curves indicate that a linear relationship between print density and log-scene luminance is not necessarily optimum for reflexion prints. This does not imply, however, that a linear correspondence between subjective scene brightness and subjective brightness of the viewed print is not optimum. Experiments are in progress to determine the optimum subjective brightness relationships.

In the curves to follow, print quality is plotted as a function of several of the factors which influence tone reproduction. For the data in each case, it is assumed that the reproduction is of a portrait scene which has a log-luminance range of 2·2. In those cases where a different choice of scene results in significantly different data, a mention of the differences will be made.

A. Quality as a Function of Negative Exposure

Consider two negative films with *D*-log *E* curves as shown in Fig. 3. Film A has a curve with a short toe; Film B has a curve with a long toe. The density ranges of properly exposed negatives on both films, however, would be similar, permitting printing of both negatives on the same contrast grade of paper.

Fig. 4 is a plot of print quality as a function of log-camera exposure for the two films. In plotting the curves, it is assumed that, for every negative exposure given, the optimum choice of paper-contrast grade and printing exposure has been made. The

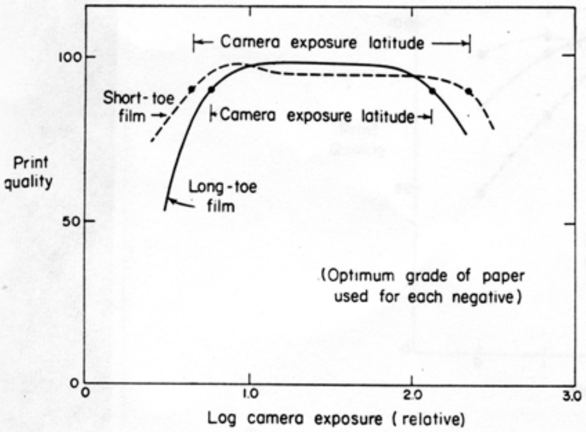

Fig. 4. Quality versus camera exposure for the two films of Fig. 3.

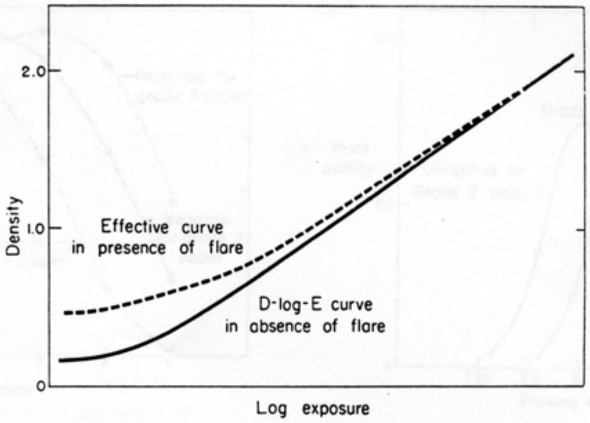

Fig. 5. Effect of flare light on the D-log E of a negative film.

abscissa represents the log exposure of the darkest significant element in the scene.

Both curves reach the maximum quality level of 100 per cent. It can be seen, however, that the long-toe Film B is capable of producing prints of highest quality over a greater range of camera exposures than the short-toe Film A. To achieve optimum quality with the short-toe film requires a critical choice of slight under-exposure and subsequent printing on a high-contrast grade of print material. With extreme over-exposure, however, the long-toe film results in negatives with an excessively high density range which available print materials cannot accommodate; hence, a loss in print quality results. The short-toe film shows a superiority in this over-exposure region.

The curves of Fig. 4 assume studio photography in which the flare light in the camera image is at a minimum. In outdoor photographs, flare light degrades the camera image of scenes containing large, bright areas of sky, sand, or water. Fig. 5 shows the effect of adding a normal amount of flare light in the photography of an outdoor scene with Film A, the short-toe film. The dashed curve is the effective characteristic curve in the presence of the flare light. The effect has been to convert the short-toe film into a long-toe film. In that case, the curve of quality *versus* log-camera exposure for Film A would be more nearly like that given for the long-toe Film B. The effect of camera flare on Film B would be to give it an even longer toe, creating an excessively flat negative from which optimum-quality prints would be difficult to obtain. These considerations indicate the desirability of a long-toe film for studio photography and a short-toe film for outdoor photography in which a normal amount of camera flare is present. It must be pointed out, however, that the differences in print quality obtainable from the dissimilar films are slight. Only when all other factors in the reproduction system are optimized will the inherent quality differences became apparent to the experienced observer.

B. Quality as a Function of Negative Development

Fig. 6 is a curve of print quality as a function of gamma, the slope of the straight-line portion of the *D*-log *E* curve of the negative film. The solid curve is representative of the maximum quality obtainable from a chosen negative, assuming that printing was done on the optimum contrast grade of print material

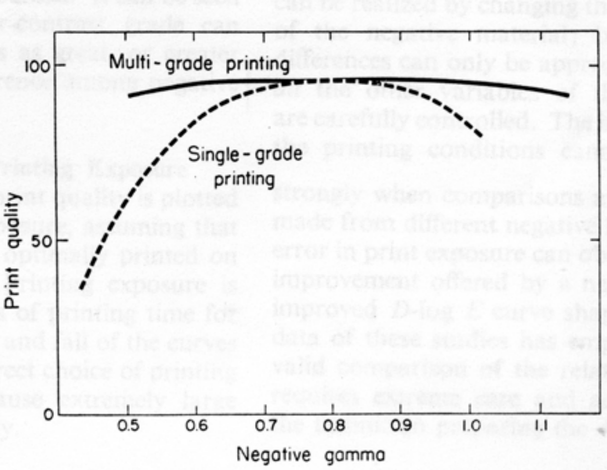

Fig. 6. Quality versus gamma for both multigrade printing and single-grade printing.

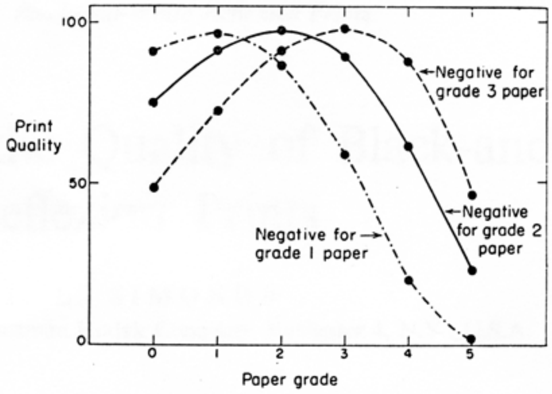

Fig. 7. Quality versus contrast grade of print material for three negatives.

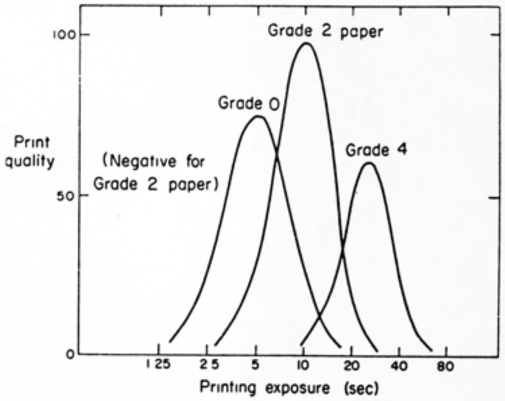

Fig. 8. Quality versus printing exposure for a negative which is optimally printed on a grade 2 paper.

for each level of gamma. The dashed curve represents the quality obtainable when only a single contrast grade of paper was used. In both cases, optimum printing exposure is assumed. The curves indicate that by proper choice of contrast grade of print material, development of a correctly exposed negative may be varied to produce a wide range of gammas without serious loss of print quality. If single-grade printing is required, development to the optimum gamma is essential for highest-quality prints.

C. Quality as a Function of Contrast Grade of Print Material

In Fig. 7 are three curves of print quality as a function of contrast grade of print material. The three curves are derived for negatives for which print-contrast grades 1, 2, and 3 are optimum. In all cases optimum printing exposure is assumed. It can be seen that incorrect choice of paper-contrast grade can result in a quality loss which is as great, or greater than, any possible quality difference among negative films.

D. Quality as a Function of Printing Exposure

In Fig. 8 are graphs in which print quality is plotted as a function of log-printing exposure, assuming that a negative was used which was optimally printed on a paper of contrast grade 2. Printing exposure is given in this example in seconds of printing time for a given intensity. The sharp rise and fall of the curves demonstrate the necessity of correct choice of printing exposures; small errors can cause extremely large departures from optimum quality.

DISCUSSION

The results obtained from the digital studies are in excellent agreement with accumulated experimental evidence. The new data are unique in that they provide quantitative relationships in place of the qualitative relationships that have been deduced from past studies. The use of the high-speed computer makes feasible the investigation of the quality attributes of a great number and variety of photographic systems. A recent evaluation of the photographic quality represented by 18,000 variations in reproduction involved approximately three hours of computing time on an IBM-705 computer; a similar investigation by direct psychophysical methods in the laboratory would be prohibitively expensive and laborious.

The data from many such computations strikingly point out an important consideration when direct visual comparisons are being made of the quality of prints obtained from different negative materials: small, but subjectively significant, quality differences can be realized by changing the *D*-log *E* characteristics of the negative material; but these small quality differences can only be appreciated when the levels of *all* the other variables of the reproduction system are carefully controlled. The importance of optimizing the printing conditions cannot be emphasized too strongly when comparisons are being made of prints made from different negative materials. Even a slight error in print exposure can obscure a potential quality improvement offered by a negative material with an improved *D*-log *E* curve shape. Examination of the data of these studies has emphasized the fact that a valid comparison of the relative merits of two films requires extreme care and accuracy on the part of the technician preparing the demonstration prints.

Reference

(1) Simonds, J. L. *Phot. Sci. and Eng.*, 5, 270–277 (1961).