LOGETRONICS

Dwin R. Craig, Technical Director, LogEtronics, Inc.,
1177 New Hampshire Ave., N.W., Washington 7, D. C.

ABSTRACT

LogEtronics, the application of well known electronic concepts and components to the exposure of photosensitive materials, now makes possible a photographic printer with provisions for completely automatic "dodging" and control of over-all exposure level. Basic principles and system parameters of the LogEtronic CP10S Contact Printer are described, accompanied by examples of comparative prints. The photographic effect of "dodging" is discussed to establish its role as the sole means for transferring maximum information from negative to print. A preliminary test of plotting precision with LogEtronic diapositive plates is reported. The importance of LogEtronics to both the user and producer of aerial photographs is stressed.

I. INTRODUCTION

LOGETRONICS, in its broadest sense, is the application of electronics both to produce and to control the exposure (generally abbreviated "logE") of photosensitive materials. The use of familiar electronic concepts and components for the first time makes possible a completely automatic device for producing uniform exposures from each portion of every negative, in one step, without relying on operator judgment—in short, a photographic printer with automatic "dodging" and exposure control.

The problem solved by such a printer is not merely that of making matched prints to produce an attractive mosaic, but is the more fundamental one of transferring the maximum amount of information from the negative to the print, whether it be on paper, film or glass.

The uncontrolled lighting conditions of aerial photography inevitably produce complex patterns of wide density variations within a given negative corresponding to variations in scene brightness. Although modern film is capable of recording detail over the brightness ranges encountered, high contrast printing material with their shorter exposure range are inherently incapable of simultaneously recording detail in areas of extreme highlight and deep shadow. As a consequence, much of the information in the original negative may never appear in the final print despite the insistent demands on cameras, lenses and films to record "more lines per millimeter." Preservation of detail must be achieved through dodging during exposure of the print through the information laden negative. This has long been recognized and most contact printers for aerial photography contain manual dodging provisions in the form of multiple light sources, a single movable source, or the use of hand made masks. More effective is the use of "unsharp" masks photographically reproduced from the negative itself.[1] The shortcomings of these various methods, best known to their users, generally fall into the category of laborious and/or ineffective. By contrast, the LogEtronic Contact Printer automatically performs both dodging and over-all exposure control in a single step, without operator judgment, to produce prints of uniform density and detail contrast throughout, from negatives having exceedingly complex patterns of density distribution.

Comparative print pairs from typical aerial negatives are dispersed throughout the paper to illustrate the striking difference between conventional and LogEtronic printing. Each pair was made from the same negative, on the same grade of paper, and received identical processing through the final reproduction here. Whereas, the presentation here is necessarily half-tone, it should be stressed that the original prints are true photographic reproductions of exceptional definition.

II. BASIC PRINCIPLE

Briefly, the LogEtronic printer uses a single cathode ray tube as the printing light source, a stationary photocell to sense the light which passes through the negative, plus a feedback loop through which the photocell continuously controls the intensity of the scanning light source. This basic principle, while having many interesting applications to other forms of photographic reproduction,[2] will be discussed in terms of the contact printer whose schematic diagram is shown in Figure 1.

The cathode ray tube, whose construction is similar to that used in laboratory oscilloscopes, produces a spot of light on a fluorescent screen through bombardment by a beam of electrons. The electron beam, deflected by voltages produced in a pair of electronic sweep generators, causes the spot to move about the face of the tube so as to scan a rectangular area. Light from this spot is projected by a simple lens to cover the negative which is held in contact with the printing paper. Light pentrating the negative, after scattering by the paper, is partially collected and transmitted to the photocell (photomultiplier). The output of the photomultiplier is fed back to the cathode ray tube through two independent electronic channels. One channel is an A.C. Amplifier which performs the dodging operation. The other channel is a Light Integrating Switch which turns the cathode ray tube OFF when exposure reaches the level specified by the Exposure Factor Control.

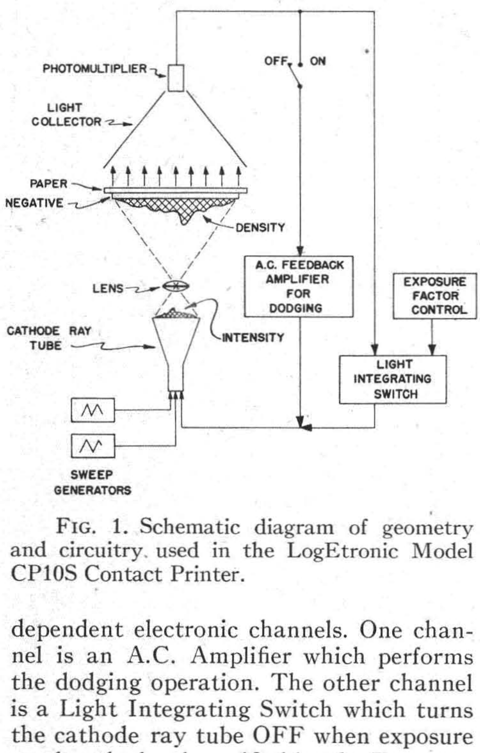


FIG. 1. Schematic diagram of geometry and circuitry used in the LogEtronic Model CP10S Contact Printer.

Signals in the dodging channel correspond to density variation in the negative and are used to modulate electron beam intensity, and thus light output, of the cathode ray tube. Signal polarity is arranged to produce inverse feedbacks meaning that when a dense region of negative is encountered by the spot, it instantaneously becomes brighter, the reverse being true for thin regions. As a result, an unsharp, positive luminous image of density variations in the negative is formed at the face of the cathode ray tube, and then projected back onto the negative. The effect, thereby, is to produce a relatively uniform distribution of light at the photosensitive surface of the printing medium which in turn produces the uniformly exposed, or dodged, print.

It should be mentioned that response in the feedback circuit is fast, compared to the rate at which the spot moves across the negative, so that scanning and exposure are simultaneous and in absolute register.

The second feedback channel contains an electronic integrating circuit which continuously totalizes the light which has passed through the printing surface. After sufficient time has elapsed for the integrated light to reach the pre-set level (determined by emulsion speed, subsequent processing and personal taste), an electronic switch biases the cathode ray tube to cut-off which terminates the exposure. Although exposure times may vary from one negative to the next, print exposure levels will be constant since only that light which reaches the emulsion is involved in the integration.

The completely electronic system described above forms the basis for the LogEtronic Contact Printer Model CP10S which produced all of the comparative print pairs shown in this article. The "conventional" prints were made with the switch in the A.C. Feedback channel turned OFF, thus maintaining constant spot intensity at the cathode ray tube. The LogEtronic prints were made with Feedback ON to produce automatic dodging as described previously. In each case, however, the Light Integrating Switch was kept operative so as to produce the same over-all exposure level for all prints.

III. Scanning Pattern

The most important requirement of the scanning pattern is uniform coverage of the area to be scanned without leaving scanning lines. The pattern used in the CP10S is generated by a pair of triangular waves of relatively low frequencies approximating 120 cycles/second and 121 cycles/second. The resulting pattern, which may be termed a drifting Lissajous figure, repeats itself at the beat frequency of once per second. The easiest mental picture to form of spot motion is that of a billiard ball striking a cushion at slightly less than 45 degrees and proceeding from there ad infinitum. With this type of pattern the spot spends equal times at all positions, and in the period of one second has traversed each dimension of the negative 240 times and has occupied 57,600 discrete positions. This figure may be used to express the number of smaller individually exposed picture elements into which the negative is divided or, stated another way, the equivalent number of individual light sources used for the exposure. Actually, spot motion is continuous and forms a diagonal cross-hatch with 57,600 intersections which, when combined with a spot large enough to give generous overlap, yields an exposure without trace of scanning lines.

IV. Optics

A cathode ray tube emitting surface of 5 inches diameter is used in the Log-Etronic CP10S. Since the scanning pattern covers only 3″×3″ it must be projected to a 10″×10″ area in order to cover an aerial negative. A simple double convex lens with an f/1 aperture is adequate since the quality of the projected spot has no influence on print resolution. However, in printing glass diapositives where the emulsions are separated by the film thickness, a smaller aperture is used to more nearly approximate a point source.

Optics of the printing stage are conventional with the negative resting on glass with the paper, film or plate held on top of it by a spring-loaded clear plastic platen. Because light is projected from a single source (the lens) onto the negative, contact problems are far simpler than those with a close-up diffuse source and excellent print resolution can be obtained even with poor contact between emulsions.

The chief function of the light collector is to collect uniformly from all portions of the negative which is simplified by ample spacing between printing stage and photomultiplier plus the use of a white diffusing surface for the interior of the collector.

V. Resolution

Print resolution is inherently good due to the use of a projected source, and is probably aided further by the use of monochromatic light. However, a special aperture must be used when printing diapositives through the base of the film. It is evident from simple geometrical optics that a point in the negative will be imaged through a film of thickness t and index of refraction n as a disk having diameter

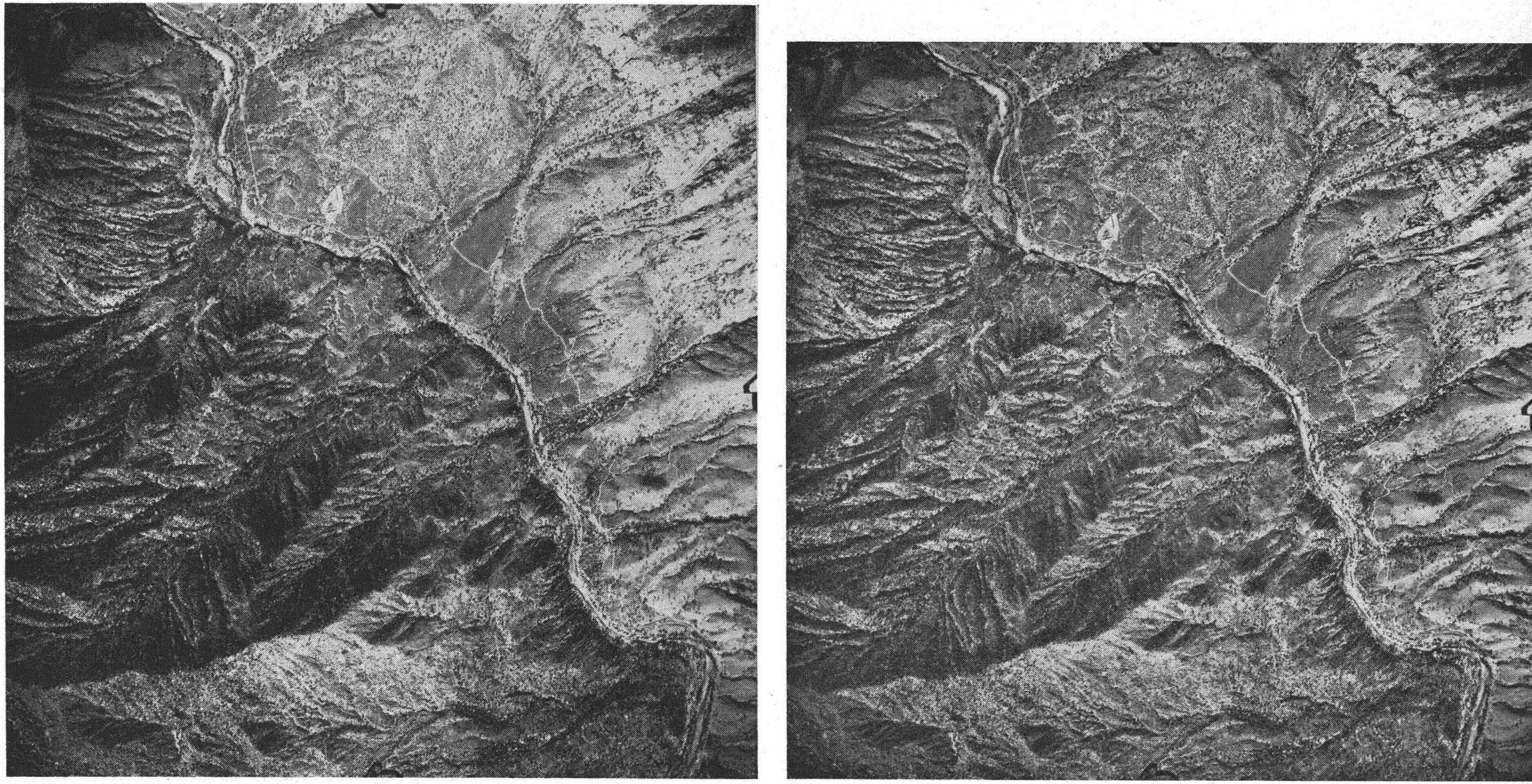
$$d=D/L\times t/n$$

when illuminated by a source of diameter D at a distance L. Because thickness and index of refraction are presumably fixed for aerial film, the ratio D/L becomes the major factor in determining the size of the imaged disk, and hence resolution. Obviously a value of zero, meaning a point light source at infinity would be ideal but proves to be unnecessary, since diffraction of even perfectly collimated light rapidly becomes the limiting factor long before D/L reaches zero. The point of diminishing returns has been experimentally determined to be in the vicinity of $D/L=0.04$ which can be obtained with a 0.8 inch aperture at a projection distance of 20 inches. With this geometry, resolution of 60 lines per millimeter has been observed when printing through a 0.006 inch film base onto glass plates.

VI. Spot Size

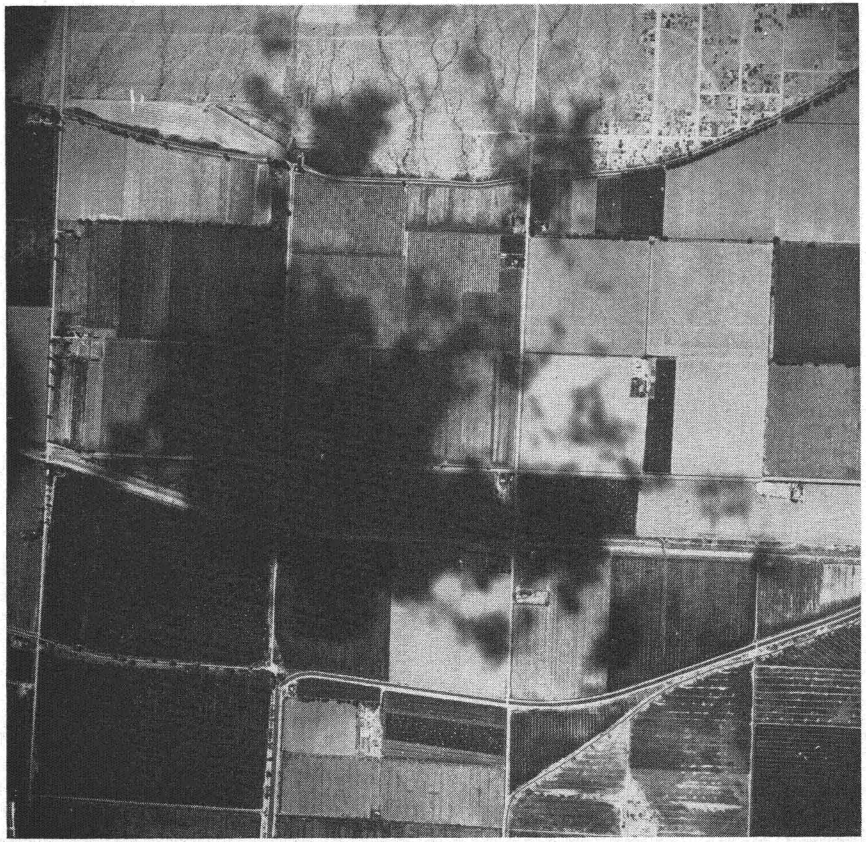
As previously mentioned, the spot may occupy 57,600 discrete positions within a frame and, if the spot be extremely small, the final exposure would have the appearance of a dot array similar to a screened half-tone. However, the spot is made sufficiently large in the printing plane, approximately $\frac{1}{2}$ inch diameter, so that there is ample overlap (90 per cent) to avoid this effect. Spot size, held large through both electronic and optical defocus, is large compared to the detail within an aerial photograph, but small compared to the total frame size. This provides good "dodging resolution" allowing both the shadow and highlight areas in mountainous terrain to be exposed independently, bringing out the maximum detail in each.

It is interesting to speculate on the results that might be achieved with an infinitely small spot, having an infinite number of discrete positions, in a system with 100 per cent feed-back. Under these circumstances all detail would be dodged out, giving a solid grey print completely devoid of information. This, of course, is impossible as well as undesirable, but a spot having the approximate dimensions of the finest negative detail is conceivable. and brief analysis shows that such a spot would produce a line drawing from a continuous tone negative. Despite this interesting possibility, no attempt has been made to produce such a small spot since the $\frac{1}{2}$″ diameter spot used in the CP10S appears to provide excellent dodging resolution in a 9×9 format. For those familiar with the technique, it should be men-



(a) (b)

PHOTOPAIR 1 (a) Conventional print of typical mountain scene. (b) LogEtronic print showing increased shadow detail.



(*a*)

(*b*)

PHOTOPAIR 2 (a) Conventional print with detail obscured by complex cloud shadow. (b) LogEtronic print showing partial removal of both large and small areas of shadow.

tioned that spot size in the LogEtronic printer is equivalent to the degree of "unsharpness" in the unsharp mask technique of dodging, where spot size is a function of the spacing between the negative and mask at the time of exposure.

VII. Feed-Back

Dodging "effectiveness," still a subjective term, must be considered in three dimensions where spot size determines the limiting complexity of the two dimensional dodging pattern that can be described in the plane of the print. The third dimension of dodging effectiveness involves both the real density difference in the negative and the "apparent" density difference of the negative as seen by the printing material during a dodged exposure. The ratio of real to apparent negative density difference will be termed the "density compression ratio" where the densities involved are measured over an area equal to that of the spot used. For example, if the extreme densities of a negative measured with a $\frac{1}{2}$ inch diameter aperture were found to be 0.5 and 1.5, the real density difference would be 1.0. Then, if these two areas were both printed to a density of 0.7, the apparent density difference would be zero and the density compression ratio would be infinite. Such conditions represent 100 per cent feed-back, since the density difference of 1.0 (or transmission ratio of 10 to 1) obviously demanded a spot intensity ratio of 1 to 10 in order to produce the same print exposure through both areas of the negative. Less than 100 per cent feed-back would, of course, permit different exposures through the two areas and the density compression ratio would be finite.

The LogEtronic CP10S employs an amount of feed-back sufficient to reduce a real negative density difference of 1.5 to an apparent negative density difference of 0.3 for a density compression ratio of 5/1. This ratio is large enough to print detail in extremely high contrast mountain scenes on a high contrast paper.

In closing this section it should be mentioned that per cent feed-back in LogEtronic printing is closely analogous to the ratio between mask and negative contrast in the unsharp mask technique.

VIII. Photographic Effect

At first glance, it might appear that a dodged print has merely been made on a lower contrast emulsion than the undodged print. This is a quite incorrect, but an understandable impression since the first glance merely conveys the general reduction in contrast without regard of the high detail contrast. In fact, printing on low contrast emulsions is frequently practiced to avoid dodging, but by no means produces the same results, except in the first impression.

The photographic effect of dodging, whether by LogEtronics printing or other methods, can be described in either of two ways; apparent compression of density differences in the negative, or modification of the characteristic curve of the printing medium.

Reference to Figure 2 will aid in discussing the first viewpoint where it is assumed that two regions of a negative have densities, when measured with a $\frac{1}{2}$ inch aperture, of 0.2 and 1.7 representing shadow and highlight areas in the original scene. In conventional printing this presents a logE range of 1.5 to the photographic emulsion for which the D-logE characteristic is shown. As a result, region *A* would be printed on the dense portion of the curve with detail disappearing into the shadows whereas detail in region *B* would be lost in the highlights—both being printed on low contrast portions of the curve. However, in a LogEtronic print, both regions would be printed on the same portion of the *D*-logE curve where contrast (slope) is greatest and where the density range is optimum for the full tonal reproduction of detail. In this case, it may be construed

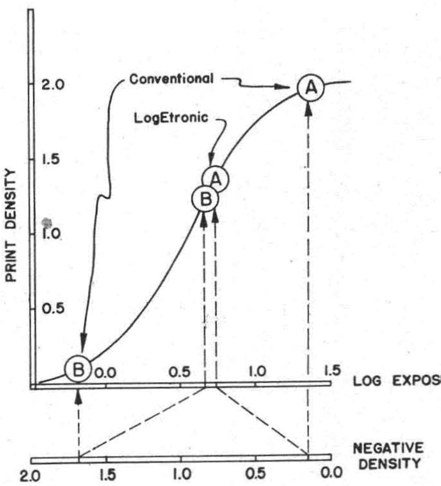
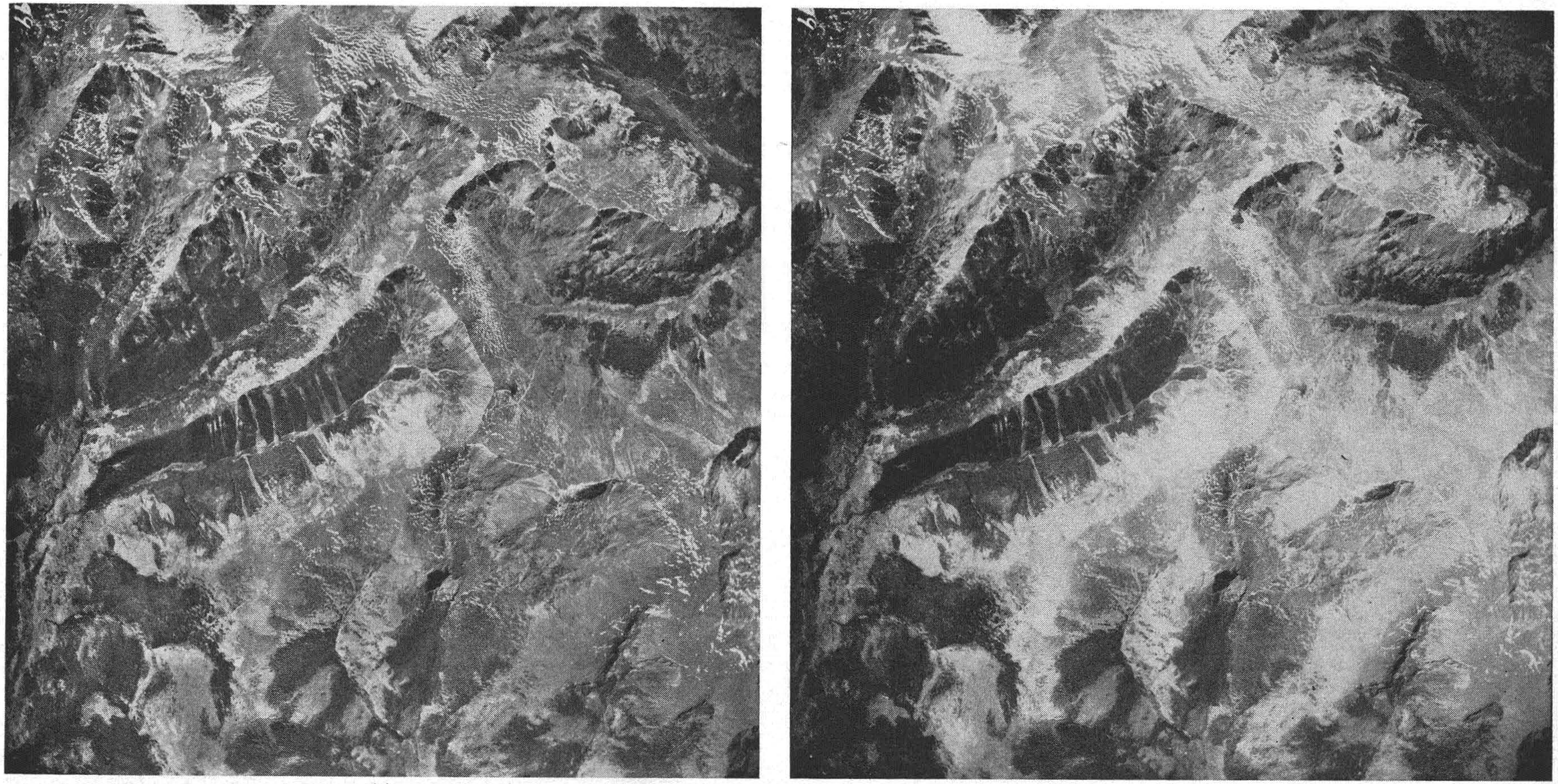


Fig. 2. Characteristic curve of typical high contrast printing material, showing the effective compression of gross negative density through LogEtronic dodging.



(a) (b)

PHOTOPAIR 3 (a) Conventional print of glacier scene on low contrast paper. (b) LogEtronic print on same paper showing increased detail contrast despite general contrast reduction.

that a negative density difference of 1.5 (0.2 to 1.7) has been reduced to 0.1 (0.75 to 0.85) yielding a density compression ratio of 15/1. Such density compression, it will be noted, decreases only the gross or unsharp contrast whereas the detail contrast within extensive regions of highlight and shadow is actually increased.

Densities measured from the prints and negative of a step wedge, plotted in Figure 3, illustrate the viewpoint that it is the characteristic of the photographic material which is modified through dodging. All densities were measured at the center of the steps which were wider than the spot diameter used in printing. It can therefore be argued that contrast of the printing material has been modified from that of the conventional print (gamma equal 1.3) to that in the LogEtronic print (gamma equal 0.2). This, of course, holds only for gross contrast, detail contrast remaining unchanged. An interchangeable viewpoint is that the exposure range for gross information is expanded through dodging while the exposure range for detail information remains fixed.

Regardless of which viewpoint is preferred, it is still necessary to choose a printing material whose contrast complements that of the detail contrast in the negative, but no longer necessary to choose a low contrast emulsion to avoid dodging.

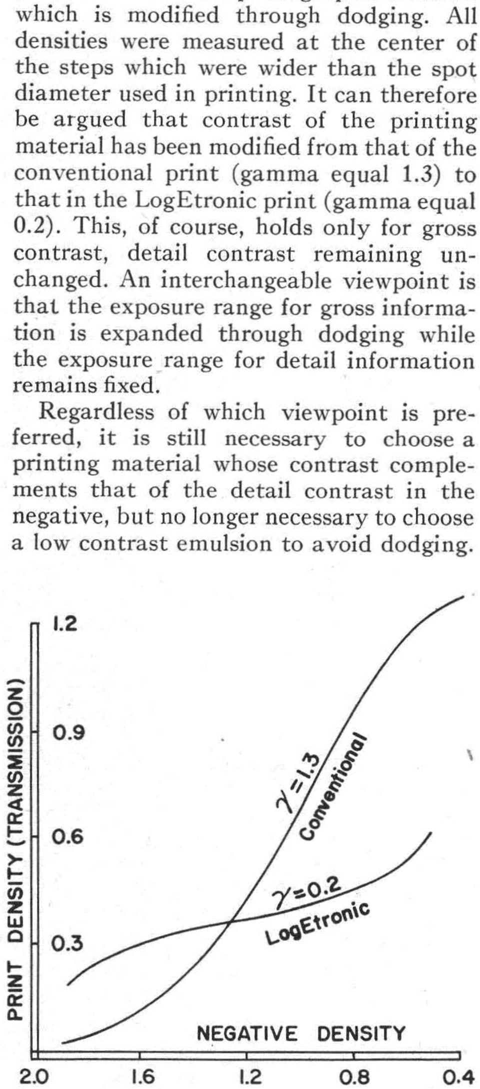


FIG. 3. Plot of negative versus print densities measured from step wedge showing magnitude of gross contrast reduction through LogEtronic dodging.

IX. Plotting Precision

Whereas it is difficult to measure, or even express, the actual information content of a negative or of a print made therefrom, it is both visually and intuitively apparent that more detail information is preserved through LogEtronic printing. In order to obtain quantitative and practical supporting evidence of this observation, two pairs of diapositive plates were made for evaluation in the Kelsh plotter. Both pairs were made from the same pair of negatives on $\frac{1}{4}$ inch Aerographic Contrast plates, printing through the film base. One pair of plates was exposed in a conventional printer and the other was exposed in the LogEtronic CP10S. The two models were set up in a Kelsh plotter at a scale of 200 feet per inch. Three operators each measured the elevation of the same five representative points in both models. The spread of data with the conventional plates was 0.4 millimeter while that with the LogEtronic plates was 0.1 millimeter. This preliminary test indicates that the precision in plotting elevation was improved by a factor of 4 through the use of LogEtronic plates, undoubtedly due to better visibility of detail in the extreme highlight and shadow areas.

These results, while encouraging, were not totally unexpected as the same order of improvement was reported by J. A. Eden on comparative measurements made from Multiplex plates printed through unsharp masks.

X. Conclusion

The basic principle of the LogEtronic printer is undeniably a radical departure from that of all other contemporary printers, and the results which have been obtained to date eloquently demonstrate the need for such a departure. The vast improvement in print quality should provide new standards for the users of aerial photographs, and such quality, obtained by automatic means, should bring large economies to the producers of LogEtronic prints.

References

1. Eden, J. A., "The Unsharp Mask Technique of Printing Aerial Negatives," *The Photogrammetric Record*, Vol. 1, No. 5, April 1955.
2. Craig, D. R., "The LogEtron" *Photographic Engineering*, Vol. 5, No. 4 1954.