lamp advance (abscissa) and time delay in seconds (ordinate). For any given intermediate tilt the exposure program can be interpolated with sufficient accuracy. Experience will show that these programs can readily be modified whenever the density distribution in the aerial negative deviates from uniformity, and therefore requires a different rate of exposure increase in foreground or background zones of the terrain images.

In lower tilt photography ($t<20°$) the program curves straighten out and have a small slope angle. The total exposure time decreases rapidly and may be as short as five seconds for near-vertical photography, while high tilt photography at 75° may require up to eight minutes.

The entire procedure of rectification consists of relatively few manual steps of aligning the photograph, film-stage and easels by precomputed data, selecting the punched program card, inserting it in the card reader (Figure 7), operating a few switches on the control panel, energizing the powerful vacuum unit which holds the screen and photomaterial flat on the easels and cools the Xenon arc lamp, and finally pushing the program button which lights the lamp and sets the exposure program in motion. At the end of the cycle, the lamp is turned off automatically and returns to its starting position, ready for the next run. The final product is a positive or negative transparency, or a paper print of completely uniform exposure and, naturally, of high geometric fidelity.

The project of building a series of instruments of this kind was sponsored by the United States Government. They will be used by several Government Services as a means of rapid rectification by precomputed orientation data of large quantities of oblique exposures ranging from verticals to 76° obliquity.

*Contrast Control for Diapositives**

JAMES G. LEWIS,
Topographic Division,
U. S. Geological Survey

ABSTRACT: *The objective of contrast control or dodging in diapositive printing is to permit a transfer of photographic images in which the contrast between minute contiguous images is retained and, at the same time, the maximum and minimum densities of the diapositive are limited.*

Contrast control in diapositive printing improves the accuracy of stereoscopic pointing in projection-type plotting equipment. The improvement is greatest for aerial negatives having extreme density ranges. Diapositives for four representative stereoscopic models were prepared in a 153/55 ratio-printer using an infrared quenching-type contrast control, an electronic feedback-type control, and using no control. The standard deviation of height readings expressed as a fraction of the flight height was 1/14,360 for the infrared-type control, 1/12,670 for the electronic control, and 1/11,140 for no control.

OBJECTIVE OF CONTRAST CONTROL

AT PRESENT (1961) almost all topographic maps are compiled from aerial photographs through the use of stereoscopic plotting instruments. Most of these instruments utilize glass-plate diapositives prepared either at negative scale or a reduced scale. Insofar as image-quality serves stereoplotting efficiency, it is desirable to transfer from the negative to the diapositive, as completely as possible, all of the imagery appearing on the original negative. To achieve such a transfer, some means of controlling image-contrast is necessary, particularly for aerial negatives having extremely large density ranges.

The objective of contrast-control or dodging in diapositive preparation is to permit a transfer of photographic images in which the

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JAMES G. LEWIS

contrast between minute contiguous images is retained and, at the same time, the maximum and minimum densities of the diapositives are limited. The range of density should be such that it can be accommodated in the viewing system of the stereoscopic plotter. When such "high-contrast" transfers are effected, the identification characteristics of images are retained and stereoscopic plotting efficiency is increased.

The value of the contrast-control in diapositive printing depends on the characteristics of the diapositive emulsion and its exposure and development. The emulsions generally used for diapositives are Class I (medium) contrast and Class II contrast. A Class III contrast is now available but was not used in the tests to be described. The emulsion characteristic, exposure, and development determine the contrast of the smallest contiguous images. The modulated printing light of the control system provides the means for limiting the integrated maximum and minimum density of somewhat larger areas of the image. In the ideal case, the "meticulousness"[1] of the modulation of the printer light is sufficient to provide an optimum contrast transfer for all small contiguous images. Meticulousness, as applied to contrast control, is defined as the degree to which small areas of the image are controlled.

EXISTING CONTRAST-CONTROL SYSTEMS

All-contrast-control systems which are applied during exposure utilize light modulation. A brief explanation of those which may be used in diapositive printing, follows:

Hand dodging.—Exposure is varied between relatively large areas by a hand-held mask placed between the printing light and the diapositive emulsion being exposed. Although judgment is permitted, this is a laborious and time-consuming task. Small area contrast control is not obtained.

Unsharp-mask techniques.—Light modulation is accomplished by placing a previously prepared unsharp positive of the exposure being printed, between the printing light and the negative. In this process light modulation is applied to somewhat smaller areas than in hand dodging. The system is time-consuming because of the need for careful registry between the unsharp positive and the negative.

Electronic feedback type.—Diagrammed schematically in Figure 1 is a velocity modulation electronic system as installed in a 153/55 diapositive printer (153/55 = ratio of camera focal-length to projector principal-

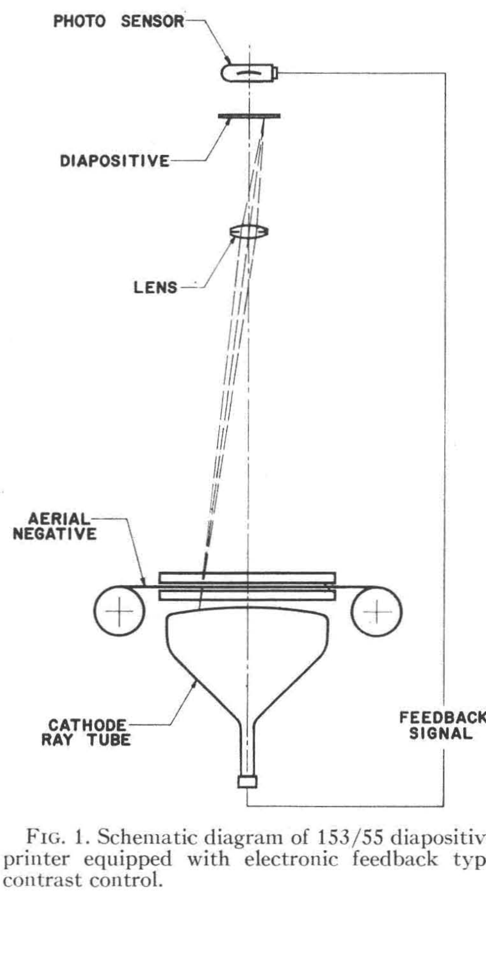

FIG. 1. Schematic diagram of 153/55 diapositive printer equipped with electronic feedback type contrast control.

[1] Jackson, K. B., Factors Affecting the Interpretability of Air Photos: *The Canadian Surveyor*, Vol. 14, No. 10, October 1959, pp. 454–464.

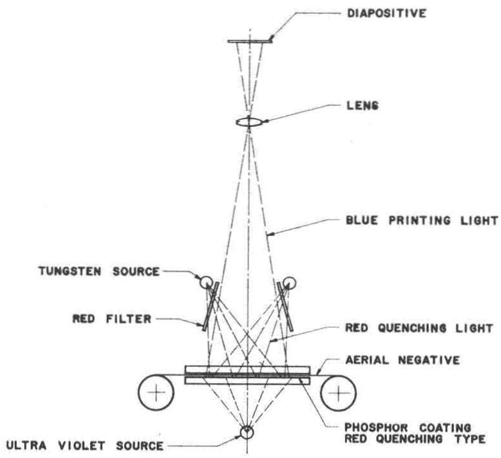

FIG. 2. Schematic diagram of 153/55 diapositive printer equipped with an infrared quenching type contrast control.

distance). The scanning spot of a large television or cathode-ray tube provides the printing light. The photo-sensor provides a feedback signal to the cathode-ray tube which causes a simultaneous and controlled variation in the speed of the moving spot on the face of the tube. The scanning speed at any given instant is inversely proportional to the density of the aerial negative in the area of the scanning spot. Automatic contrast-control is thus provided in areas as small as the moving spot.

Infrared quenching type.—Figure 2 illustrates an infrared quenching system installed in a 153/55 diapositive printer. An ultraviolet light-source excites a fluorescent screen coated with an infrared quenching-type phosphor. The screen emits a blue light to which the diapositive emulsion is sensitive. The brightness of the screen is varied by the quenching action of the infrared light, the quenching being greatest in areas where the negative is least dense. The screen thus emits a modulated blue light as though an unsharp mask had been inserted between the film and the screen. The size of the smallest area in which contrast control can be obtained is proportional to the distance between the aerial negative and fluorescent screen.

The Geological Survey implemented the electronic feedback type of control for diapositive preparation several years ago in one Area office of the Topographic Division. The infrared quenching type seen here was installed recently in one diapositive printer for production use, and already shows considerable promise.

RESEARCH IN CONTRAST CONTROL

In order that a sound judgment could be developed as to the value of contrast-control systems, it was felt that quantitative tests should be conducted. The tests were planned so that evaluations could be made for identical models utilizing diapositives printed without dodging, and those printed with both the electronic feedback and the infrared quenching-types of control. The planned analysis called for determinations of relative consistency of height reading under the three conditions of contrast control, and for statements of preference by experienced stereocompilers based on stereoscopic viewing of the several models.

Eight aerial negatives forming four stereoscopic models were selected as having the range of negative densities normally encountered in map compilation. ER-55 diapositives were prepared for the four stereo pairs using the electronic and the infrared quenching types of contrast control and also using no control. The three stereo models were set up on adjacent ER-55 compilation units. Stereoscopic elevation readings were repeated on five selected points in each model, by 10 experienced people. The stereoscopic readings on any single point were not repeated until all other points in the series had been read. The standard deviations given later are therefore not comparable to so-called consecutive pointings of stereo observation. Mr. T. J. Blachut[2] has commented on this important factor of stereoscopic measurement in a report on "The Second International Mapping Experiment, Renfrew Test Area." Twenty additional experienced stereocompilers examined the models and gave judgments as to comparative quality for map compilation.

The points selected for stereo measurement represented four problem areas encountered in production. Deep-shadow areas, large white-glare areas, timber, and dull low-contrast areas were considered.

Model set No. 1, shown in Figure 3, depicts rolling terrain having a large deep-shadow area completely covering the north side of a large granite mountain, namely, Stone Mountain in Georgia. This area also was about 90 per cent covered with timber, and contained a number of small ponds and several roads. The points selected for reading are numbered 1 to 5. In this model, note that no point was

[2] Blachut, T. J., Results of Experimental Plotting for 1:50,000 maps. Second International Mapping Experiment, Renfrew Test Area: Report to the IX International Congress of Photogrammetry, London, 1960.

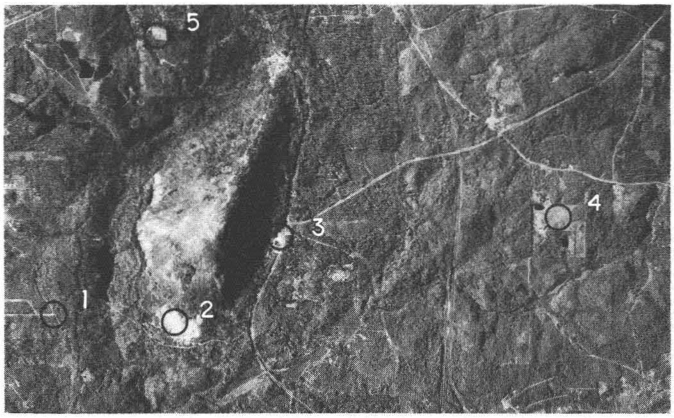

FIG. 3. Terrain covered by stereomodel set 1 with 5 points where measurements were made.

read in the shadow of the mountain, an area where contrast control was an obvious asset, as is shown in the next two illustrations. The standard deviations of the readings, expressed as a fraction of the flying height for all observations in this set of stereomodels are given in Table 1. (In all cases, control-type A refers to the electronic-feedback system and control-type B, to the infrared-quenching system.) Stereocompilers' preferences for contrast control are given in Table 1.

TABLE 1

RESULTS OF STEREOSCOPIC MEASUREMENTS AND OPERATOR OPINIONS

Model set number	*Stereoscopic observations H ÷ (Standard deviation)* *Contrast control* *Type A*	*Type B*	*No control*
One	12,190	10,950	10,770
Two	12,670	16,560	9,940
Three	16,150	16,560	15,380
Four	11,330	15,380	10,420
All models	12,670	14,360	11,140
Model set number	*Stereocompilers giving first preference*		
One	9	14	7
Two	19	11	0
Three	16	4	10
Four	5	21	4
All models	49	50	21
All model sets (4)	*For control*	*Against control*	
All operators (30)	99	21	

The total range of density in the aerial negative was 0.4 to 1.92. The range of negative-density in the areas where points were read was 0.98 to 1.92. It can be concluded that for all areas except in the mountain shadow, contrast-control has only slightly improved, but has definitely not limited the accuracy of stereoscopic pointings.

Figures 4 and 5 show the definite advantage of contrast-control in the mountain shadow. No points were selected for measurement here because of no identifiable imagery in the uncontrolled model. All diapositives used in model set 1 were Class II contrast, and were developed in DK60a for 5 minutes at 68°F.

Model set 2 shown in Figure 6, again presented an area of some relief, but with less timber cover than in set 1. In this model a very extensive white area on the side of a large hill, and the pattern presented by a large orchard, were of interest. The total

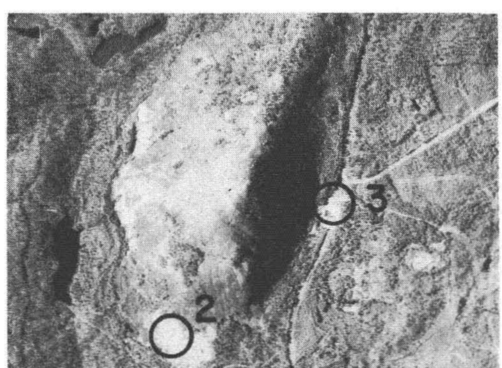

FIG. 4. Mountain shadow area from model set 1 with no control.

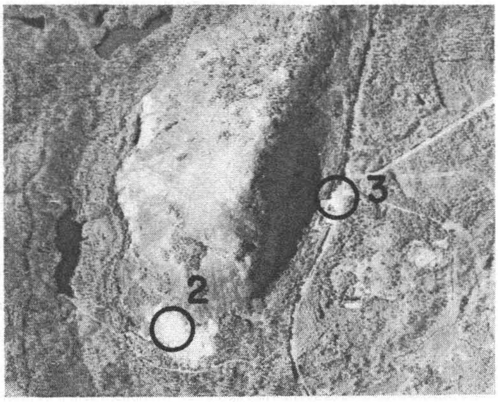

FIG. 5. Mountain shadow area from model set 1 with contrast control.

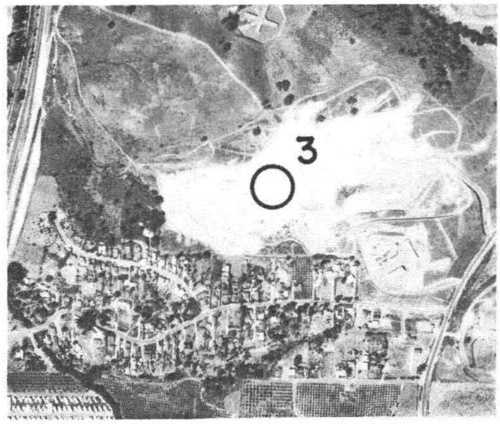

FIG. 7. Area around point 3 in model set 2 with no control.

density range in this aerial negative was 0.4 to 1.9. Points numbered 1 to 5 were selected for stereoscopic measurement. Note that point 3 was selected in the large white area at a location hardly detectable in the uncontrolled model. In Table 1 the standard deviations of readings on all points are given. The standard deviations for point 3 were: *Control type* A—1/7,260, *Control type* B—1/12,670, and *No control* 1/5,170.

Figures 7 and 8 show the area around point 3, with and without contrast-control. The advantage of contrast-control is especially evident for areas such as that surrounding this point where the aerial negative density extended to 1.9. Stereocompilers' preferences are given in Table 1. All plates were Class II contrast and developed in DK60a for 5 minutes at 68°F.

Model set 3, shown in Figure 9 offered flat terrain with a 50 per cent cover of dense tim-

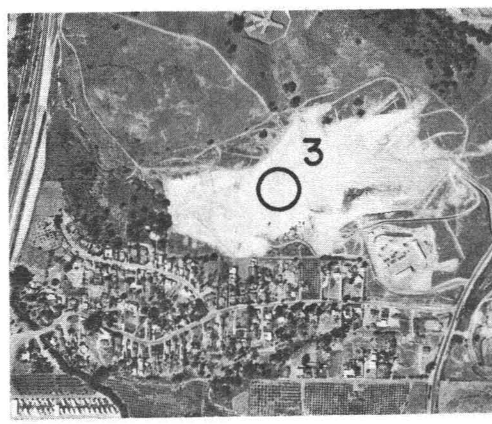

FIG. 8. Area around point 3 in model set 2 with contrast control.

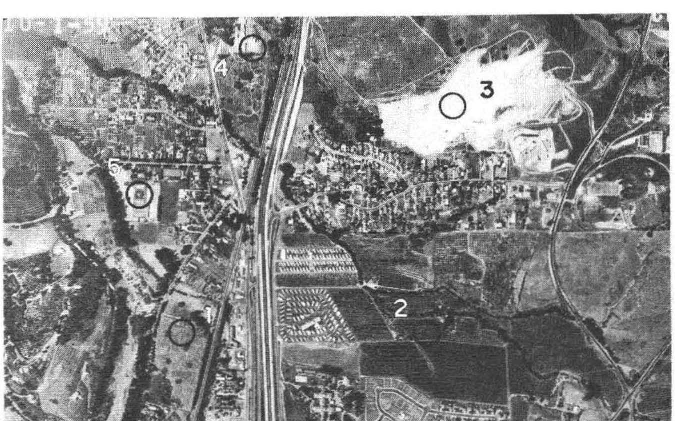

FIG. 6. Terrain covered by stereomodel set 2.

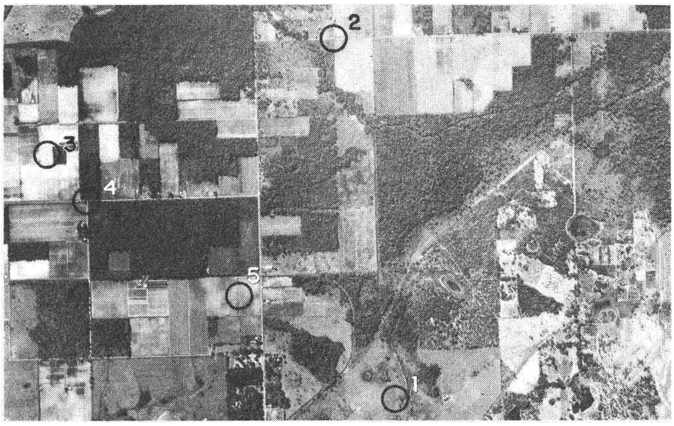

FIG. 9. Terrain covered by stereomodel set 3.

ber. The total range of density in this aerial negative was 0.36 to 1.04, well within the desirable limits of 0.30 to 1.5, as specified for aerial negatives. The standard deviations of readings on all points were: *Control-type* A —1/16,150, *Control-type* B—1/16,560, and *No control* 1/15,380. These values show no significant advantage for contrast-control. The deviations, however, are the lowest recorded for the four model sets. The limited density range of the aerial negative no doubt contributed to the low standard deviations and to the lack of a significant difference between controlled and uncontrolled models.

The number of preferences of stereocompilers for the different control types are given in Table 1. All plates were Class II contrast and were developed in DK60a for 5 minutes at 68°F.

Model set 4, shown in Figure 10, contained rolling terrain. This model is characterized by large leveled areas cleared for an industrial-type activity. The total density range in the aerial negative was 0.4 to 2.8. The former occurred in the river and the latter only on the sunny side of the long buildings. The density range of the negative in the area used for measurement was 0.8 to 1.62. The standard deviations of readings on all points are given in Table 1. The values show an advantage in this model for type B control as compared to type A control. The reason has not been conclusively determined. Microdensitometer traces on the diapositives across the points measured showed no significant differences in contrast between the two types of control, but did show that for most of the points measured, type A control produced a darker diapositive. Strong preference for type B control in this model suggests that type A control produced a diapositive of too great a density-range for best measurement with projection equipment. The larger range was attributed to the lack of meticulousness of the

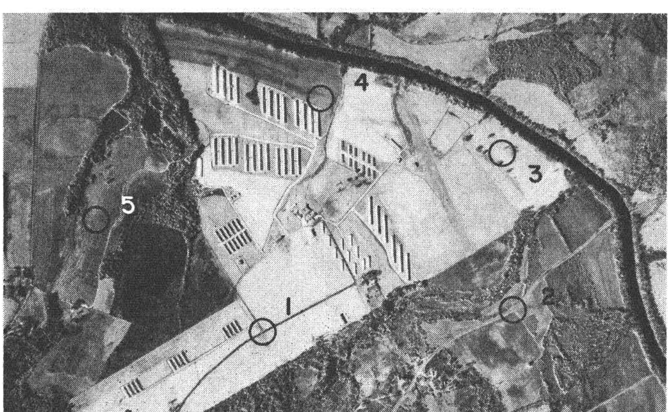

FIG. 10. Terrain covered by stereomodel set 4.

type A control. Stereocompilers preferences are given in Table 1. All diapositive plates were Class I medium contrast and were developed in DK60a for 5 minutes at 68°F.

Table 1 gives the combined results of the stereoscopic measurements, and stereocompilers' opinions for the four model sets. The standard deviations are: *Control-type* A—1/12,670, *Control-type* B—1/14,360 and *No control* 1/11,140. Forty-nine stereocompilers expressed first preferences for type A and 50 for type B control; 99 preferences for a contrast-controlled model and 21 preferences for no control.

Conclusions

It can be stated that contrast-control in diapositive printing improves the accuracy of stereoscopic pointings. The percentage of improvement obtained is directly related to the density range of the aerial negative. The negatives used in the research reported herein were not extreme or unusual examples, but were those which might normally be encountered in mapping operations. The percentage of improvement for the contrast-controlled models therefore is not nearly as great as would have been obtained with extreme density conditions of the type that would exist in negatives of snow scenes or rugged mountain terrain.

V. S. Milner and M. N. Tsygano[3] of the USSR recently reported on the improvement of accuracy of stereoscopic measurement using the unsharp-mask technique. The areas chosen for study and the points used for measurement were extreme and, therefore, the results are not directly comparable to those of this study. It is interesting to note, however, that their results are similar to those reported in this paper. They reported an increase in the accuracy of stereoscopic measurements of from $1\frac{1}{2}$ to 2 times (34 to 50 per cent). Note in Table I that in model set four, type B control showed a 40 per cent improvement over no control.

It is hoped that this study may benefit others by furnishing quantitative data in an area where pictorial quality is often the only guide.

[3] Experiments in the Use of the Unsharp-Mask Method of Preparing Contact Prints and Diapositives: Geodesy and Cartography, Nos. 3 and 4, USSR Ministry of Internal Affairs.

*Autofocus Rectifier Modified for Electronic Dodging and Automatic Exposure Control**

REX R. MCHAIL,
Photogrammetric Engr.,
Bausch & Lomb, Incorp., Rochester 2, N. Y.

(Abstract is on next page)

THIS paper discusses the basic construction and operational principles of a Bausch & Lomb Autofocus Rectifier that has been modified to provide electronic dodging and automatic exposure control. The rectifier is illustrated in Figure 1. This development program was supported by the U. S. Navy, Bureau of Weapons, under the direction of the U. S. Naval Photographic Interpretation Center. The instrument is currently being tested and evaluated at its facilities in Suitland, Maryland. It is important, therefore, that it be understood that, while this paper does not necessarily reflect the official views of the Defense Dept., it does reflect their consideration to permit Bausch & Lomb, Inc. as prime contractor to present this report of the development program. Credit for the elec-

* Presented at the Society's 27th Annual Meeting, The Shoreham Hotel, Washington, D. C., March 19–22, 1961.