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Printing Sources of Image Deformation

Flattening of film so that its emulsion does not deviate from a plane is a major problem in aerial cameras and THE problem in printers using centrally projected light.

ABSTRACT: *The results of an investigation of diapositives printed with a contact printer using centrally projected light showed that proper contact between negative and diapositive emulsion must be achieved in order to obtain diapositives with an image geometry equivalent to that of the negative. Several sources of improper contact of the two emulsions were encountered in one particular printer and modifications were introduced to eliminate them.*

INTRODUCTION

DIAPOSITIVES and not the original film negatives are usually used in plotters and comparators. These diapositives can be printed either with printers projecting the negative through a lens or with contact printers. If a projection lens is involved, its distortion will result in point displacements. However, displacements resulting from distortion of the projection lens are the same for each diapositive and could, if so required, be eliminated with a compensation plate.

Deviations of either negative or diapositive emulsion from a plane will, in using printers which project the negative through a lens, result in positional displacements. These deviations can be eliminated by bringing the negative and diapositive emulsions into contact.

Contact printers using centrally projected light permit conveniently the addition of an automatic dodging procedure which reduces highlights and shadows occurring in the negative in order to improve the readability and interpretability of the printed diapositive by bringing out finer details.

Contact printers with an autododging facility are widely used. Printing of diapositives using these printers requires extreme operational care and frequent production control to ensure that the diapositive is of the same metrical quality as the negative.

Metrical aspects of diapositives printed with contact printers using centrally projected light are discussed in this article.

THE MAJOR PROBLEM

Flattening of film so that its emulsion does not deviate from a plane is a major problem in aerial cameras and *the* problem in printers using centrally projected light. The elastic film must be supported by a rigid plate in order to yield a stable surface. In addition, this rigid plate and the film have to be brought into contact by removing the air between them.

The problem can technically be solved in four ways[3], but only one of these is suitable for contact printers: the mechanical flattening by pressing the negative film (and the diapositive with it) against a reference glass plate. This solution has been used in Great Britain in aerial cameras for several decades and has been thoroughly investigated there.[1] The only difference in its use in a printer rather than in an aerial camera is that the time available to achieve contact between reference glass plate and film is not as severely limited. On the other hand, the situation is more complicated as a result of the addition of the diapositive material. It is no longer really required to

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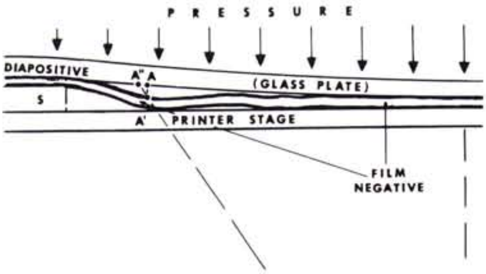

FIG. 1. Image shift resulting from improper contact between negative and diapositive emulsion ($A \rightarrow A''$).

achieve total contact between reference glass plate and film. Total contact between the negative emulsion and diapositive emulsion is needed instead. As both negative film and diapositive glass or film can show variations in their thickness, and because the two are generally sandwiched between two rigid plates, air between reference glass plate and film and/or between diapositive material and pressure pad may prove to be helpful.

A separation between negative and diapositive emulsion will result in a positional displacement approximately in radial direction (Figure 1). A point A' of the negative should be printed at position A and is actually printed at A''. Assuming a support S would be positioned around the image format between reference glass plate and negative film, extended air pockets can be expected. Several diapositives were printed on glass plates using such a support, which was the mask in the LogEtronic printer. As could be expected, the glass plates rested on the support as well as in the center on the negative film reaching contact in these areas. In the remaining area the negative film floated freely between reference glass plate and diapositive plate reaching a random unrepeatable position. The unrepeatability of the position is clearly demonstrated in Figure 2 which displays residual deformation after a similarity transformation[5] to an ideal 1-cm grid of three diapositives printed from the same negative on a Friday, the following Monday and the following Wednesday. The residual deformation of a diapositive printed from the same negative earlier on a contact printer using prallel light and transformed as the three diapositives is, for comparison, given in Figure 3. The vectors show required corrections. Therefore, the vector that indicates the actual shift from point A to point A'' in Figure 1 will point towards the center of the photograph as do many vec-

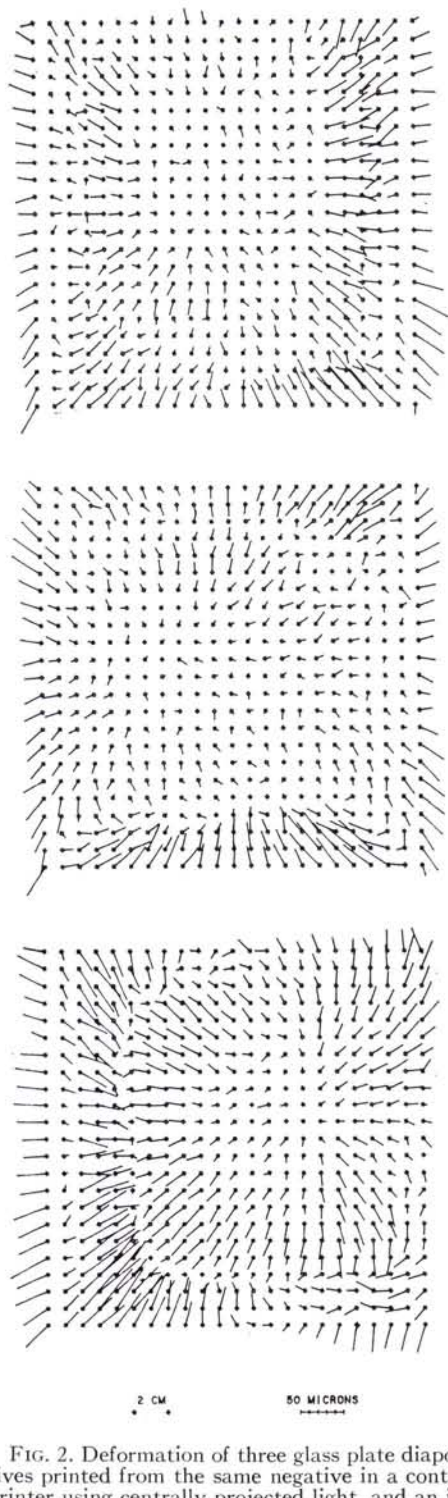

FIG. 2. Deformation of three glass plate diapositives printed from the same negative in a contact printer using centrally projected light, and an improperly placed mask.

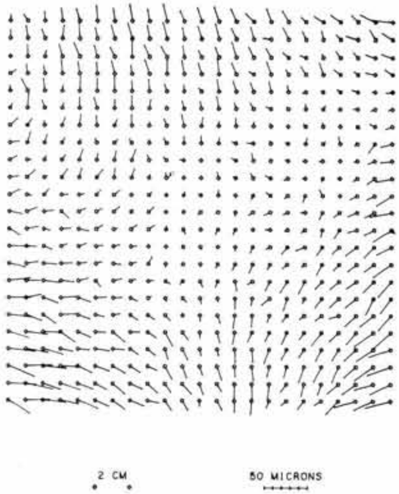

FIG. 3. Deformation of a diapositive printed in a contact printer using parallel light from the same negative measured to obtain Figure 5.

tors in Figure 2 of points located somewhere between center and format edge.

Elimination of the supporting scotch-tape frame and repeated printing on three successive days of the same negative used for Figure 2 yielded three diapositives on glass plates with the residual deformations indicated in Figure 4.

Repeatability of Printing Performance

In order to control the repeatability of the printing performance of a contact printer using centrally projected light, six diapositives were printed, one each on $\frac{1}{8}$-inch glass and on .007-inch film on three successive days.

Prior to commencing printing on the first day, the negative was measured. Comparison of the results from the negative itself (Figure 5) and the diapositive printed from the same negative earlier in a contact printer using parallel light (Figure 3) suggest that dimensional changes other than an overall scale change have taken place.

The deformation of the three glass diapositives is given in Figure 4, the deformation of the three film diapositives in Figure 6, the differences between glass and film diapositive printed on the same day in Figure 7. The deformation of all six diapositives seems to be more similar to the average of Figures 3 and 5 rather than Figure 5, the negative measured prior to printing the first diapositive, alone. This observation could suggest that dimensional changes took place during the measure-

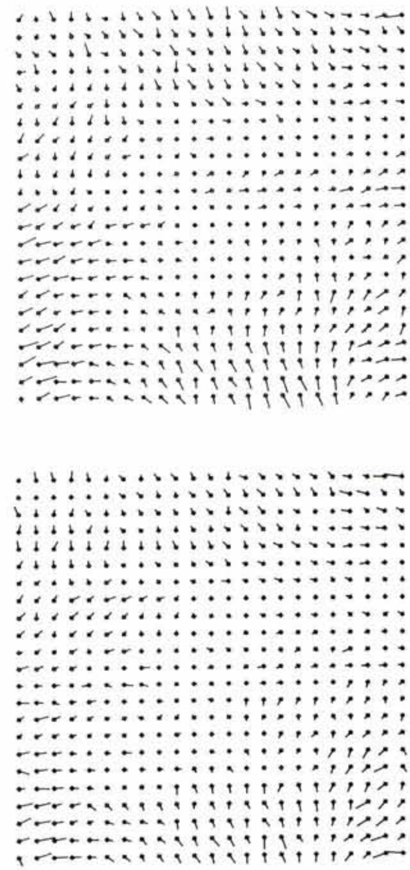

FIG. 4. Deformation of three glass plate diapositives printed from the same negative on three successive days in a contact printer using centrally projected light.

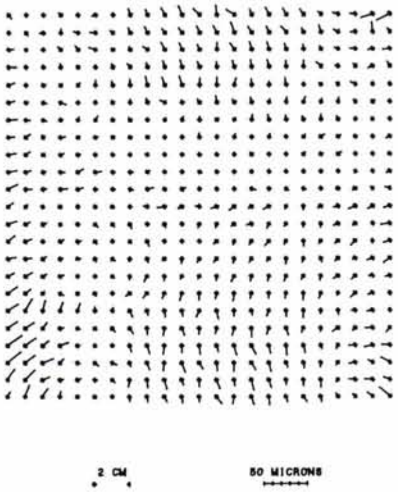

FIG. 5. Deformation of the negative from which all discussed diapositives were printed except that on which Figure 12 is based.

ment[5], or that the pressure used for the flattening of the film in the printer and/or in the comparator caused a small but recognizable differential scale change.

An attempt was made to determine the deformation introduced by the printer by reducing the deformation of the six diapositives by that of the negative. The residuals indicating the difference between the deformation of the negative and the diapositives are given in Figure 8 for the glass plate diapositives and Figure 9 for the film diapositives. A comparison of these graphs indicates a larger similarity between the glass and film diapositives, respectively, than between glass and film diapositive printed on the same day, thus suggesting that part of this deformation is caused by differences in handling and processing resulting from the difference in material.

An attempt to eliminate the deformation differences caused by handling of the diapositive by reducing the deformation of two of the glass plate and film diapositives with that of the third one was then made. The results are shown in Figure 10 for the glass plate diapositives and in Figure 11 for the film diapositives. These four vector diagrams indicate image deformation introduced by the printer only.

The *rms* deformation in x- and y-direction for all diagrams shown in Figures 4 to 11 is given in Table 1. As the diapositives printed on the second day were used to form differences with those printed on the first and the third day, values for only two diapositives were obtained in Columns I and VII. Reducing the values given in Table 1 by the measuring accuracy $m_x = \pm 2.0$ μm and $m_y = \pm 1.4$ μm[6] or, in the case of differences, by the measuring accuracy values multiplied with $\sqrt{2}$, $\sqrt{2}$, gives the values of Table 2. These values suggest that a deformation in x and y direction of ± 2 to 4 μm can be caused by the printer.

The values in Tables 1 and 2 and Figures 4, 6 and 7 indicate no significant difference between the use of glass plate diapositives and .007-inch film diapositives. It can therefore be concluded that the values given in Table 2 for the difference between photographs indi-

TABLE 1. RMS RESIDUAL DEFORMATION IN MICROMETERS IN x- AND y-DIRECTION FOR FIGURES 4 TO 11

Figure	*I* *10*	*II* *8*	*III* *4*	*IV* *7*	*V* *6*	*VI* *9*	*VII* *11*
x	3.3	4.2	5.9	4.2	5.4	3.3	4.9
y	2.9	3.4	5.7	2.6	5.3	3.0	2.9
x		3.5	5.2	3.8	4.9	4.1	
y		3.9	4.7	2.8	4.2	3.3	
x	4.1	5.0	6.7	3.6	6.3	4.8	4.0
y	3.1	4.2	6.0	2.6	5.9	4.0	3.4

I. Deformation differences between two glass-plate diapositives printed on successive days.
II. Deformation differences between glass-plate diapositives and the negative.
III. Deformation of the glass-plate diapositives.
IV. Deformation differences between glass-plate and film diapositives printed on the same day.
V. Deformation of the film diapositives.
VI. Deformation differences between the film diapositives and the negative.
VII. Deformation differences between two film diapositives printed on successive days.

TABLE 2. RMS RESIDUAL DEFORMATION IN MICROMETERS IN x- AND y-DIRECTION FOR FIGURES 4 TO 11, REDUCED BY THE MEASURING ERRORS

	*I**	*II*	*III*	*IV*	*V*	*VI*	*VII*
x	2.6	3.0	5.6	3.1	5.0	1.6	4.0
y	2.1	2.8	5.6	1.7	5.1	2.3	2.1
x		2.0	4.8	2.5	4.4	2.9	
y		3.4	4.5	2.0	4.0	2.7	
x	3.0	4.1	6.4	2.2	6.0	3.9	2.7
y	2.5	3.7	5.8	1.7	5.7	3.5	2.8

* See Table 1.

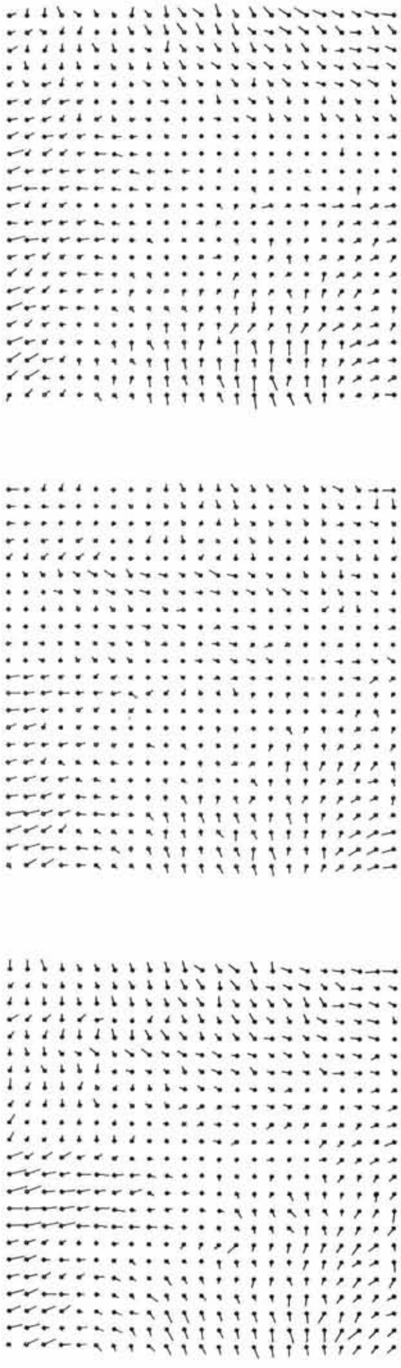

FIG. 6. Deformation of three film diapositives printed from the same negative on three successive days in a contact printer using centrally projected light.

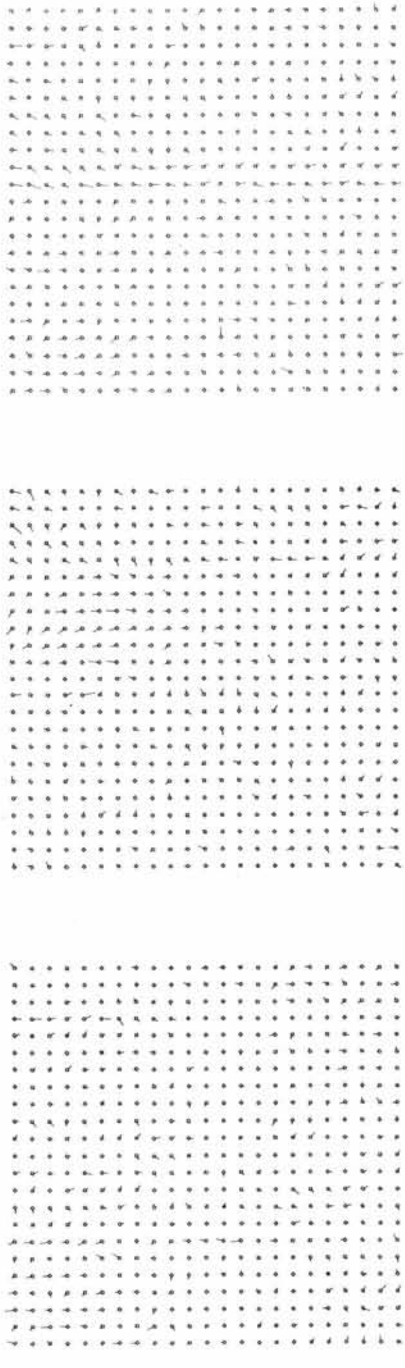

FIG. 7. Differences between the deformation of glass plate and film diapositives printed one immediately after the other. (Difference between Figures 4 and 6).

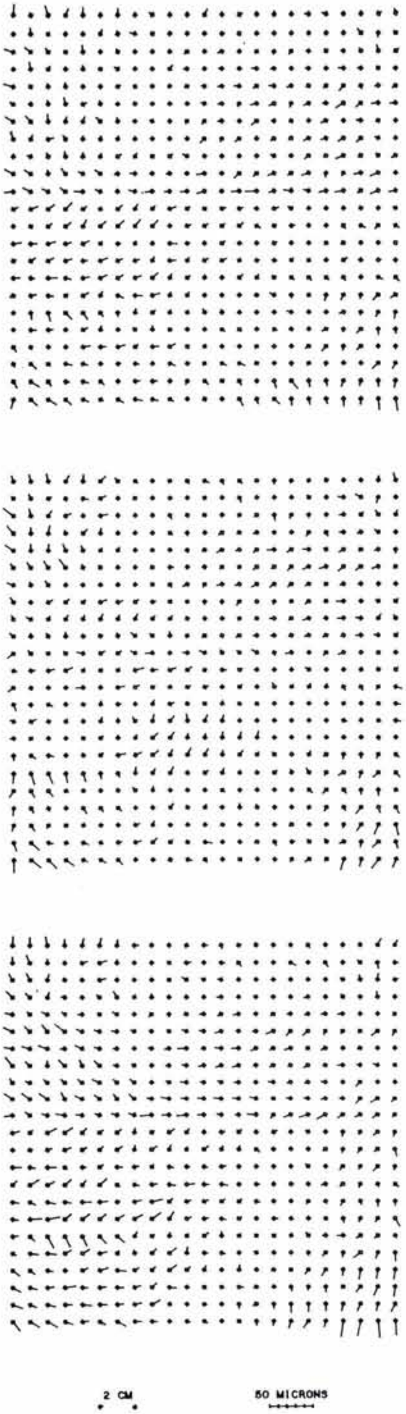

FIG. 8. Differences between the deformation shown in Figure 4 and that of the negative (Figure 5).

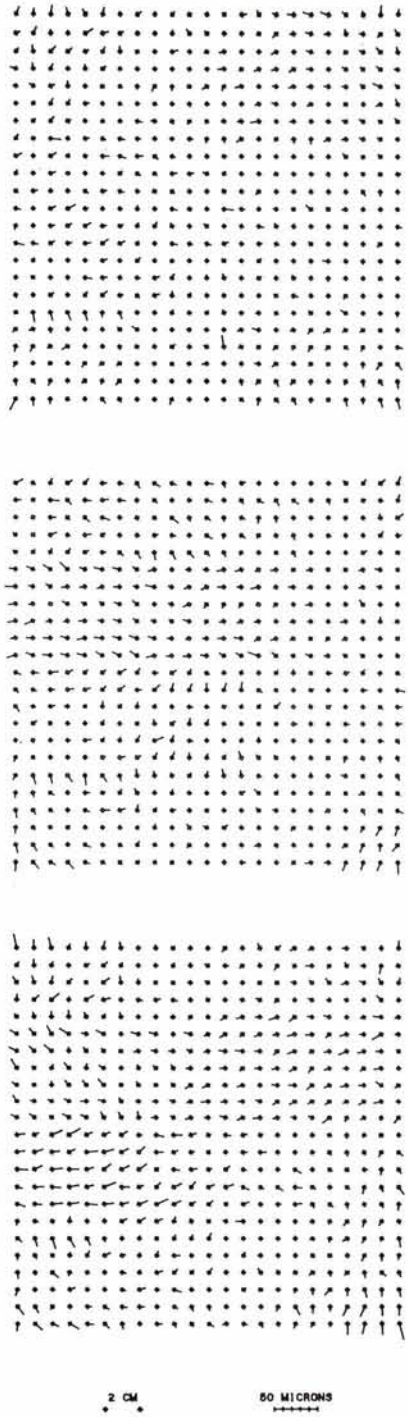

FIG. 9. Differences between the deformation shown in Figure 6 and that of the negative (Figure 5).

cate *rms* values for deformation caused by the printer. These values are slightly larger than ± 1 to 3 μm given by Ligterink and Zijlstra[2] and smaller than the ± 6 μm obtained[3] by Schwidefsky[4].

Figures 8 and 10 show in each graph, in the sixth row from the bottom, several points with similar deformation which are the results of a local disturbance of the general deformation pattern of Figure 5. This disturbance is unique to the measurement of the negative, as a comparison with Figures 3, 4 and 9 shows; it can therefore be concluded that it is the result of the mensuration process.

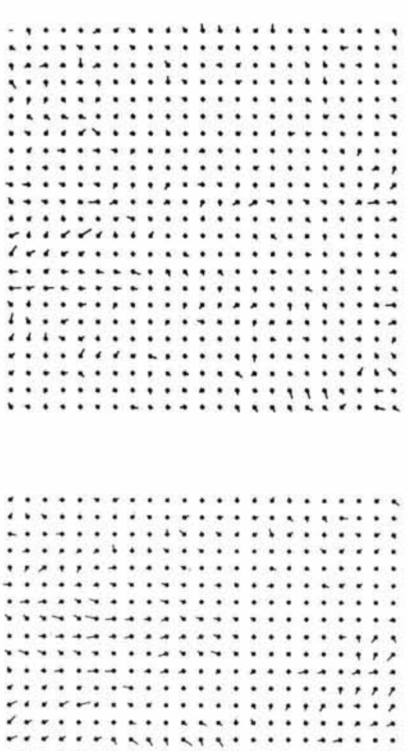

FIG. 10. Differences between the deformation of two glass plate diapositives printed from the same negative on two successive days (Figure 4 *top* minus Figure 4 *center* and Figure 4 *bottom* minus Figure 4 *center*).

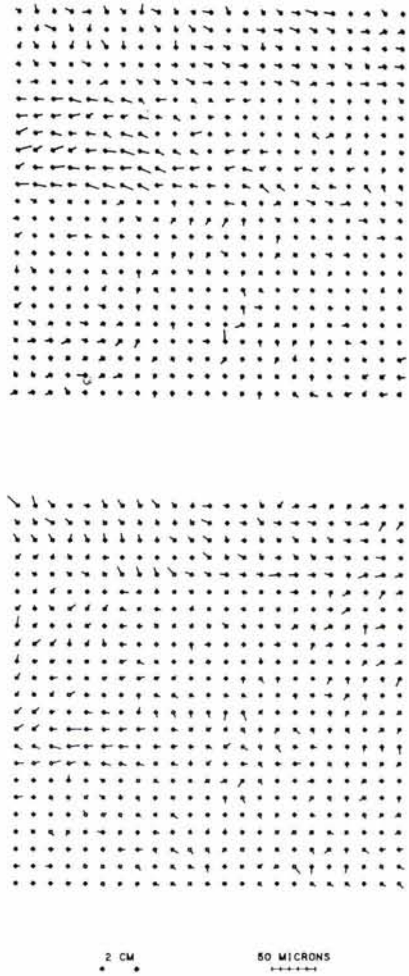

FIG. 11. Differences between the deformation of two film diapositives printed from the same negative on two successive days (Figure 6 *top* minus Figure 6 *center* and Figure 6 *bottom* minus Figure 6 *center*).

ERRORS INTRODUCED BY A CONTACT-PRINTER

The six diapositives leading to Figures 4 to 11 were printed in a LogEtronic Contact Printer Model Mark II using the recommended procedure for printing glass diapositives—with the exceptions that a glass plate instead of the provided plastic plate was used between diapositive and pressure bag and that the automatic switch was de-activated and the raster triggered manually. The reasons for introducing these modifications can be seen from Figure 12, which displays the errors originally encountered with this printer:

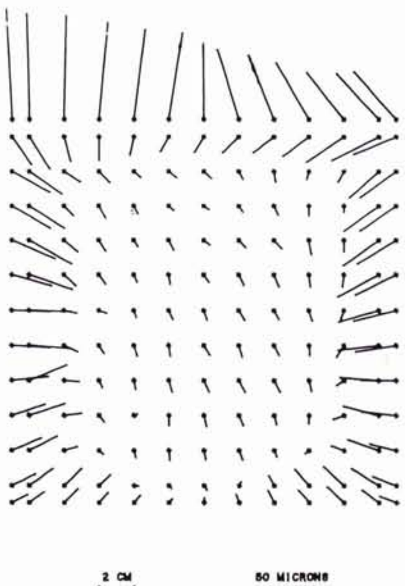

FIG. 12. Deformation of a diapositive printed prior to the modification of the LogEtronic Contact Printer Mark II showing the effects of bending of the plastic pressure plate and of too early triggering.

improper contact between negative and diapositive emulsions resulting from an undesired flexibility of the plastic plate, too early triggering of the scanning mechanism and improper masking of the printer stage area not needed.

Disregarding for a moment the top line in Figure 12, a systematic pattern can be seen which, according to Figures 1 and 2, suggests that negative and diapositive emulsions were not in contact along at least the outer two lines. Obviously, the plastic plate was pressed down sufficiently at the center but not at the edges of the format, i.e., the glass plate bent. Consequently, it was replaced by a $\frac{1}{4}$-inch glass plate.

The top two lines show a spacing which changes by more than 80 μm. This change cannot be caused by film deformation but only by a change in the position of the film during the exposure of the top line. It was found that the automatic switch was triggered too early.

The exposure of the diapositive began at the top before the diapositive had reached a stable position. This type of deformation never occurred after introduction of the manual triggering.

The printer stage has an open area of 40 cm by 49 cm ($15\frac{3}{4}$ by $9\frac{3}{8}$ inches). The largest negative size accepted by the printer is 35.6 cm by 45.7 cm (14 by 18 inches) although aerial photographs usually have a size of 23 cm by 23 cm (9 by 9 inches) only. The area of the printer stage not needed is masked off to prevent extraneous light from reducing the control over the dodging process and to minimize border enhancement. A mask approximately the density of the negative can be used to cover either the stage area not needed or only an area around the negative. The latter is being done at the Mapping and Charting Establishment using red scotch tape. Putting this tape on top of the printer stage results in a supporting frame yielding results as those in Figure 2. Hence, the tape has been fixed to the under side of the printer stage and no mask at all is used on the upper side of the printer stage. This arrangement has proven to be satisfactory.

Conclusions

Contact printers using centrally projected light can add substantially to image deformation. Any such printer should be investigated throughly and, if this seems necessary, be modified in order to guarantee dimensional accuracy.

Results obtained with such a modified printer indicate a good repeatability of the printing performance and a dimensional quality which will suffice for most photogrammetric purposes. Local image deformation corrections based on a reseau can eliminate the local deviations from an overall deformation pattern which are likely to be introduced during the printing of the diapositive.

The performance of the printer should be tested periodically. No modification to the printing procedure must be made unless its dimensional effect on the diapositives has been investigated and proven to be negligible.

References

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