Practical Paper

Is Your Contact Printer *Really* a "Contact" Printer?

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ABSTRACT: A comparative test was performed for the purpose of determining the magnitude of the vertical errors in the stereo model introduced during the "contact" printing of the Mylar film diapositives. Using both grid models and aerial photo models, the elevation of a preponderance of points were read and recorded from the diapositive models, the same points were read and recorded from the negative models (negatives from which the diapositives were produced), and the difference of the two sets of elevation values were calculated. A total of 25 diapositive grid models were produced from the same pair of grid negatives, and a total of six diapositive aerial photo models were produced from the same pair of aerial photo negatives. Three different types of diapositive materials were used and three different pressure systems were used in various combinations. The results indicated a greatly improved fidelity of the diapositive stereo models to their respective negative stereo model when the diapositives were produced using a "rigid" pressure plate applied directly on top of the diapositive material during exposure on the Log-E Mk II used for this test.

INTRODUCTION

All of us involved in the production of topographic maps from aerial photographs are well aware of the fact that there are many different types and magnitudes of errors introduced into the overall photogrammetric process. Some are known, some are unknown; some consistant, some random; some additive, some subtractive; some easily compensated, some compensated with difficulty.

In this paper, the author hopes to shed some light upon one possible point of entry of one particular type of error which can be random both in location and in magnitude. The point of entry with which we are concerned is the process of film diapositive "contact" printing.

It is obvious that, in order to produce a diapositive from a negative with the maximum of fidelity, it is necessary to keep the two materials in direct contact, emulsion to emulsion, during the entire period of light exposure. To whatever degree contact is *not* maintained during exposure, the diapositive will lose fidelity in the form of horizontal distortion and/or resolution loss, depending upon the type and angle of incidence of the exposing light rays. Yet, obvious as it may be, the results of this test indicate that the "contact" printer at the location where this test was conducted probably *was* exposing film diapositives *without* total contact across the entire image format.

The instruction manual for the electronic-dodging "contact" printer recommended the use of a neutral density mask with a window cut from it the same size as the image area to be exposed. Theoretically, this mask could be placed anywhere between the projection optics and the "stiffner." It is my belief, however, that most people in this industry place the mask directly on top of the photographic duplicating material before lowering and latching the hood for exposure. The "standard" (as far as we could surmise) pressure system on the under-side of the hood consists of an inflatable plastic air bag and a 1/16-inch thick plexiglass "stiffner" directly under the air bag. With sufficient pressure in the air bag, the stiffner makes contact with the mask upon lowering and latching the hood.

The mask that we were using was a green, neutral density material, which was delivered from the printer manufacturer as standard equipment, to the best of our knowledge. Using a micrometer, the thickness of the mask was determined to be 0.013 inches. If the stiffner applies normal pressure on the mask (hence, on the diapositive and the negative), it can only be quaranteed to do so around the edges of the window where the mask is in contact with photographic material. For the stiffner to apply pressure on the photographic materials *inside* the window area, it must deform from a relatively flat sheet into one with some compound curves. This is conceivable, to a certain degree, where it could apply some pressure in the center of the window area, but it is also obvious that there will be an area of unknown width from the inside edge of the mask window toward the center of the window where the stiffner will not be able to apply pressure on the photographic materials around any of the four sides

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of the image area. This condition could vary considerably from one printer to the next. Consequently, no form of quantitative analysis was attempted in this regard. The point is simply to present a *possible* explanation for the results obtained in the following described test.

There are several reasons to believe that an even greater gap can occur between stiffner and photographic materials, but for the sake of conservatism, we will consider only the thickness of the mask (0.013 inch) as the depth of the "cavity" inside of the window area. Because most photographic materials tend to curl in the direction causing a concave surface on the emulsion side, the diapositive and negative will tend to curl away from one another in the center when placed emulsion to emulsion without flattening pressure. It is reasonable to assume that some air could be trapped between diapositive and negative when the hood is lowered, causing the diapositive to remain "bubbled up" into the mask window cavity to the point of contact with the stiffner, and thus causing a separation between diapositive and negative during exposure at least somewhere between the inside edges of the window and the center of the window. It is very likely that the maximum separation would occur approximately one inch in toward the center from the extreme corner of the window. Note that this is also the approximate optimum location for vertical control points in the stereo model.

The projection distance of the printer from the lens to the top of the stage plate measured approximately 20 inches (508 mm). Considering the normal 6-inch focal length aerial photography with 60 percent end-lap and 30 percent side-lap, the corner of the "neat" stereo model would be located approximately 4.78 inches (121.4 mm) from the photo center. With the use of like triangles, the radial horizontal displacement of the image at this location on the diapositive could then conceivably be (the horizontal radial distance from the photo center) divided by (the printer projection distance) times (the vertical separation of the diapositive from the negative).

This value would be approximately 0.003 inches (76 μm), caused by a separation of 0.013 inches between diapositive and negative at that location. Since this radial horizontal displacement would always be positive, the "X" component would cause a positive vertical displacement in the stereo model of approximately 1.9 feet with 1:6000 scale photography. Using a vertical control point at this location in the stereo model would cause surrounding elevations to appear lower to whatever degree *less* separation is maintained during exposure. It should be noted that the radial horizontal displacement of the image decreases as the radial distance from the photo center decreases, assuming an equal separation between diapositive and negative across the entire image area. Also, we can assume that there is relatively little separation around the extreme edges of the image area where the edges of the mask around the window are applying pressure. Under the vertical control conditions described above, these areas toward the center of the stereo model as well as around the extreme edges of the stereo model (outside the neat model) would appear lower in elevation.

These same general relationships between the elevations of various points within the stereo model can be seen in the actual test data (see Figure 1). However, we did not perform any material tests for the physical relationship of the photographic materials during exposure, and merely suggest them as one possible, logical explanation for the test results. Regardless, we do believe that the results indicate very clearly that the fidelity of the diapositive to it's negative is greatly improved with the use of some form of modified pressure system on the printer.

TEST PROCEDURE

PRODUCTION OF FILM, GRID NEGATIVES

In order to simulate, as nearly as possible, the "normal" *aerial* model relationships and to assure that the same grid intersections were read in all negative and diapositive grid models in the same orientation in the stereo plotting instrument, the *master*, 5-mm interval, ¼-inch glass positive grid plate was annotated prior to printing the *film* grid negatives. Using the "normal" 60 percent end-lap and 30 percent side-lap to determine the "neat model corners," the nearest grid intersections to those positions were determined to be (at contact scale) 90 mm in "X" (bx) and 80 mm in "Y" from the principal point, both plus and minus directions. These four *neat model corners* were subsequently used exclusively to level all negative and diapositive grid models in this test and are indicated on the grid model reports with a *large circle* (see Figure 1). In addition to the "neat model corners," the *principal point* and its *conjugate point* (at 90 mm in "X") were annotated on the master grid plate (indicated on the grid model reports with a cross), and all *intermediate points* to be read in the models were annotated on the master grid plate and indicated on the grid model reports with a *small circle* (extra points read are indicated on the grid model reports with a *dot*).

This annotated *master* grid plate was placed emulsion up on the printer stage plate. For the grid *negatives*, two pieces of Agfa-Gevaert Litex 0710 p film were cut to approximately 36 inches by 15 inches. One piece was placed emulsion down on the master grid plate. A 9.5 by 9.5 by ⅛-inch clear glass pressure plate was centered over the image area. The mask was placed over these materials and the printer hood was lowered and latched and exposure was accomplished. (The printer bag pressure was adjusted prior to this, such that a pull-scale attached to the hood handle indicated the normal 10 pounds of peak pull to latch the hood over this same amount of material on the stage plate.) The film negative was removed from the printer and processed. The other piece of film was exposed and processed in an identical manner. These *film grid negatives* (Polyester base, approximately 0.004 inches thickness) were expected to perform in a comparable manner as a normal section of 0.004-inch aerial film negatives when producing diapositives. In order to further simulate an aerial negative, both film grid negatives were trimmed to 9.5 inches in "*Y*" with the image area centered and left untrimmed in "*X*" at 36 inches in order to lay across the entire stage area of the printer in the same manner as a roll of aerial negatives.

Regardless of the care taken in the production of these film negatives, it was probable that there could even then be some degree of non-similarity between the two film negatives. Hence, the identifier (#1) was etched into the emulsion of one film negative and (#2) etched into the emulsion of the other film negative (correct reading, emulsion up). This procedure established a means by which to distinguish one from the other, to assure the proper orientation of each on the contact printer during diapositive production, to assure proper orientation in the stereo plotter during *negative* model readings (negative #1 on the left and negative #2 on the right, both emulsion up), and likewise to assure the same individual and relative orientation of all *diapositive* grid models during readings in the stereo plotter. Under these conditions, we are no longer concerned with the absolute flatness (or not-flat) characteristics of the *negative* grid model. Consequently, a direct comparison of each *diapositive* grid model to the *negative* grid model can be performed, the difference being only that introduced during the printing and processing of the diapositives.

In addition, film negative #2 was further modified. Using a thin liquid felt tip pen, all of the major grid intersections to be read were made into a small cross (approximately 1 mm in width) by opaqueing a small portion of the grid lines on all four sides of the intersection. This was performed on the base side of the negative. All grid lines on negative #1 were left undisturbed (full lines). In so doing, the plotter operator then has the option of using two different methods for relative orientation and for height determination in the grid models (negative and diapositive). Especially for height determination, he can use not only the "normal" stereo method, but also, as a double-check, he can conveniently (and in the author's opinion, more accurately) determine the absence of "*X*" parallax by observing the two ends of the *cross* relative to the continous grid line of the other image. This was simply an attempt to improve the "repeatability" of multiple readings at any one point, at any one time, in any one model.

Production of Film, Aerial Negatives

The stereo pair of aerial photo negatives used in this test were produced in "normal" fashion. The photography was flown for a mapping project which included the urban area of a small Midwest town with a large number of street intersections. Within the total stereo coverage of this test model, there was a total of 142 reasonably good image points selected for reading, dispersed at fairly consistant intervals (see Figure 4). Of these 142 points, 77 were white-painted manhole covers (the client had requested they be located both horizontally and vertically during stereo compilation). Other *unpainted* manhole covers were also apparent at many other street intersections, which helped to improve the height determination at those locations for the purpose of this test. In approximate values, the photography was flown at 3,000 feet above mean terrain with 60 percent end-lap and 41 percent side-lap (flight line side gain being ½ mile in width), using a Jena 15/23/23 (6 inch focal length) aerial camera and Kodak 2405 film. Again, the point must be stressed that we are not concerned with "absolute" elevation values for the purpose of this test. Whatever inaccuracies exist in the aerial negative relative to true ground datum is of no concern because the aerial negative is simply "assumed" to be, and *established* as, the "absolute" base datum (or starting point) from which all subsequent data is generated for relative comparisons.

Production of Film Diapositives

It would be well to note at this point that it was not planned, at the outset, to perform such an extensive test as is described herein. Prior to this test, we were convinced that a problem existed and that the ideal solution would be to use a ¼-inch *glass* pressure plate for the production of film diapositives. However, for practical reasons, we not only down-graded to a ⅛-inch glass plate, but on down to a ⅛-inch *Plexiglass* plate in order to eliminate the possibility of breakage and to facilitate the mounting of the lighter material directly onto the under-side of the mask. This can be accomplished (even with ¼-inch Plexiglass) with the use of double-back, thin Mylar carpet tape. The pressure plate should be approximately 10 by 10 inches, which will produce a ½-inch overlap around the edges of the physically open-window mask, providing ample surface to be taped.

This "compromised" material selection allowed the flow of diapositive production to continue in approximately the same time frame as previous production (without the use of any pressure plate). Hence, the original "plan" for this test was merely to produce Groups "A" and "B" (which we had hoped would prove our assumptions) and also produce Group "C" simply to show that the heavier (and less practical) ¼-inch Plexiglass plate would probably not improve the results sufficiently to justify it's use. However, after reading the models and accumulating the numbers, the results indicated an approximate 30 percent improvement in the fidelity of the models in Group "C" relative to those in Group "B" (see Table 1). All 30 diapositives for these three Groups were produced on the same day under identical printing and processing conditions, except for the use of a different type of pressure "system" for each Group. Also, it should be noted that the printer bag pressure was adjusted prior to printing such that the pull-scale indicated the same (recommended) 10 pounds for each of the three Groups in order to maintain a "consistant" pressure on the respective materials in each case. All three Groups ("A", "B", and "C") were produced using Kodak 4556, Ortho III, 10 by 10-inch cut film (0.007 inch Estar Base) placed emulsion to emulsion with the film grid negative in the same orientation and position on the printer stage plate. The mask was the last material to be placed over all other materials just prior to the hood being lowered with the 1/16-inch stiffner, air bag, etc. The hood was latched and exposure accomplished. All diapositives were processed in an Agfa-Gevaert processor at the same process speed (3) in the same chemicals and dried at the same temperature (55° centigrade). After processing, each diapositive was immediately labeled with a felt-tip pen in the lower corner outside of the image area to be used. Because the two film *negatives* were previously etched with the identifiers—(#1) and (#2), respectively—these numbers were consequently "photographically" imprinted onto the diapositives, identifying each for proper orientation in the stereo plotter. In addition, each diapositive was labeled with the felt-tip pen in the following manner: By random selection, one each of the (#1) and (#2) diapositives from Group "A" were labeled "A1" to the left of the photographically-imprinted identifier (#1 or #2). Hence, these two diapositives were now identified as A1#1 and A1#2, respectively. This pair of diapositives was later used to produce diapositive stereo model A1, identified as such on all model reports and computed deviation reports. In Table 1, it is found in Group "A," and indicated as MODEL #1. All other diapositives were labeled in like manner for all the remaining grid models in Groups ("A", "B", "C", "D", and "E").

The grid model diapositives for Groups "D" and "E" were produced in an identical manner as those in Groups "A" and "B", respectively, except for the type of diapositive material used (see Table 1). For economic reasons, the Ortho III material was chosen to produce the Groups "A", "B", and "C" because our stock of "normal" black-and-white Aerial Duplicating film was rather low at the time. However, before even reading all of the models in Groups "A", "B", and "C", it was realized that it would be perhaps more meaningful to conduct the test using the most common diapositive material used for stereo plotting. Because there were not yet enough results accumulated from Groups "A", "B", and "C", it was not thought necessary to use the 1/4-inch Plexiglass plate. Hence, there is no Group in this category equivalent to Group "C" (see Table 1).

The *aerial* model diapositives (Groups "F" and "G") were produced in as nearly identical a manner as possible to the *grid* model diapositives except for two factors. The negatives were "normal" *aerial* photos and the diapositive material was a *third type* (Agfa-Gavaert, Aviphot 0.007-inch base). At this point, there were sufficient model readings completed in Group "C" to know that the 1/4-inch Plexiglass Group was definitely necessary and the 1/8-inch Plexiglass could be eliminated from final consideration. Also, due to some very "practical" considerations, it was decided to produce only enough diapositives sufficient for three stereo models in each Group (see Table 1).

Stereo Model Reading (Grid Models)

The same Wild B8S Aviagraph was used for all negative and diapositve (*grid* and *aerial*) model readings. All respective negative and diapositive models were placed into the B8S in the same orientation and read by the same instrument operator. The grid *negatives* were placed into the B8S with the image #1 in the left plate carrier and image #2 in the right and both with the identifier numbers "correct reading." The instrument principal distance was set at 152.00 mm. Because the distance between principal points was predetermined at 90 mm (at contact scale), the plotter base (*bx*) was set at 180 mm for a 2× instrument model scale. For height reading, a 1:10,000 metric glass scale was used as a 1:1,000 metric scale by ignoring the last zero of all numbers. It was then possible to read the grid model elevations direct in μm units. The least division on the glass scale was 0.1 mm (100 μm). Regardless of the ability to determine the "Z" position of a stereo grid intersection in the stereo model, we could only, at best, estimate the "value" of that position to the nearest 10 μm reading on the glass scale. Consequently, all grid model readings were recorded in multiples of 10 μm.

The negative grid model was set using "normal" relative and absolute orientation procedures except that the base setting was left undisturbed at 180 mm for every grid model. For *relative* orientation, the "neat model corners" were used in addition to the two "principal points." For *absolute* orientation (leveling), only the four "neat model corners" were used and there was no discernable "warp" in the negative grid model at these leveling points. The four "neat model corners" were indexed at 1000-μm elevation on the glass scale, and all other points in the model were read and then recorded on a grid model test report. The relative and absolute orien-

TABLE 1. COMPARISON OF DIAPOSITIVE MODEL MAXIMUM VERTICAL DEVIATIONS FROM THEIR RESPECTIVE NEGATIVE MODEL ELEVATIONS FOR ALL 31 DIAPOSITIVE MODELS IN THIS TEST

	Diapositive Grid Models Vertical Deviation from Negative Model (μm at Instrument Model Scale = 2× Contact Scale)										Diapositive Aerial Models Vertical Deviation from Negative Model (Feet at Ground Scale) (Photo Scale: 1″ = 500′)					
Type of Material	KODAK 4556 ORTHO III					KODAK 4421 AERIAL DUP. FILM					AGFA-GAVAERT AVIPHOT					
Date Produced	2-20-82					2-26-82					3-6-82					
			Maximum Deviation					Maximum Deviation					Maximum Deviation			
Type of Pressure Plate Used	Group Letter	Model #	+ Dir.	− Dir.	Total Spread	Group Letter	Model #	+ Dir.	− Dir.	Total Spread	Group Letter	Model #	+ Dir.	− Dir.	Total Spread	
		4	108	210	318		2	98	210	308		1	1.7	4.1	5.8	Worst
		5	137	154	291		3	112	160	272						
None	A	2	97	120	217	D	1	112	137	249	F	3	1.1	2.0	3.1	Representative
		1	113	60	173		4	102	143	245						
		3	97	60	157		5	82	148	230		2	0.9	2.1	3.0	Best
		3	52	50	102		4	52	37	89						Worst
		4	62	26	88		1	52	37	89						
1/8″ Plexiglass	B	2	42	36	78	E	3	42	37	79						Representative
		1	32	40	72		5	42	36	78						
		5	42	24	66		2	32	36	68						Best
1/4″ Plexiglass		1	46	22	68							1	0.5	0.6	1.1	Worst
		5	32	20	52											
	C	3	32	14	46						G	3	0.4	0.6	1.0	Representative
		4	26	20	46											
		2	30	12	42							2	0.3	0.5	0.8	Best

tation and reading and recording of this negative grid model were repeated four additional times. The five readings were then averaged and recorded for each of the 83 points in the model. This "average" *negative* grid model then became the "absolute base datum" to which to compare all *diapositive* grid model elevations and finally compute and record the differences as shown in Figures 1, 2, and 3 and in Table 1, (Groups "A", "B", "C", "D", and "E").

The height reading "accuracy" is difficult to define. An attempt can be made only to define the "repeatability" of the five readings on this *negative* grid model. Even then, the negative grid model was *re-set* for each of the five readings. This procedure produced an "average" of not only the point height determination, but also an average of the relative and absolute orientation solutions for each model setting. The "averages" were not rounded off to the nearest 10 μm (as the actual readings were) and these odd μm units were carried on through the final deviation computations (see Figures 1, 2, and 3). Even if one were to round off all final deviation values to the nearest 10 μm, it would not significantly change the impact of the results as seen in Table 1. In addition to the above factors, the *negative* model was very difficult to read because the B8S has a black floating mark and the negatives were "mostly black". For this reason, the negatives were made as "thin" as possible while still maintaining the grid line definition. In spite of all this, the numbers were sufficient for the gross differences later seen in the *diapositive* grid models relative to this "average" *negative* grid model.

Regarding the actual numbers, the *worst* deviation of any one reading of any one point in any one setting, relative to the *average* for that one point, was 42 μm. There was one at 36 μm, one at 28 μm, four at 26 μm, four at 24 μm, and one at 22 μm. All of the remaining 402 readings of the total 415 (83 points in the model times 5 readings = 415) deviated from the average by less than 20 μm. It can be stated that 96.9 percent of all *negative grid model* height determinations were within less than ± 20-μm deviation from their averages at instrument model scale (this is equivalent to ± 10 μm at contact scale). Also, for those of us who think better in terms of "feet" at a "normal" map scale, this is approximately equivalent to ± 0.2 feet (± 0.1 contour interval) using a 6-inch focal length aerial camera at 3,000 feet A.M.T. for a 1500 "C-factor" (2-foot contour interval). This can also be stated as 1:15,000 of the flight height A.M.T.

It would be well to note at this point that it was chosen to read and record all grid model elevations and deviations in μm units at *instrument model scale* because it is convenient to make a direct comparison to the values of the *aerial* model test results. Because the photo scale of the *aerial* model was 1:6000, the 2× instrument model scale was 1:3000. Therefore, one foot at this model scale equals 101.6 μm. For practical purposes, it can be stated that in Table 1, 100 μm in the grid models is approximately equal to 1 foot in the aerial models (10 μm ≅ 0.1 foot, etc.).

The *diapositive* grid models were set, read, and recorded in an identical manner as the *negative* grid model except that each model was read only once. However, each point was re-read several times in succession and the nearest 10-μm mentally-determined mean was recorded for that point. The *diapositive* grid models were much easier to read (in comparison to the *negative* grid models) and the actual height determination at any one point at any one time in any one model could be repeated to ±10 μm at instrument model scale. However, considering also the possible errors introduced during the relative and absolute orientation of the model, again one could not expect the over-all repeatability to be better than ±20 μm at instrument model scale.

There was a definite residual "Y" parallax and model "warp" in the diapositive models produced

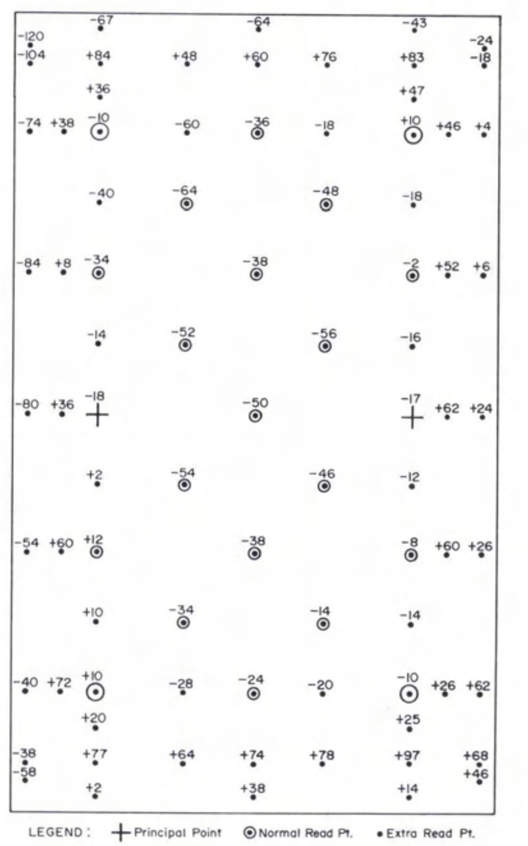

FIG. 1. Representative grid model A2 indicating vertical deviation of diapositive model from negative model using no pressure plate (μm at instrument model scale = 2× contact scale).

without any pressure plate (see Figure 1). The four "neat model corners" had to be meaned to plus and minus 10 μm in three of the Group "A" models and plus and minus 20 μm in the other two models of that Group. In comparison, three of the Group "B" (1/8-inch pressure plate) models had to be meaned to plus and minus 10 μm and the other two read "flat" at the four "neat model corners." All five models in Group "C" (1/4-inch pressure plate) read "flat" at the four "neat model corners" (see Figure 3). There was no "noticeable" residual "Y" parallax in these Group "C" models.

In general terms, these same relationships of presence and absence of model warp and residual parallax were present to approximately the same extent in the models of the "D" and "E" Groups, respectively, as they were in the similar "A" and "B" Groups (see Table 1).

Simply as a side note, an interesting and unexpected phenomenon was discovered after reading the film negative grid model. The elevations indicated a fairly uniform "spherical hump" with +80 μm in the center of the model and −52 μm to −86 μm in the absolute corners of the stereo model (relative to the four index points at the "neat model corners"). You are reminded that these *film* grid negatives were produced using a "rigid" 1/8-inch glass pressure plate. For the sake of curiosity, it was decided to set a model in the B8S using the "original" 1/4-inch glass positive grid plates and make a rough comparison. This model was read twice and the maximum total spread between the two readings at any one point was 20 μm (± 10 μm) at instrument model scale. The average of these two readings also indicated (as did the *film* negative grid model) a fairly uniform "spherical hump" but only to the extent of +35 μm in the center of the model and −30 μm to −50 μm in the absolute corners of the stereo model (relative to the four index points at the "neat model corners"). Note that this "spherical hump" is very dissimilar to the model deformations caused by a lack of uniform pressure during exposure (see Figure 1). In the latter case, there is an obvious "high ridge" running completely around the model

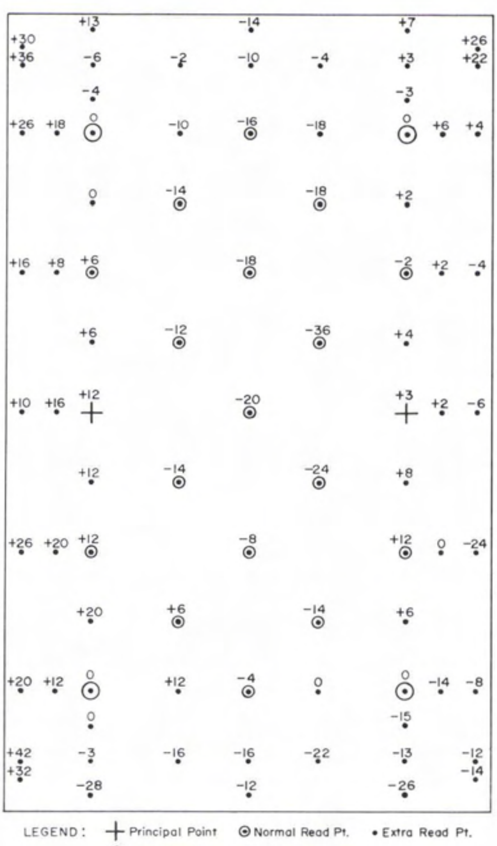

FIG. 2. Representative grid model B2 indicating vertical deviation of diapositive model from negative model using 1/8-inch Plexiglass pressure plate, (μm at instrument model scale = 2 × contact scale).

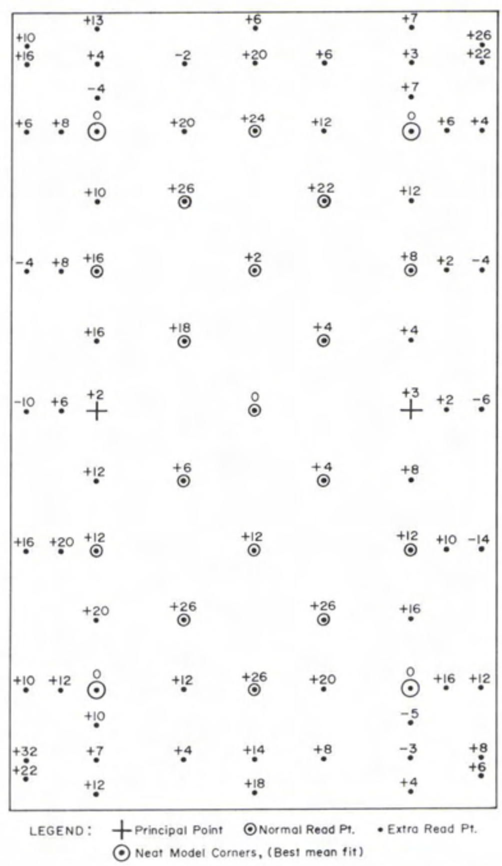

FIG. 3. Representative grid model C3 indicating vertical deviation of diapositive model from negative model using 1/4-inch Plexiglass pressure plate, (μm at instrument model scale = 2 × contact scale).

just slightly outside the "neat-model" perimeter from which the model falls in the negative direction both toward the center and toward the absolute edges.

The "spherical hump" phenomenon was not investigated further due to the lack of necessity relative to this test. Again, as a reminder, the film grid negatives were produced on "thin" (0.004 inch) film (in comparison to the "thicker" (0.007 inch) film used for all of the final diapositives. Considering this fact, it could be speculated that the increased "spherical hump" phenomenon seen in the *film* negative grid model may have been caused by film deformation during or after processing.

For the purpose of this test, however, the "spherical hump" phenomenon can be ignored for the same reason that any other "constant" factor in the procedure can be ignored. Regardless of the "absolute" flatness (or unflatness) of the film negative grid model, it was established as the "absolute" base datum, because all film grid diapositives were produced from this one pair of film grid negatives.

Stereo Model Reading (Aerial Models)

In general, the attempt was made to handle the *aerial* models in a manner as nearly similar to the *grid* models as possible. Because this portion of the test was merely an "after-thought," and due to the obvious dissimilarity of the aerial models relative to the grid models, this section is included primarily as a point of interest intended to show at least a similar "configuration" of the end results (not as a quantitative comparison).

The reasons for the above qualifying statements should be obvious. For the purpose of relative and absolute orientation of the model, the "ground" images of an aerial model are not as fine or consistent as are the "grid line" images of a grid model. Likewise, for all point height determinations, the "ground" images are somewhat less conducive to producing consistancy or "repeatability." Also, when there is any appreciable amount of residual "Y" parallax, it is much more difficult for the instrument operator to separate "X" and "Y" parallax during point height determinations in the aerial models. In a grid model, it is possible to move slightly away from a grid intersection in the "Y" direction and thereby reduce the "impression" of the "Y" parallax. However, in the aerial model, this cannot be done because all images in that general area will contain approximately the same amount of "Y" parallax, and there may also be a greater change in "absolute" model elevation for the same distance moved from the point of interest. Regardless of these facts, the similar "configurations" and "relative" quantitative changes can be seen in Table 1, even considering the limited number of aerial models produced.

The negative aerial model was set in the B8S three consecutive times. As can be seen in Figure 4, there were four horizontal ground control points and six vertical ground control points used for the *first* absolute orientation of the negative model. From this setting, elevations were established on the two points in parentheses near the two *upper* "neat model corners" in order to establish "pseudo" vertical control points for this test, all of which are located approximately in the neat model corner (optimum) locations. The two successive negative models and all six diapositive models were leveled using those four points shown in parentheses. Again, you are reminded that the absolute "ground truth" is not of interest to us for the purpose of this test. It was only approximated for the purpose of a rough comparison to the original map for the sake of curiosity.

At this point it is interesting to note that the actual elevation readings for the negative model and for the Group "G" diapositive models compared quite favorably to the original map elevations. Also,

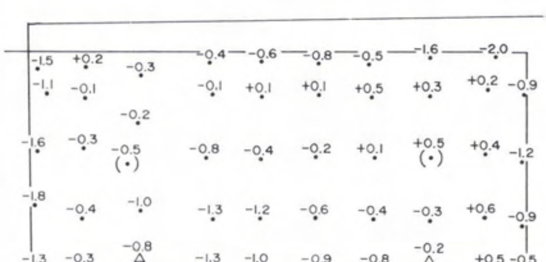

FIG. 4. Representative aerial model F3 indicating vertical deviation of diapositive model from negative model using no pressure plate (feet at ground scale) (photo scale: 1:6000).

the original diapositives (from which the original map was produced) were re-set and again the elevations agreed quite well. These revelations were rather perplexing (because there was no pressure plate used to produce the original diapositives for the mapping project and hence considerable discrepancies were anticipated). However, there existed one major additional variable in this "rough" comparison. These original diapositives were produced on the "contact" printer by exposing *through the base* of the aerial negatives (*not emulsion to emulsion*). At that time, diapositives were produced in a manner to be also compatible with a projection plotter (correct reading, emulsion down in the plate carriers). It could be speculated that, due to the natural curl of the negative and diapositive material being both in the same direction, there was less separation during exposure (compared to the emulsion-to-emulsion diapositives produced without any pressure plate). It is assumed, however, that these "favorable" results are due to merely a random coincidence because we *did* have problems with the other models in that project and, in fact, *re-made* several diapositives during the production of the original map.

Returning again to the "planned" test procedure, the readings from the three negative-model settings were averaged for each of the 142 points in the model. The worst deviation of any one reading of any one point in any one setting, relative to the average for that one point, was three readings at 0.4 foot. There were nine at 0.3 foot and four at 0.2 foot. All of the remaining 410 point readings of the total 426 (142 points in the model times 3 readings = 426) deviated from the average by less than 0.2 foot. It can be stated that 96.2 percent of all negative aerial model height determinations were within less than ± 0.2 foot deviation from their averages at ground scale in "feet" (± 20 μm at instrument model scale, ± 10 μm at contact scale). As in the negative *grid* model average, these numbers for the negative *aerial* model average also include some possible deviations caused by a slightly different relative and absolute orientation of the three negative-model settings.

The six *diapositive* aerial models were set, read, and recorded in an identical manner as the *negative* aerial model except that each model was read only once. However, each point was re-read several times in succession and the nearest 0.1-foot mentally-determined mean was recorded for that point. The repeatability of the *diapositive* aerial model readings is estimated at ± 0.2 foot at ground scale in "feet." As in the grid models, there was a definite residual "*Y*" parallax and model warp in the aerial diapositive models produced without any pressure plate (see Figure 4). The four "psuedo" vertical control points had to be meaned to plus and minus 0.2 foot in one model of Group "F", plus and minus 0.3 foot in one model, and plus and minus 0.5 foot in the remaining model of that Group. In comparison, one of the Group "G" (1/4-inch pressure plate) models had to be meaned to plus and minus 0.2 foot and the other two models in this Group had to be meaned to only plus and minus 0.1 foot at the "psuedo" vertical control points (see Figure 5). There was no "noticeable" residual "*Y*" parallax in these Group "G" models.

As can be seen in Table 1, some of the maximum deviation values for the Group "F" aerial models approach twice the value of the respective Group "D" grid models. It could be speculated that the primary cause for this unexpected discrepency is the previously-mentioned inability of the instrument operator to separate "*X*" and "*Y*" parallax during height determination at these extreme points in the aerial model.

FURTHER DISCUSSION OF THE RESULTS

It is interesting to note that, even in the grid models with extreme deviations (over 300 μm "total

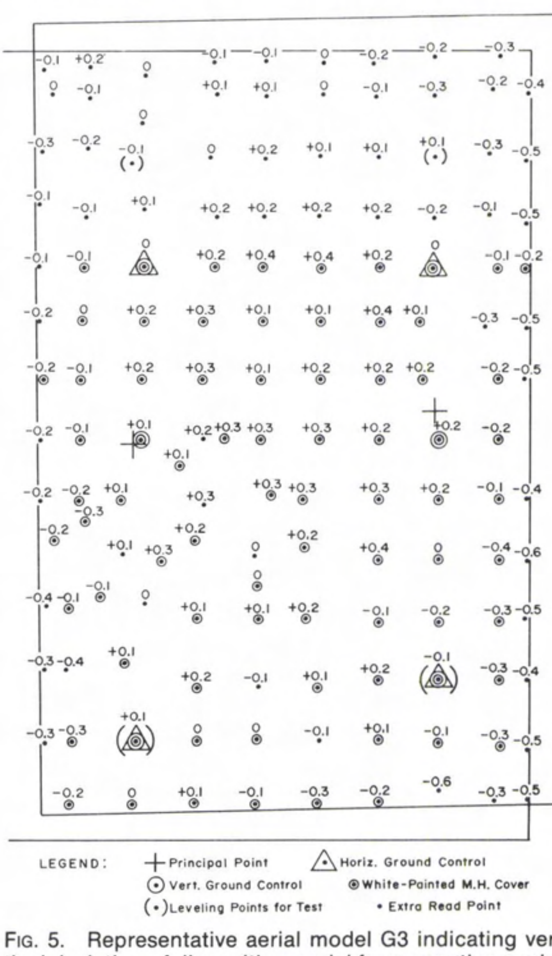

FIG. 5. Representative aerial model G3 indicating vertical deviation of diapositive model from negative model using 1/4-inch Plexiglass pressure plate (feet at ground scale) (photo scale: 1:6000).

spread"), the "neat model corners" leveled to plus and minus 20 μm. In normal practice, this is considered to be a very good vertical control "fit." The *model* would appear to be good.

These models were all "set" using vertical control in "optimum" locations (at "neat model corners"). We are all aware of the fact that it is not always (indeed, seldom) possible to locate the vertical control points (or analytical pass points) precisely at these locations. Consider how the results of model A2 (Figure 1) would appear if, by necessity, the vertical control points were located further out toward the edges, perhaps at the four points with values of +84, +83, +77, and +97. These four points could be meaned to approximately ±10 μm and the model would appear to "fit" the vertical control very well. It is obvious, however, that in this case, the center of the model would now be approximately −130 μm.

Consider another case in which only one vertical control point is located outside the "neat model," perhaps at the point with the value of −120 μm (near the upper left corner). This point and the remaining three "neat model corners" could be leveled to approximately plus and minus 35 μm. Again the "fit" appears to be "acceptible."

Consider the third case in which the four vertical control points were located perhaps at the points with values of −120, +83, +77, and −10. Leveling on the lower-left (+77), lower-right (−10), and upper-right (+83), all indexed to zero, the upper left point (−120) would now be approximately −300 (too much to mean out). This would appear to be a 3-foot vertical ground control "bust" on a 2-foot contour-interval map (1500 C-factor). The suveyor is called and asked to check his field notes. You are informed that all vertical control points were "turned through" and they check okay. Sound familiar?

One could also consider the possible mismatch of the edge between two adjacent flight lines, especially where the models on one line are "offset" in the "X" direction from the models of the other line. This situation can cause very serious problems in "edge match," the degree of which would depend upon the location of the vertical control points of each flight line relative to the respective "neat model corners."

The above (rather extreme) possibilities are mentioned in light of the fact that the results of model A2 (Figure 1) indicate only *slightly over* 1/4 contour interval (1500 C-factor) deviations within the "neat model" (mapping) area when the vertical points are located at *optimum* positions. The point is that a *less optimum* configuration of ground control locations (as in actual practice) can produce far greater deviations *within* the "neat model" (mapping) area than those indicated in any of the Group "A" deviation reports for this test.

BEYOND THIS TEST

The author has, since the completion of this test, had occasion to work with film diapositives produced on a LogE *Mk III* (color) printer and very similar problems were observed. Upon attempting to use a 1/4-inch Plexiglass pressure plate with Kodak 4111 Vericolor film, a new problem was encountered. The pressure plate appeared to cause an exposure imbalance. The color diapositive was quite dense in the center and less dense toward the edges, using "normal" exposure and processing. This same printer produced well balanced color diapositives *without* the 1/4-inch pressure plate and also well balanced black-and-white diapositives *with* the 1/4-inch pressure plate. By the "trial and error" method, it was discovered that a sheet of double-matte Mylar drafting film placed into the printer system between the pressure plate and the 1/16-inch stiffner eliminated the problem (this drafting film was, consequently, taped onto the top side of the mask.

The final combination of solutions for the general problem of "film flattening," to whatever degree it may exist on other printers, could vary considerably. This author had heard of one case in which the printer exposure control was supposedly modified with a time-delay device. This delay between applying pressure to the photographic materials and the initiation of the exposure cycle could, conceivably, allow time for *more* of the air to escape from between the negative and diapositive before exposure commences. However, it does not seem probable that this time delay, *alone*, would be an adequate solution to the problem, in most cases. Perhaps the ideal solution would be to use both a "rigid" (at least "semi-rigid", 1/4-inch Plexiglass) pressure plate *and* a time-delay device.

It is quite possible that the production of *glass* diapositives, for any length of time, could cause the 1/16-inch Plexiglass stiffner to become "permanently" deformed to the extent that it would not flatten completely under the normal pressure from the air-bag. This speculation is made for the following rather limited reasons: (1) Both the Mk II and the Mk III printers were used for many years to produce *glass* diapositives; and (2) as mentioned previously, the mask used on the Mk II for this test had a *physically-open* window, whereas the mask used on the Mk III was a continuous sheet of material containing a *photo-mechanical* window. In this latter case, there is no physical window "cavity" into which the film diapositive can "bubble up." The 1/16-inch stiffner, if so deformed, could allow the diapositive to "bubble up" in a very similar configuration as the physically-open-window mask. Indeed, it appears possible that *both* speculative causes could have contributed to the rather extreme deviations observed in this test on the Mk II.

CONCLUSION

The results of this test, shown in Table 1, indicate an improvement in the fidelity of the stereo film *diapositive* models to their respective stereo film *negative* models when a "semi-rigid" pressure plate is placed directly on top of the photographic materials during exposure of the film diapositives. The test was performed on *one* Log-E Mk II printer with black-and-white film diapositives, *only*. Hence, no generalized conclusion can be drawn for all "contact" printers, under all circumstances in use by the photogrammetric community. However, it can be "concluded" that "perhaps" further (and more scientific) investigation into the herein suggested problem is warranted.

The final emphasis is directed toward the title of this paper and the fact that a serious question is posed; one which only the reader can answer.

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