cally, we might ask whether an approximation or expediency linkage, remote control or some sort of indirect solution could be chosen instead of the orientation system or the space and tie-rod system as described. One reaches the conclusion, however, that the simplest, geometrically correct solution is also the most economical and most reliable. Any deviation from these ideas would lead to complications and sources of error.

In order that the instrument be usable for both focal-lengths mentioned above, it must have exchangeable mechanical adaptors to regulate the focal distance from the base terminals, and the reflectors must be correspondingly adjustable in height.

A plotter complying with the requirements given here has been developed and is in production in Heerbrugg. It is called the *WILD B8 Aviograph* (Figure 8). Even the first work with this instrument showed that all the requirements are fulfilled and that the accuracy obtained in plotting from wide and super wide-angle photographs, complies fully with the standards set. The correct basic principle of the rigid distance between the measuring mark from the space-rod, in combination with well-made mechanical cardans and parallel guides and a close tolerance for the flatness of the granite plate, all produce good relative height accuracy which approaches that of a first-order plotter. Similarly, the positional accuracy in the mechanical model is well within the plotting accuracy, while the mechanical stability of the pantograph is responsible for making full use of this planimetric accuracy in the transfer to the enlarged plotting.

A special pantograph has been developed for the *B8*. It is a linear pantograph supported at one point only on a robust vertical axis, thus reducing inertia to a minimum. Movement of the bearing-mounted pencil carriage is controlled through a gearbox with interchangeable gear ratios and a cable drive. The mapping accuracy is within 0.3 mm. when the plotting carriage is at the end for the pantograph, i.e. at the extreme and least favorable position.

It can be concluded that the *WILD B8 Aviograph* is indeed a desirable plotter which the photogrammetrist has had in mind for simple and inexpensive, but nevertheless reliable and accurate, instruments.

Variations in Aerial Photo Image Recovery Resulting from Differences in Film and Printing Technique[1]

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(Abstract is on next page)

INTRODUCTION

In the aerial photographic industry, electronic printers are supplementing or replacing conventional contact printers for more efficient and automatic production of prints and diapositives. Quality improvement and material savings in certain types of mapping photography have been noted, but

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little information is available on the merits of the two printing methods for the interpretation of forest photography. In this study, three interpreters evaluated the methods in terms of tree crown counts on two types of photography.

Printers

The purpose of any photographic printer is to pass light through the negative and to activate the photo paper emulsion with the reverse of the negative density pattern. To control the tonal pattern in the final print, it is often necessary to vary the exposing light intensity over certain portions of the negative —a process commonly called "dodging."

ABSTRACT: *An evaluation of image quality on infrared and panchromatic photographs printed by electronic and conventional methods was made in terms of the per cent of actual tree crown images observed on four film-filter printing combinations by forest photo interpreters. Counts made on ten forest plots located on each stereo pair of vertical photos were submitted to analysis of variance by split plot design to evaluate the main variables and the interaction between them. No significant difference between printing methods was indicated, but a significant difference at the 1% probability level existed between film-filter combinations. Results of the interpreters' personal evaluations, recorded systematically throughout the test, concurred quite closely with the statistical analysis. These results tend to indicate that if the quality of printing is high, the selection of the film-filter combination has more influence on the interpreters' ability to obtain information from an aerial photograph than does the printing method.*

In the conventional contact printer the source of light is typically a large group of uniformly spaced lights. Manually controlled switches are used to adjust to a certain extent the intensity of the light that will pass through various portions of the negative. Duration of exposure is also manually controlled on most conventional printers.

Electronic printers employ a small moving spot of light produced by a cathode-ray tube (1, 2), and thus are capable of dodging much smaller areas more intensively than conventional printers can. The over-all degree of dodge, known as scan, can be pre-selected (along with exposure time) to produce a print ranging from an exact reversal of the negative with no dodging, to a scan in which existing negative contrast is considerably reduced. In this study, a fairly heavy or "full" scan was employed in order to produce a slightly flat print closely approximating the tone of conventional contact prints.

Study Organization

The study was carried out at the University of Minnesota's Cloquet Forest Research Center located in northeastern Minnesota. The area offered a wide variety of cover types representative of the region, and was also covered by good recent aerial photography of two types: (a) panchromatic minus blue and (b) infrared minus blue. The scale was 1/15,840. Both films had been exposed in the summer along identical flight lines within a period of a few minutes. It was thus possible to evaluate the comparative image quality of prints produced on the standard contact printer and on an electonic printer at full scan, for two commonly used film-filter combinations.

Ten one-half acre plots were established in a variety of forest types as depicted on the photographs. To reduce ground-count errors due to mislocation, the plots were located with reference to some feature easily identified on both the ground and on all four sets of stereo photographs.

From the photo-scale and results of similar studies (3, 4, 5, 7) it was anticipated that crown-count errors would be large and negative. However, two of the three interpreters counted more crowns on one photo plot than were actually on the ground. This necessitated transforming the mean per cent error of tree crown-counts into angle (arcsin transformation of percentage) for analysis of variance by the split-plot design (6).

Two plot diagrams (4) were placed on the photographs and were viewed stereoscopically to guide the interpreters while counting. The diagrams were made up as small segmented circles representing one-half acre at 1/15,840 scale, and mounted on thin glass plates (Figure 1). The orientation of the plates was changed for each count to various azimuths, randomly selected from eight choices ranging clockwise from 270° to 290°.

The interpreters counted trees in the five

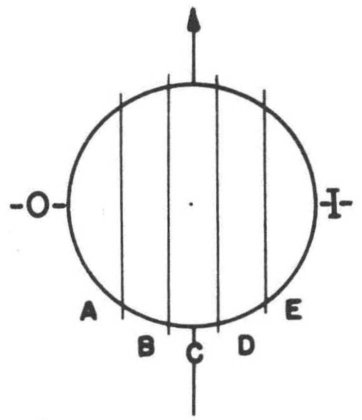

FIG. 1. Diagram of tree count transparency.

segments on the plot diagrams separately and recorded the count for each segment individually on the tally sheet. They were not permitted to total the segment counts for individual plots until all the interpretation was completed.

The second portion of the test was a subjective evaluation of the four types of photography by the interpreters according to the following criteria:

General over-all photo quality.
Preference when counting conifers.
Preference when counting hardwoods.
Relative lack of eye strain.

After the interpretation was completed, the plots were visited to determine the exact number of vertically exposed crowns, species composition, and stand-size classes. This inspection showed that selection of plots in the office had provided a good cross-section of forests in northeast Minnesota. Table I briefly describes the sample plots.

RESULTS OF INTERPRETATION

Differences in photo and field measurements were subjected to analysis of variance comparing interpreters, plots, printing, and film-filter, as well as the interaction between plots, printing, and film-filter. Results of the analysis are given in Table II.

Variation due to method of printing was not significant (Figure 2), and the small difference in mean error between the two printing methods would have no practical effect.

A highly significant difference, independent of the printing method, existed between the two film-filter combinations. The panchromatic photography appeared to be superior or equal to the infrared for all plots except one. However, the difference between the two types of photography was quite variable on each plot (Figure 3). With this small sample, species or size-class combinations did not produce a discernible trend in count success.

The difference between the film-filter combinations is important not only statistically but also for practical purposes. If total mean recovery (in terms of crown count) on panchromatic film were taken as 100 per cent, total mean recovery by the infrared photography would be about 73 per cent.

The over-counts on panchromatic photography by two interpreters resulted in the indication that infrared photography was

TABLE I

DESCRIPTION OF SAMPLE PLOTS AND PROPORTIONS OF GROUND TREE COUNT RECOVERED FROM ALL PHOTOS

Plot number	*Forest type and stand density*	*Vertically exposed crowns*	*Tree crown recovery*		
			Interpreter A	*Interpreter B*	*Interpreter C*
		Number		*Per Cent*	
1.	Pine poles, well stocked	295	40	33	46
2.	Upland hardwood poles, well stocked	311	36	36	48
3.	Spruce-fir poles, medium stocked	239	36	38	50
4.	Pine sawtimber, medium stocked	53	85	100	148
5.	Pine poles, well stocked	345	40	34	48
6.	Lowland hardwood poles, medium stocked	174	54	53	69
7.	Pine seedling-sapling, medium stocked	249	20	16	29
8.	Upland hardwood poles, well stocked	334	33	31	42
9.	Spruce poles, well stocked	265	33	42	56
10.	Spruce poles, well stocked	331	33	35	43

TABLE II

ANALYSIS OF VARIANCE OF MEAN ERRORS OF THE CROWN COUNT ON FOUR TYPES OF STEREO PHOTOGRAPHY

Source of variation	*DF*	*Mean squares*
Interpreters	2	314.31
Plots	9	903.27**
Error (a)	18	121.60
Total (a)	29	
Printing	1	.56
Plots×printing	9	12.99
Error (b)	20	9.72
Total (b)	59	
Film-filter	1	1,769.29**
Plots×film-filter	9	161.89**
Printing×film-filter	1	1.27
Plots×printing×film-filter	9	28.71
Error (c)	40	26.52
Total (c)	119	

** Significant at the 1 per cent level.

superior on plot 4. The over-counts may be attributed to the generally higher image quality of the panchromatic photography used in the test. On the panchromatic prints interpreters may have divided the large sawtimber crowns into several trees, or considered protruding branches within the crown canopy as individual trees. On a percentage basis the over-counts were particularly noticeable because the ground count on plot 4 was very low.

INTERPRETER EVALUATION TEST

The interpreters' evaluation of the prints concurred with the objective portion of the test. The interpreters unanimously selected the panchromatic photography for all the criteria considered. When broken down by printing methods within the two groups, however, opinion was divided. Two interpreters selected standard panchromatic prints as the best while the other felt that electronic panchromatic prints were superior to all others. All three interpreters preferred standard panchromatic prints for counting crowns of both hardwoods and conifers.

With infrared photography interpreter opinion also varied. The men preferred electronic prints for counting conifer stands and conventional prints when counting hardwood stands. The electronic prints had lighter and sharper images in the conifer stands, but showed a loss of detail through lack of a sharp edge gradient on the hardwood crowns. When eye strain and fatigue were considered, standard panchromatic prints were the unanimous choice, while the other three prints were acceptable with about equal preference levels.

DISCUSSION

Three principal factors account in varying degrees for the nonsignificant difference between the two printing methods.

Automatic printers may not sufficiently improve print contrast to bring out the steep edge gradient on fine detail necessary to make small crowns stand out from uniform background tones. The extra compression of contrast from the extremes of black-and-white toward an equilibrium point gives a flatter and grayer over-all appearance to the automatic print. Contrast compression may cause small crowns to merge with the background tones, thus nullifying possible improvement in gross detail.

The forest types and locations in the test may not have been so responsive to manipulations of printing as might other combinations of species, size class, density, topography, and aspect.

Considerable differences in print quality are often noted when inspecting aerial photographs, and can often be traced to the operator of a conventional printer, as electronic printers are very consistent. The prints for this project were all of uniformly high quality and thus electronic prints did not exhibit the advantages they might when operators of conventional printers turn out poor work.

Information observed and interpreted as

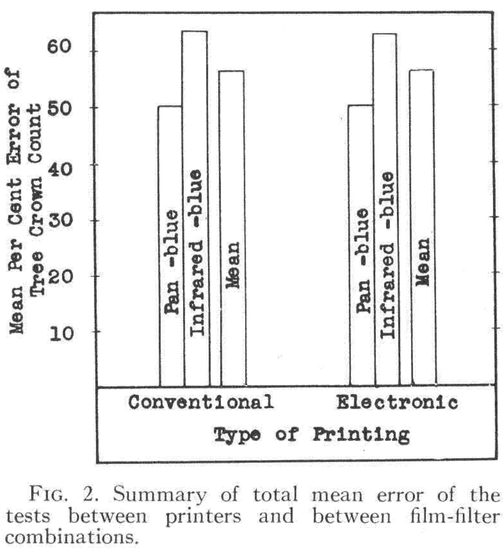

FIG. 2. Summary of total mean error of the tests between printers and between film-filter combinations.

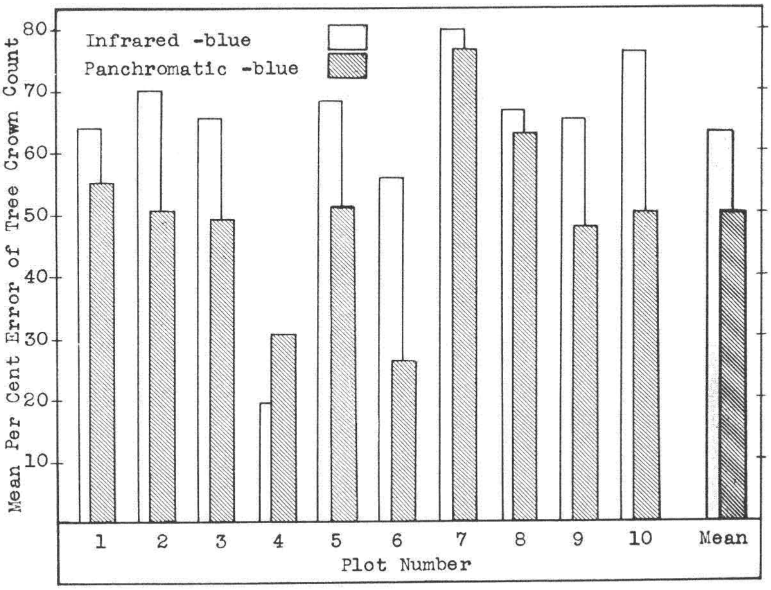

FIG. 3. Mean error of crown count recovery between panchromatic and infrared photography, by individual plots.

individual tree crowns was apparently not influenced by the transfer method on any forest type in the test. The only noticeable difference between printing methods was the subjective evaluation by the interpreters.

CONCLUSIONS

In a study of medium-scale aerial photography of forest stands in northern Minnesota, little difference was found between full-scan electronic prints and conventional contact prints.

A highly significant difference in tree crown image recovery was found between the panchromatic and infrared photography used in the test. The difference was independent of the printing method and large enough to be of practical importance.

The photo interpreters showed a definite personal preference for the panchromatic photography and a general preference for the standard method of printing.

A possible advantage of electronic prints where cloud or topographic shadow is encountered was not investigated, nor were the effects of lesser degrees of scan upon image quality determined.

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