*Recent Developments in Aerial Film**

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ABSTRACT: *Samples of aerial film consisting of an experimental emulsion coated on the much discussed Cronar base were furnished to the U. S. Geological Survey by the DuPont Company. This paper describes the procedures used by the Geological Survey in testing this material. The dimensional stability of this film base (both over all and differential) was checked in the ambient temperature and humidity of the four Survey photogrammetric photographic laboratories. Diapositives were prepared and used in experimental bridging tests. These tests, though limited, prove the Cronar to be a product which will undoubtedly improve the accuracy of the photogrammetric mapping system.*

INTRODUCTION

IN THE past several years, great strides have been made in the improvement of the materials and equipment which are used in the production of maps by photogrammetric means. As one component of the mapping system is improved, it is possible to isolate and sometimes eliminate errors caused by the unimproved components. In this paper, no attempt will be made to enumerate or discuss the myriad of factors which influence the final accuracy of the photogrammetrically produced map; instead, the discussion will be confined to that extremely important component of the mapping system—the aerial film. In particular, the paper will deal with recent Geological Survey experiments with a new film base.

For the past several years most of the mapping photography used in this country has been taken with a film support designated as Topographic base. A complete description of this film may be found in an excellent article by Dr. Calhoun which appeared in PHOTOGRAMMETRIC ENGINEERING in 1947.[1] In the following discussion of film-base materials, the Topographic base will be used as the standard for comparison. The quality of the recorded image on the film and the reproduction therefrom are also important and will be briefly discussed.

[1] Calhoun, J. M., "The Physical Properties and Dimensional Stability of Safety Aerographic Film," PHOTOGRAMMETRIC ENGINEERING, Vol. XIII, No. 2, (June, 1947).

THE PROBLEM OF STABILITY

The film base and the image captured by the emulsion constitute the materials from which almost all map information for depicting natural features is derived. The basic requirement for this film-emulsion combination is that it record all images captured by the lens of the camera, in complete detail and in their true relative positions. With present-day lenses the rays forming the images reach the emulsion with a small amount of distortion; that is, lateral displacement from their actual relative positions in nature. When the film is used in the mapping process, either for direct measurements or for the production of prints or diapositive plates from which measurements are to be made, the accuracy of the measurements is a function of the ability of the film base to maintain the images in their correct relative positions. Another way to state this is that the film must have dimensional stability; it must not be affected by temperature, humidity or the necessary handling during processing.

Many of the woes and ills affecting the photogrammetric process are blamed, with some justification, on the emulsion-film combination; there is almost universal opinion that the presently available materials do not have the degree of stability that is necessary for the best results. The random errors and distortions which occur in present-day film bases, and which often go undetected, can defeat the most careful countermeasures to compensate other errors, such as lens distor-

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tion, which affect the accuracy of the final map. Needless to say, much research has been conducted in quest of better film base materials and emulsions, and the continuing demand for such improvements has spurred the development of materials which now show great promise. During the past year, a film base material which exhibits excellent properties of dimensional stability and photographic emulsions which render greatly improved photographic imagery have been produced and are now commercially available. For example, the Eastman Aerographic Plus X type emulsion has excellent photographic qualities.

The New Product

The encouraging new development which has prompted this discussion is an emulsion-coated base material labeled "*Cronar*" by its manufacturer, the E. I. duPont de Nemours Company. The base is a polyester material which has had wide application in many fields because of its inherent toughness; it has been used extensively in lithography, and as a base for drafting of various kinds, where dimensional stability is required. All indications are that here is a base material which will satisfy to a great extent the requirements for use in the aerial photographic mapping process. Although this fact has been generally recognized for some time, samples in the form of aerial roll film have only recently become available.

In 1959, the DuPont Company furnished two rolls of this film to the Geological Survey for testing. Steps were taken immediately to institute a testing procedure to determine the applicability and adaptability of Cronar to Geological Survey photogrammetric mapping operations.

Test Procedure

The test procedure was composed of several parts:

1. Produce negatives from both Cronar and conventional film in an actual flight test.
2. Measure selected distances on these negatives under various conditions of temperature and humidity representing the range of working conditions.
3. Using the regular Geological Survey procedure, measure negatives before each use (using the fiducial marks imprinted by the camera); this yields data for the computation of the calibrated focal lengths required to give optimum results when printing diapositives. (This procedure is essential when printing diapositive plates to be used in the convergent low-oblique mapping system.)
4. Using the recorded data, prepare diapositive plates for use in ER-55 projectors.
5. Perform both horizontal and vertical bridging.

An additional test was to determine if the images which are viewed in the models showed a significant improvement as a result of the new photographic emulsions described above.

Flight Test Over Controlled Area

A contract was negotiated with a commercial mapping company for the aerial testing of the film. This testing required a plane equipped with two cameras of equal quality and characteristics synchronized to make simultaneous exposures. One camera was loaded with the conventional Topographic base film and the other with the Cronar base film.

An area approximately 6 miles long, located near Goleta, California, was selected as the test terrain. Ten horizontal control points lying within the test area were marked on the ground with white circles approximately 3 feet in diameter, and 16 well-distributed points of known elevation were located on the photographs, to permit absolute orientation of the test strips. At one end of the area, in the city of Santa Barbara, a school playground with tennis courts and other circular and square game layouts provided excellent resolution test patterns. The lines in the figures were white paint of various widths, ranging from 3 to 10 inches. The aircraft made five passes over the area, at an altitude of 5,500 feet above ground, shooting a total of seven exposures with both cameras in each pass. The Base/Height ratio for successive exposures was approximately 0.63. Prints from the two simultaneously exposed sets of negatives were properly annotated with pertinent information concerning the horizontal and vertical control.

Location of Tests

The Topographic Division of the Geological Survey has four Area offices where stereophotogrammetric mapping is conducted —Arlington, Virginia; Rolla, Missouri; Denver, Colorado; and Menlo Park, California. The two sets of negatives and prints along with the control plots were sent to each of these offices for independent measurements and bridging tests. Since some of the offices had encountered more problems than others with respect to dimensional stability in the presently used film, each was instructed to make the measurements under the same ambient temperature and humidity conditions as is used in the normal mapping procedures.

Tests for Dimensional Stability

Before measurement, the film was stored under normal conditions and given the same treatment as the film previously forwarded for mapping use. After at least a week of storage, the film was measured under carefully recorded humidity and temperature conditions. Three of the Areas used a glass scale having a least reading of 0.1 mm. under a 40× shop microscope having a graticule of 0.01 mm. The temperatures ranged from 60 to 80 degrees F. and the relative humidities ranged from 21% to 65%. Before each measurement under a different condition of temperature and humidity, the film was allowed to season for several hours.

A somewhat crude but interesting experiment was also conducted in the Washington office. Pieces of the two films were measured at about 65° and 50% relative humidity, the ambient temperature and humidity of the office, then placed in a film can containing a soaked sponge, and allowed to remain there for 16 hours. The film was then measured and placed in the can for another 31 hours making a total time of 47 hours. By this time the film was obviously saturated. Measurements were then made with the film in this condition.

The dimensional change in film has been attributed to three factors (a) the absorption of moisture by the film base, (b) the variation in temperature, and (c) the pull of the emulsion on the base after having been affected by both the absorbed moisture and temperature. An explanation of these phenomena will be left to the manufacturers. The results of our measurements closely paralleled the figures for coefficients of humidity and expansion published by each manufacturer. At the same time, it must be admitted that the methods of control of humidity and temperature were crude compared to the precise methods used by the scientists of the companies who publish the figures.

Results of Tests for Dimensional Stability

Now there can be noted the results of the measurements and their application to the mapping system, based on a composite of the findings of all four Area offices. The total expansion of the Cronar base in line of flight, under relatively constant temperatures and a relative humidity increase of 38% was 0.06%, and that of the Topographic base was 0.25%. In the direction transverse to the line of flight, the Cronar also expanded 0.06% and the Topographic base expanded 0.25%. The Topographic base has a net expansion of more than four times that of the Cronar in each direction.

The most significant finding, and the one of greatest potential to the improvement of the mapping system, is the relatively small differential shrinkage of the Cronar film base. Again we quote an average of the hundreds of measurements made during the tests: where the differential shrinkage for Topographic base film varies from 0.05 to 0.10 mm., the differential in the Cronar varies from 0.00 to 0.02 mm. *It can be deduced that the Cronar has approximately one-fifth the differential shrinkage of the Topographic base film.*

Space will not permit a full discussion of the effect of the various distance or dimensional changes of the film on the final model or the resultant errors. Many papers have been published containing formulas which can be used for exact computations of this kind. It should be kept in mind, however, that uncompensated lens distortion and any distortion in the projectors or viewing system can also contribute errors.

Stereoplotting Tests

In the instrumental phase of the tests, the results of the horizontal bridge of the six models did not show a really significant variation. The Cronar-bridged points fell within 5 feet of the plotted positions; the bridged points with the Topographic base showed a difference on the order of 10 feet. Trials with a greater number of models using a wider range of flight heights are indicated.

The vertical solution arrived at, with the same diapositives as were used in the horizontal solution, was more accurate with Cronar film. The established elevations using diapositives made from Cronar film showed an average deviation from true elevation of approximately 2.2 feet with a maximum deviation of 6 feet. The established elevations using the Topographic base diapositives showed an average deviation of 3.7 feet with a maximum deviation of 9 feet. A test made with the Wild A-8 showed a mean square error of 1.97 feet for the Topographic base and 1.47 for the Cronar. One of the Area offices, using the ER-55 projector reported a mean square error of 2.36 feet for the Cronar and 3.63 feet for the Topographic base.

As might be expected, the results of the tests in the various offices did not completely agree. Also, there was some variation in the manner of reporting and presentation.

Resolution of Stereo Models

One interesting development was that some of the fine detail on the Topographic base, and the even finer detail on the Cronar, did not print on the diapositives and consequently was lost in the model. Here again, there is resurrected the question of whether the photography or the instrumentation is at fault when fine detail is lost in the model. The advent and continuing use of the automatic dodging techniques may solve part of the problem of lost imagery. The printing of diapositives through the film base support may also be a contributory factor.

Conclusions

The conclusions of all four Area offices were in remarkably close agreement. Since all tests were conducted under actual working conditions, random and systematic errors caused by equipment, personal error, and misidentification of points have contributed to the variations.

The author has found it impossible to state the conclusions better than one Area office did, in reporting their results. "The following conclusions mark the Cronar base film as definitely superior to the Topographic base film, and they enumerate the operational benefits that would result from its adoption:

"1. Cronar film has approximately one-fifth the differential distortion of the Topographic base film. This characteristic would strengthen both analytical and instrumental aerotriangulation. Convergent oblique models are especially sensitive to nonhomogeneity of the film base.

"2. Cronar film base has a humidity coefficient of linear expansion approximately one-fourth that of the Topographic base. Its use would eliminate the need for special air-conditioning systems and film seasoning equipment in the photo laboratory.

"3. The stability of the Cronar film was further evidenced by its ability to recover after extreme variations in temperature and relative humidity. The Topographic base film, however, developed a permanent curl after being subjected to extreme conditions. Cronar, therefore, is less susceptible to permanent deformation should it be abused in processing.

"4. The chemical stability of polyester film is well known. Cronar, therefore, would be inert to organic solvents such as acetone which have been known to deform the base of Topographic film."

"5. Based on visual inspection of fine ground patterns, both the resolution and acutance of the Cronar emulsion are superior to the emulsion of the Topographic base."

*Aerial Photographic Investigation of Leaching and Sapping as an Erosion Process**

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STANDARDS of map accuracy stipulate that ninety per cent of contours are to be within one-half contour-interval of the ground elevations through which they pass. Although contour accuracy compared with terrain elevation is governed by this consideration, there is another factor in topographic accuracy which cannot be so simply stated and is dependent upon the stereo-topographer to a larger extent than the instrumental accuracy of his readings. A map may comply with topographic standards while the slope portrayal may be in error by a complete contour interval in the space of three contours. With an interval of 10 units a correct slope of 20 may be shown as either 10 or 30. Not only is the amount of error in excess of the inferred accuracy, but the slope characteristic may be destroyed.

Weathered slope characteristic is a function

* The opinions or assertions contained herein are not to be construed as being officially endorsed by the U. S. Navy Hydrographic Office or the Navy Department.