*Physical Properties of Estar Polyester Base Aerial Films for Topographic Mapping**

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ABSTRACT: *Three new aerial camera films for topographic mapping—Kodak Panatomic-X, Plus-X and Tri-X Aerographic Films—are now made on 0.004-inch thick Estar polyester base. A gelatin backing provides static protection and greatly reduces curl. Both emulsion and backing are hardened for elevated temperature processing. The thinner base permits more exposures for a given roll diameter and the thinner emulsion permits more rapid drying after processing, compared with present acetate topographic films. Estar base provides superior tensile strength, stiffness, and tear strength. Humidity and thermal coefficients of linear expansion are only about one-third that of acetate film. Limited tests using optical interference patterns have shown less dimensional distortion in Estar film than in acetate topographic film.*

"ESTAR"[1] base is made from polyethylene terephthalate, a polyester which was discovered by Whinfield and Dickson (1) in England before World War II. It was first used commercially as a textile fiber and later as a plastic sheeting. For many years there has been speculation and hope that it would make an ideal base for topographic aerial films. This interest has been due to the superior dimensional stability and other physical properties that can be obtained with film base made from this polymer (2).

The characteristics of an experimental litho film coated on pilot plant samples of polyester base were described at a meeting of the American Society of Photogrammetry by J. M. Centa (3) in 1955. At the 1960 Annual Meeting, W. E. Harman, Jr. (4), described some preliminary field tests with a polyester base aerial film, which demonstrated definite advantages over acetate film, in the accuracy obtainable in topographic mapping.

A new family of aerial negative films is now available on 0.004-inch thick Estar base:

- SO-136 Kodak Panatomic-X Aerographic Film (Estar Base)
- SO-135 Kodak Plus-X Aerographic Film (Estar Base)
- SO-138 Kodak Tri-X Aerographic Film (Estar Base)

[1] "Estar" is a registered Trade Mark of the Eastman Kodak Company.

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These emulsions cover a wide speed range and all are hardened for elevated temperature processing. The Panatomic-X Aerographic emulsion is entirely new. The Plus-X and Tri-X Aerographic emulsions are improved versions of emulsions which have been used before on acetate base (5).

Each of the new Aerographic films on Estar base has a hardened gelatin backing which provides static protection and greatly reduces curl, a troublesome characteristic of aerial films in the past. The gelatin backing

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

TABLE I

THICKNESS OF AEROGRAPHIC FILM LAYERS

Film	*Base*	*Type No.*	*Thickness, mils*			
			Emulsion	*Gel Backing*	*Base*	*Total*
Kodak Panatomic-X Aerographic Film	Estar	SO-136	0.21	0.18	4.0	4.4
Kodak Plus-X Aerographic Film	Estar	SO-135	0.31	0.24	4.0	4.6
Kodak Tri-X Aerographic Film	Estar	SO-138	0.51	0.37	4.0	4.9
Kodak Plus-X Aerographic Film	CAB	5401	0.49	none	5.2	5.7
Kodak Super-XX Aerographic Film	CAB	5425	0.76	none	5.2	6.0

Note: The emulsion and backing thicknesses are typical measurements; the base thickness is nominal. CAB = cellulose acetate butyrate.

has a matte surface which minimizes contact with the emulsion when wound in rolls. The backing on the Plus-X and Tri-X films is clear, but the backing on the Panatomic-X film contains an antihalation dye needed for photographic purposes. This dye bleaches during processing.

Estar base is manufactured by a quite different process than is cellulose acetate base. It is cast from the molten polymer and contains no solvents or plasticizer, which might slowly diffuse away and cause shrinkage with age.

PHYSICAL PROPERTIES

The thickness of the various layers of each of the new films is given in Table I, compared with the present Type 5401 Plus-X, and Type 5425 Super-XX Aerographic films on cellulose acetate butyrate base. Estar base for topographic mapping is 0.004 inch thick, which permits approximately one-third more film exposures for the same diameter roll. (Estar base 0.0025 inch thick has been made for aerial reconnaissance films on special order, but is not recommended for ordinary topographic mapping.) The new emulsions are also significantly thinner than formerly, which permits better definition and more rapid drying after processing.

Estar base is transparent, colorless and essentially free of imperfections. Its physical properties are summarized in Table II. The two most outstanding characteristics of Estar base for an aerial film are its greatly superior strength properties and its superior dimensional stability, compared to acetate base. The high tensile strength (Figure 1)

TABLE II

TYPICAL PHYSICAL PROPERTIES OF AEROGRAPHIC FILM BASES[a]

Property	*Estar Base*	*Cellulose Acetate Butyrate Base*	*Test Method*
Nominal thickness, mils	4.0	5.2	
Specific gravity, gms./cc	1.39	1.26	
Refractive index, N_D	1.65[b]	1.48	
Water absorption, %	0.5	4.5	ASTM D570-57T
Water swell from 15% RH, %	0.08	0.85	
Yield strength, psi	14,000	9,500	ASTM D882-56T
Tensile strength, psi	28,000	10,500	ASTM D882-56T
Elongation at break, %	110	50	ASTM D882-56T
Modulus of elasticity in tension, psi	650,000	400,000	ASTM D882-56T
Plastic flow, %	0.01	0.25	[c]
MIT double folds, No.	>10,000	35	ASTM D643-43 (Method B)
Tear propagation strength, gms.	160	40	ASTM D689-44
Tensile heat distortion temperature, F.	325	275	ASTM D1637-59T

[a] Tests made at 70F°.-50% RH, except where indicated otherwise.
[b] Average refractive index in plane of sheet; index in thickness direction is 1.50.
[c] Four hours loaded, 20 lbs/inch width; four hours unloaded.

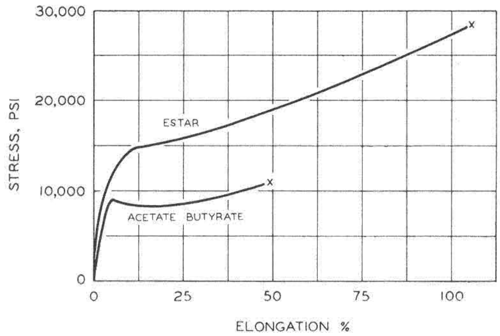

FIG. 1. Stress-strain curves for Kodak Aerographic Film base at 70°F.—50% RH. Instron tensile machine at 50% elongation per minute.

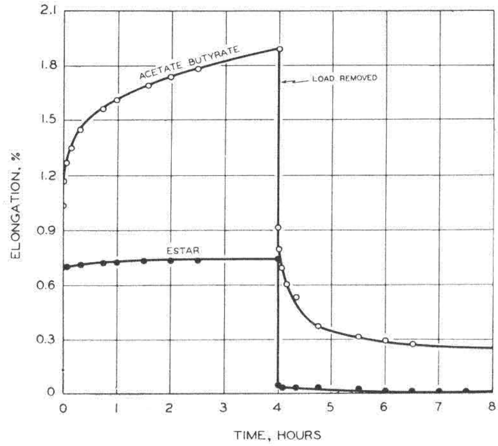

FIG. 2. Creep and recovery curves for Kodak Aerographic Film base at 70°F.—50% RH. Load, 20 lbs./inch width.

and modulus of elasticity (stiffness) of this base enable it to be used in a lower thickness. The lower plastic flow of Estar base (Figure 2) means that it is much more resistant to deformations of all kinds than is acetate butyrate base. Still more important from a practical standpoint is the exceptional tear resistance of Estar base. It is virtually impossible to initiate a tear unless the film is first nicked or cut. Even when a tear is started, it requires about four times the force to continue the tear as does acetate film. This means that there is much less chance of film tearing in cameras, processing machines or other handling operations.

The possibility of brittleness is important with aerial films, which are often used at low temperatures or under dry conditions. Laboratory brittleness tests made by pulling a loop of film rapidly through a wedge (6) at 15% R.H. and measuring the width of the wedge at the point of failure are reported in Table III. (The larger the wedge value, the

TABLE III

TYPICAL PHYSICAL PROPERTIES OF KODAK AEROGRAPHIC FILMS

Properties[a]	*Film*	*Panatomic-X*	*Plus-X*	*Tri-X*	*Plus-X*	*Super-XX*
	Base[b]	*Estar*	*Estar*	*Estar*	*CAB*	*CAB*
	Type No.	*SO-136*	*SO-135*	*SO-138*	*5401*	*5425*
Wedge brittleness[c] at 15% R.H.		no breaks	no breaks	nobreaks	0.16	0.10
Film break, inch						
Emulsion crack, inch		0.17	0.25	0.27	0.22	<0.10
Backing crack, inch		0.18	0.11	0.12	—	—
Film curl,[d] 100/R inch^{-1}						
20% RH		+7	+12	+17	+140	+250
50% RH		−1	−2	+1	+ 85	+110
70% RH		−4	−7	−7	+ 67	+ 77
Water absorption after processing						
Weight of water, % of dry film		19.	23.	44.	18.	48.
Weight of water, lb./sq. ft. of dry film		0.006	0.0085	0.017	0.007	0.020

[a] All tests made at 70°F.
[b] CAB = cellulose acetate butyrate.
[c] Unprocessed film tested by American Standard Methods for Determining the Brittleness of Photographic Film, PH1.31-1958 (Method B).
[d] Processed film tested by American Standard Methods for Determining the Curl of Photographic Film, PH1.29-1958 (Method A).

more brittle is the film.) In this test none of the Estar films break, whereas the acetate films do. However, very fine cracks can occur in the emulsion or gelatin backing if the film is bent sharply, as in the wedge test, under very cold or very dry conditions. These fine emulsion cracks sometimes heal in processing and sometimes are visible as a density difference. This should not happen in a well-designed camera, where rollers in the film path are not too small in diameter. The important fact is that Estar films retain a high degree of flexibility at all relative humidities and at temperatures down to at least −60°F.

The presence of a gelatin backing is a relatively new feature for aerial film. It is used to provide static protection and reduce curl. The flatness of Estar films should be especially attractive to the user, because curl has long been troublesome in handling processed aerial negatives. The improvement in curl is indicated by the data shown for several relative humidities in Table III and Figure 3. The curl tests were made by determining the radius of curvature of a film sample approximately 3 inches square and expressing in units of 100 divided by the radius in inches. On this scale a curl value of 100 corresponds to a cylinder of 2 inches diameter, and a curl value of 200 corresponds to a cylinder of 1 inch diameter, and so forth. A positive value means curl towards and a negative value means curl away from the the emulsion side.

Figure 4 illustrates the advantage of the

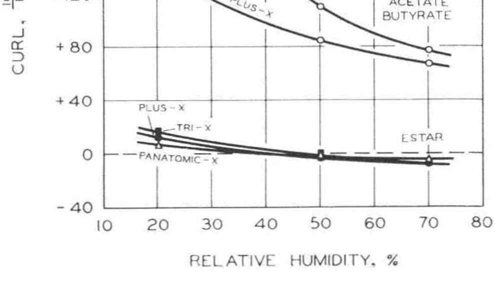

FIG. 3. Curl of processed Kodak Aerographic Films versus relative humidity at 70°F. (R= radius of curvature)

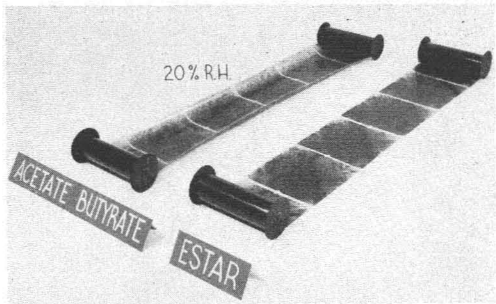

FIG. 4. Illustration showing flatness of processed Kodak Plus-X Aerographic Film (Estar Base) compared with Kodak Super-XX Aerographic Film (acetate butyrate base) at 70°F.−20% RH.

Estar film in flatness under practical conditions. One has to feel and handle both types of film to appreciate the difference. This improvement is due to the gelatin backing, not the base. Of course, any film stored in roll form for a period of time will take on a little roll curl due to plastic flow. This effect is inversely proportional to the diameter of the roll and increases with time and temperature, but is normally small compared to the curl of unbacked film.

A gelatin backing, even though it is well-hardened, does require a few precautions. The unprocessed film is a little more susceptible to keeping troubles, because of the emulsion-gelatin contact in the roll. As already mentioned, this is minimized by the matte-surface of the backing. Storage at 60°F. or lower is recommended for periods up to six months, and 50°F. or lower for periods of a year or longer. Temperatures over 80°F. should be avoided before use. These conditions are the same as those recommended for acetate film; it is simply more important that high temperatures be avoided with gelatin-backed films.

Estar Aerographic films have been processed satisfactorily in both rewind tank equipment and in continuous machines. Obviously, both sides of a gelatin-backed film must be dried after processing. The forced-air mechanical-roll film-dryer commonly used for aerial film is designed to blow air at only the emulsion side. It must be run somewhat slower to allow the backing on Estar films to dry. However, a simple modification with enclosure or baffles, which directs some air at the back of the film, permits normal operating speeds. With a suitably designed dryer, Estar Aerographic films dry more rapidly than acetate films, because the emulsions are thinner and the base absorbs so little water that its

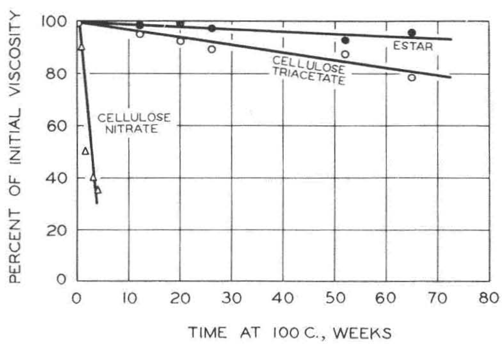

FIG. 5. Effect of heating processed Kodak aerial film at 100°C. on viscosity retention of base. Data for cellulose nitrate from Fordyce (7).

removal does not add to the drying load. For example, Plus-X Aerographic Film on Estar base dries in about one-third of the time required for Super-XX on acetate butyrate base. Comparative data on the water content of these films before drying are listed in Table III.

Processed gelatin-backed aerial film must also be stored with proper regard for humidity and temperature. The film should have an equivalent relative humidity of 40–50% when wound and should be stored at the same condition, at not over 80°F. (These are the same conditions recommended for conventional aerial film.) If the gelatin-backed film reaches an equivalent relative humidity of 70%, contact marks (ferrotyping) may occur and at 90% there may be actual sticking between laps. Of course, such severe humidities are dangerous to any film because of moisture and fungus attack.

Estar base is chemically very stable. It is insoluble in all common solvents, although it can be degraded by strong acids and strong alkalis. Polyester base has not been in existence as long as cellulose acetate base, so that less is known about its permanence. Accelerated aging tests have been run on coated and processed films under a variety of conditions, and all of these have shown Estar base to be chemically as stable or more stable than standard acetate base. One such accelerated test is illustrated in Figure 5, which shows the retention of intrinsic viscosity of the base for over a year at 100°C. Intrinsic viscosity is a measure of the molecular weight or average length of the polymer chains, and decreases with chemical degradation. (The control film tested in Figure 5 is on cellulose triacetate Aerecon base, which is similar in chemical stability to cellulose acetate butyrate Aerographic base.) It is apparent from this very severe test that the chemical stability of Estar base is even higher than that of acetate base, and of course, both are very much higher than the old nitrate type of base used prior to World War II. Less severe aging tests have been run for over three years at temperatures of 78° to 120°F. and humidities from 20 to 60% with satisfactory results.

With respect to safety characteristics, Estar base film ignites only with difficulty and burns very slowly. The base melts at about 510°F., and in the event of fire the molten polymer may flow, but it burns only slowly. Estar base film passes the American Standard Specifications for Safety Photographic Film, PH 1.25-1956, and has been approved by the Underwriters' Laboratories, Inc., as a slow-burning safety film.

DIMENSIONAL STABILITY

Although there are many properties, both photographic and physical, which are essential to a satisfactory aerial film, it is dimensional stability which is of most interest with polyester base for topographic mapping. This is a complex subject and cannot be answered simply, since no material—even glass plates—holds size absolutely.

First, compare the various dimensional change characteristics of Estar base films. These include the reversible changes caused by temperature and humidity, and permanent shrinkage resulting from processing and subsequent aging. The theory involved in various types of dimensional change in photographic films has been discussed previously (8, 9). Laboratory measurements have been made with a pin-gage on 35 mm. strips of film over a 10-inch gage length. It is realized that dimensional changes averaged over this gage length do not tell the whole story as regards accuracy for topographic mapping, but they do provide one valuable comparison. The possibility of non-uniform dimensional changes is discussed later.

Estar base film has only about one-third the thermal coefficient of linear expansion of acetate butyrate base film (Table IV). This will reduce film dimensional changes in cameras when the temperature cannot be controlled.

The humidity coefficients of linear expansion of Estar base films also average about one-third that of acetate butyrate base film (Table IV). Here it should be noted that the film dimensions versus relative humidity curve is not linear for polyester base film as it virtually is for acetate base film (Figure 6).

TABLE IV

TYPICAL DIMENSIONAL CHANGE VALUES FOR AEROGRAPHIC FILMS[(a)]

Direction of Test[(e)]			*Thermal Coefficient of Linear Expansion, % per Degree F.*[(b)]	*Humidity Coefficient of Linear Expansion % per 1% R.H.*[(c)]		*Processing Dimensional Change, %*[(d)]	
Material	*Base*[(f)]	*Type No.*		1	2	1	2
Kodak Panatomic-X Aerographic Film	Estar	SO-136	0.0015 (SO-136, SO-135)	0.0021	0.0023	+0.005	0.000
Kodak Plus-X Aerographic Film	Estar	SO-135		0.0025	0.0029	−0.050	−0.010
Kodak Tri-X Aerographic Film	Estar	SO-138		0.0032	0.0035	−0.020	−0.025
Kodak Plus-X Aerographic Film	CAB	5401	0.004 (5401, 5425)	0.0070	0.0075	−0.04	−0.05
Kodak Super-XX Aerographic Film	CAB	5425		0.0080	0.0085	−0.05	−0.06
Aluminum			0.0013				
Steel			0.0006				
Glass Plates			0.00045				

(a) Films tested according to American Standard Method for Determining the Dimensional Change Characteristics of Photographic Films and Papers, PH1.32-1959.

(b) Thermal coefficients measured between 70°F. and 120°F. at 20% RH on unprocessed film.

(c) Humidity coefficients measured between 15% and 50% RH at 70°F. on unprocessed film.

(d) Processing dimensional change measured at 70°F.—50% RH. Both unprocessed and processed film brought to 50% RH from a lower humidity.

(e) Direction 1 is axis of molecular orientation of base; direction 2 is at right angles. These are not necessarily length and width directions in the case of Estar base.

(f) CAB = cellulose acetate butyrate.

The curves are much steeper below 50% R.H. where the humidity coefficients are calculated. Above 50% R.H. there is appreciably less change in dimension for Estar films with change in humidity.

The gelatin emulsion and backing are responsible for the larger portion of the humidity dimensional change in polyester base films because of the lateral compression they exert upon the base. This is the reason for the curves for the three Estar films in Figure 6 falling in the order of the emulsion thickness. In fact, there is an approximately linear relationship between the gelatin/base thickness ratio and the humidity coefficient as indicated in Figure 7. The points in this chart for zero emulsion thickness are the humidity coefficients of the base alone. Naturally, the gelatin thickness is held at a minimum in manufacture consistent with other physical and photographic requirements.

Another factor which must be considered in analyzing humidity dimensional changes of resin base films is hysteresis, that is, the failure of the film to return to exactly the same dimensions when a given relative humidity is approached from a lower and from a higher humidity. This phenomenon was explored in an earlier paper (9) on polystyrene base film and applies in a similar manner to polyester base film. It is caused by the gelatin layers, not the base. Dimensional hysteresis is of secondary importance with acetate film, because the humidity coefficients are relatively large. Typical dimensional hysteresis curves for unprocessed and processed Estar base film are reproduced in Figure 8. From this it is apparent that the humidity coefficient is really not a constant, and that one cannot calculate the dimensions of a film at a given relative humidity exactly from any coefficient.

The low rate and amount of swell of Estar base film in water (to simulate processing solutions) compared with acetate butyrate base film is indicated in Figure 9. One would expect that upon drying, a polyester base film, which contains no solvent or plasticizer, would show no permanent shrinkage. This is not true because of the compressive effects of the gelatin on the base during drying and the hysteresis effects already mentioned. Figure 8 shows the shift in the hysteresis curve for Estar base film after processing, which is

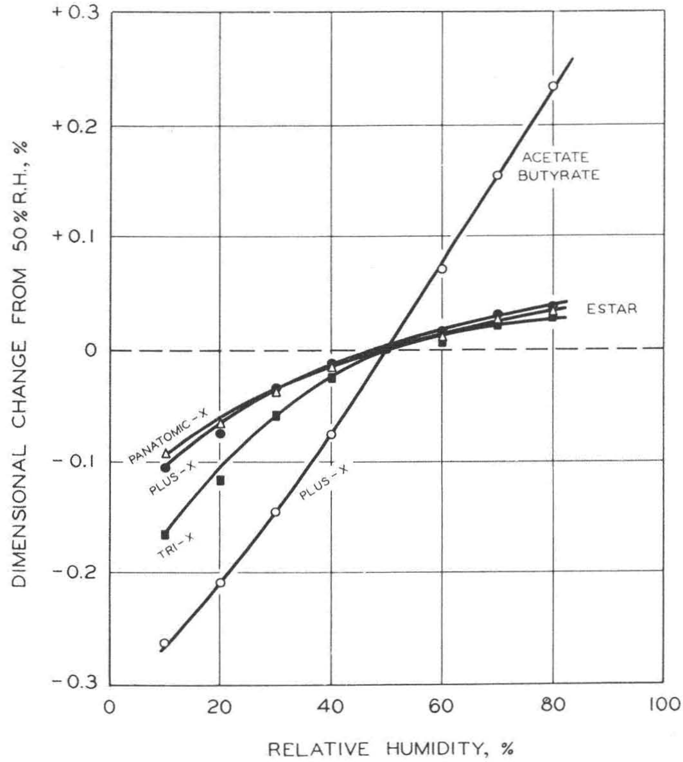

FIG. 6. Change in dimension with relative humidity for Kodak Aerographic Films (adsorption curves).

due to the decrease in modulus of elasticity and the thickness of the emulsion (9). The result of these various factors is that the net change in dimension from processing may be either a slight swell, no change, or a slight shrinkage, depending on the conditions. In spite of these complications, Estar base films show smaller dimensional changes on processing and drying than acetate butyrate film, under the same conditions (Table IV).

Another factor of interest in connection with processing topographic film is the possibility of stretching because of tension, particularly with continuous processing ma-

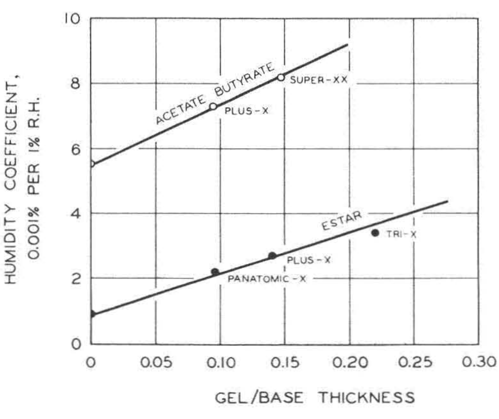

FIG. 7. Effect of gelatin/base thickness ratio on the humidity coefficient of unprocessed Aerographic films between 15% and 50% RH at 70°F.

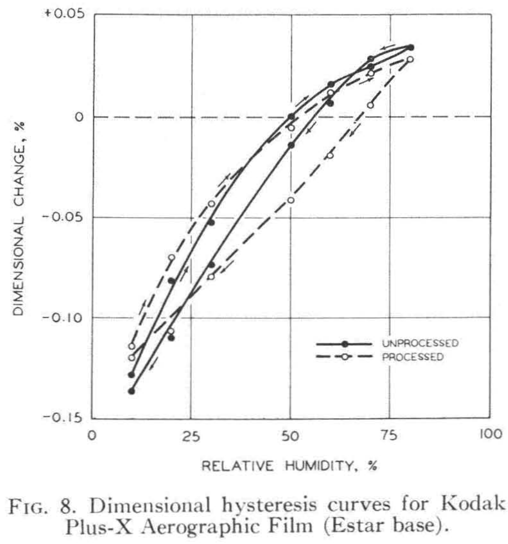

FIG. 8. Dimensional hysteresis curves for Kodak Plus-X Aerographic Film (Estar base).

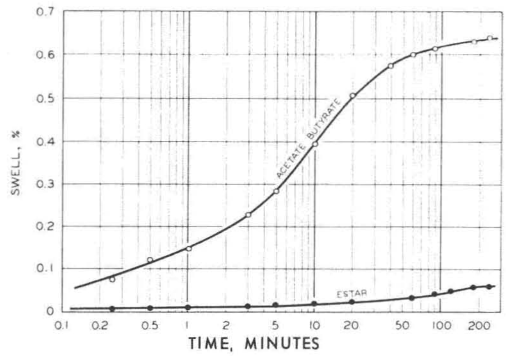

FIG. 9. Rate of swell of Kodak Aerographic Films in 70°F. water, starting from equilibrium at 70°F.–50% RH.

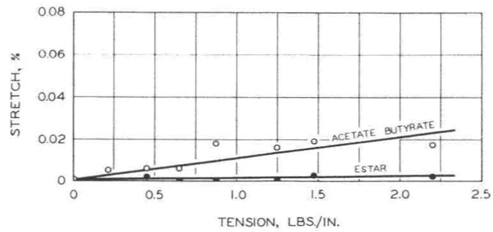

FIG. 10. Effect of tension during processing and drying on the lengthwise stretch of Kodak Plus-X Aerographic Films. Film dried at 70°F.–50% RH and measured after 24 hours recovery.

chines. Figure 10 shows the amount of lengthwise stretch remaining after strips of Aerographic film were subjected to various tensions during processing and drying. (Some widthwise contraction is caused by any lengthwise stretch, which is not shown in the figure.) Even though the Estar film is thinner, it offers much greater resistance to stretch under tension, particularly when both films are wet. Of course, the tension is deliberately exaggerated in this test. Some continuous machines have a tension in the neighborhood of 0.5 lbs. per inch, but rewind tank machines and mechanical roll film dryers have considerably lower tensions. It is not possible to state a limiting processing tension, below which either film will show no stretching, but Figure 10 should be a useful guide. Some continuous processing machines do have tensions which are undesirably high for topographic film.

The shrinkage of Estar films with age is very small indeed, because there is no solvent or plasticizer in the base. The small shrinkage which does occur is caused by relaxation of the base or lateral compression from the emulsion. Typical aging curves are plotted in Figure 11 for keeping at 78°F.-60% RH and 120°F-20% RH. The latter is an accelerated condition. These curves do not yet extend very far because Estar base films made under production conditions are still very new. However, it is known from tests made on earlier pilot plant coatings and accelerated tests on production coatings, that the shrinkage of Estar films should not exceed about 0.05% in five years under normal conditions and may be less. This is a significant improvement over the most stable acetate film.

Uniaxialism, that is the uniformity of properties in different directions in the plane of the film, is more important in topographic mapping than over-all dimensional changes that can be corrected by a change in magnification in the stereo plotter. It is well known that acetate topographic base has very slightly different properties in the length than in the width, because it is unavoidably stretched a little in the machine direction during manufacture (8). In the case of Estar base, very slight differences in physical and dimensional properties also exist in different directions. However, the properties may not be a maximum in either the length or width direction, but at some angle in between these. Table IV shows the dimensional properties in the direction of maximum orientation and in the direction at 90 degrees to this. Every effort is made in manufacture to keep these small differentials at a minimum.

Another consideration is the effect of storing film in roll form on length-width dimensional differences. When this was first investigated some years ago, it was found to be a significant factor with acetate film. (8)

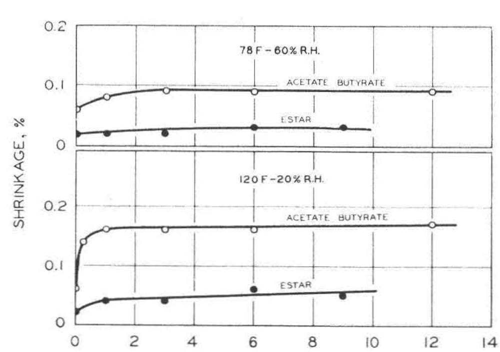

FIG. 11. Processing plus aging shrinkage of Plus-X Aerographic Films stored at two different conditions. All measurements made after reconditioning to 70°F.–50% RH.

Because of plastic flow during storage, the length-width differentials increase, compared to film stored in flat strips. A preliminary study with Estar Aerographic film has shown much less effect of roll storage and, hence, lower length-width differentials.

The possibility of random or non-uniform dimensional changes in aerial film has been raised many times by photogrammetrists. However, there are so many possible sources of error in the photogrammetric system that it is difficult to determine which, if any, are caused by the film itself when properly handled. Methods of studying film distortion by means of a reseau grid exposed on the film are almost prohibitively laborious. However a new method using a halftone tint printed on the film from a glass master, which when superimposed with the original produces an interference pattern called a moiré, was described recently. (10) The evenness of the spacing of the spots in the moiré pattern provides quantitative information on the dimensional uniformity of the film. Tests made on Aerographic Film on acetate butyrate base by the moiré method showed film dimensional distortions intentionally caused by water-spotting, excessive processing machine tension and abnormal heating. When the film was handled properly, no serious random distortions were found.

Only preliminary comparisons between Estar and acetate Aerographic films have been made, as yet, by means of the moiré method. In one trial, 9½-inch wide rolls of Estar and acetate butyrate Aerographic films were exposed to a 300-line halftone tint on a glass plate at 70°F.-50% RH without preconditioning, processed in a rewind tank, and dried on a mechanical roll film dryer. The negatives were then conditioned at 70°F.-50% RH and registered with another halftone glass master, which had been accurately enlarged 0.08% from the original. (This device was necessary because a 300-line screen does not produce a sufficiently fine moiré pattern for the small dimensional changes being measured.)

The moiré patterns obtained were photographically copied on a high contrast negative material (which reproduces only the dense spots of the interference patterns), with the results shown in Figure 12. The grid lines were added in printing for reference purposes. The larger moiré spots and the larger spacing between them for the Estar film, indicate a smaller over-all processing dimensional change than for the acetate film.

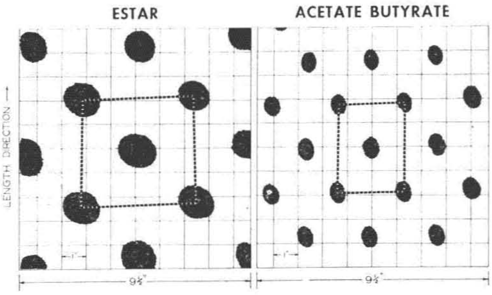

FIG. 12. Photographic reproduction of actual moiré patterns obtained with Kodak Plux-X Aerographic Films exposed to a 300 line halftone tint, processed in roll form and registered with a halftone master. The reference grid was added in printing. (See text for additional explanation.)

If the dimensional change in the film is uniform, in all directions, the moiré spots will form a perfect square. The broken lines in Figure 12 show that this is nearly true in the case of the Estar film, whereas the moiré pattern forms a rectangle in the case of the acetate film, indicating greater systematic distortion. Of course, this is a very sensitive test and it does not mean that the acetate film has actually become a rectangle of this proportion.

Knowing the number of lines in the original halftone, it is possible to calculate the size-change quite accurately, from such a moiré pattern in both length and width. It is also possible to calculate the size-change in the two diagonal directions, which gives a measure of any skewness. Furthermore, one can estimate the random distortion, if any, by the appearance of the pattern and any curvature of the rows of moiré spots.

The over-all dimensional changes as a result of processing, calculated from the moiré patterns in Figure 12 are:

	Estar Film	*Acetate Butyrate Film*
Length	−0.022%	−0.045%
Width	−0.025	−0.095
Difference	0.003	0.050
Diagonal 1	−0.026	−0.065
Diagonal 2	−0.024	−0.063
Difference	0.002	0.002

These figures show an appreciably lower length-width distortion for the Estar film. However, the differentials in the diagonal direction are equally small for both films. It will be noted that the above values for processing dimensional change, which were measured on rolls, differ somewhat from those obtained on flat strips shown in Table IV. This is attributed to the effects of storage in roll form mentioned earlier, and possibly to some small humidity dimensional change after exposure to the halftone master.

Analysis of the moré patterns in Figure 12 shows that in this particular test, the Estar film relative to the acetate butyrate film has:

1. Approximately 1/3 the over-all size change.
2. Approximately 1/10 the systematic distortion between the length and width.
3. Approximately the same extremely small random distortion, indicated by the negligible curvature of the line of moiré spots.

It cannot be concluded that exactly the same result would be obtained under various other practical conditions. A great deal more investigational work with larger amounts of film remains to be done before any more definite conclusions can be drawn regarding very small distortions in Estar film.

Conclusions

These new films on Estar base offer a number of practical advantages to the user in strength properties, flatness, and dimensional stability. Limited trade tests have indicated that they can be handled in conventional mapping cameras and processing equipment. It is not yet known what increase in mapping accuracy will result from the improved film characteristics. In the final analysis, it will be the practical experience of photogrammetrists which will determine the advantages of Estar base films.

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