Drying of Processed Aerial Films

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ABSTRACT: *The conditions required for drying processed aerial films to obtain optimum physical properties were investigated. The study was made on a forced air mechanical roll film dryer, U. S. Air Force Type A-5, and included both unbacked cellulose acetate butyrate base and gel-backed Estar polyester base aerial films. Simple air baffles added to the dryer doubled the drying rate of gel-backed films.*

Ideally, processed film should emerge from the dryer at an equivalent relative humidity of 50 %. Film dried only to sensible dryness may be far from this ideal condition. Differences in the gel layers and in the moisture absorption capacities of acetate and polyester base affect the film drying rate. By selecting the right combination of drying conditions, it is possible to approach optimum drying for both types of film. For example, operating the dryer at 2 ft./min. requires 70° F.-20% RH drying air for Super-XX Aerographic Film, Type 5425, on acetate base and 90° F.-50% RH air for Kodak Special Plus-X Aerial film (Estar Base), Type SO-135, and Kodak Special Double-X Aerial Film (Estar Base), Type SO-223. Data are given for a variety of drying conditions.

INTRODUCTION

DRYING of processed aerial film, in most laboratories, has never received much attention. As long as the processed film felt dry and did not stick together, it was considered satisfactorily dried. For optimum physical properties drying of aerial topographic film only to "sensible" dryness (dryness to the touch) is not enough. Ideally, film should emerge from the dryer with a total moisture content equal to that which it would hold when equilibrated to room temperature air at 50% relative humidity.

Drying of film to an equivalent relative humidity of 50% before winding into a roll has been shown by Adelstein and Leister (1) to produce the least non-uniform dimensional changes in the film upon subsequent aging in open rolls at 50% RH. Processed film at 50% RH equilibrium will have less curl and brittleness than film in equilibrium with a low relative humidity. This condition will also eliminate ferrotyping and the possibility of the laps sticking together caused by high humidity. Raw aerial films are packaged in equilibrium with 45%–55% RH. So size changes caused by humidity coefficient of expansion will be minimized if the processed film is dried and kept at this condition.

The purpose of this paper is to discuss how these optimum physical properties resulting from drying film to 50% RH equilibrium may be obtained using a commercial dryer operating under various drying conditions. The theoretical aspects of rapid drying of aerial films have been discussed by Boyd (2). A general appraisal of drying systems has been made by Fisher (3).

EXPERIMENTAL

The aerial films investigated in this study included:

1. Kokak Super-XX Aerographic Film, Type 5425.
2. Kodak Special Plus-X Aerial Film (Estar Base), Type SO-135.
3. Kodak Special Double-X Aerial Film (Estar Base), Type SO-223.

The physical properties of Estar polyester base aerial films have been described by Calhoun, Adelstein and Parker (4). The Estar base aerial films all have a gelatin backing, which is a relatively new feature for aerial film, to provide static protection and reduce curl. Drying of processed gel-backed aerial films offers no major problem but these films do have different drying characteristics. It is important that both sides of the film be adequately dried before the film is wound into a roll.

The dryer used in this study was a forced air mechanical roll film dryer, U. S. Air Force Type A-5, as shown in Figure 1. This dryer described by Bagley (5) is still widely used by

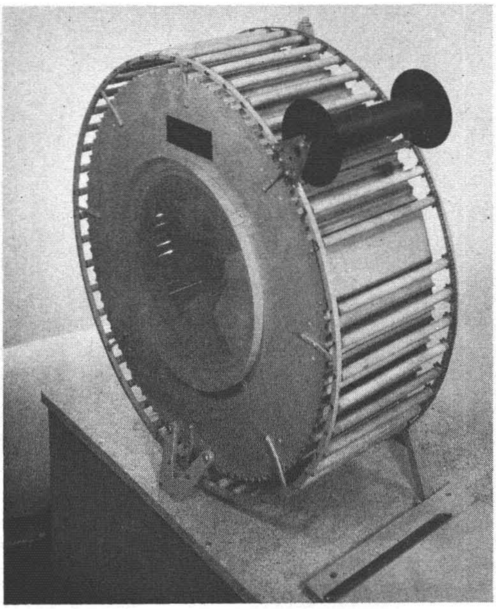

FIG. 1. Aerial Roll Film Dryer, U. S. Air Force Type A-5.

many commercial aerial photographic concerns, although continuous processing machines are coming into use. The wet film passes through the dryer, emulsion side in, between the cylinder and rollers. High velocity drying air impinges on the emulsion and holds the film against the driven backing rollers. The rollers transport the film around the circumference of the dryer to the take-up spool. Although the actual data to be presented were obtained on this particular model dryer, many of the principles discussed may be applied to other types of aerial film dryers.

In the experimental part of this program the films were processed on a Morse B-5 Rewind Processor using recommended developers and processing times for the products. Kodak Photo-Flo solution was used in the water tank on the dryer. A good wetting agent, such as Photo-Flo, greatly aids the air knife in removing the liquid water from the film before it enters the dryer. It also prevents the formation of water spots.

The drying conditions were varied by operating the dryer in an adjustable controlled condition room. For each set of operating conditions, the location in the dryer of the sensible dry point for both the emulsion and the back side of the film was determined by feel. Samples were cut from the film as it emerged from the dryer and immediately sealed in bottles. These film samples were analyzed for moisture content by the evacuation method described by Colton and Wiegand (6).

RESULTS

The Type A-5 dryer was designed primarily to dry unbacked aerial films. There is no provision on this dryer for forced air circulation on the back side of the film. However, gel-backed polyester base films can be dried on this equipment without modification, but at a reduced rate. By adding simple sheet metal air baffles to deflect a portion of the exhaust drying air across the back of the film, the drying rate of the thin gel backing can be greatly increased. The modified dryer with six pairs of air baffles installed is shown in Figure 2. More efficient baffles could probably be designed, but this is a simple scheme which can easily be carried out in the field at a very low cost. The comparable times required to obtain sensible dryness with and without baffles are given in Table I. The baffles reduced almost in half the drying time required for the gel-backed Estar base film and even slightly reduced the drying time of unbacked acetate butyrate base film.

The moisture absorption characteristics at various relative humidities for the three films studied are shown in Figure 3. For practical purposes these curves are independent of temperature over normal room temperature variations. The greater moisture absorptive capacity of the Kodak Super-XX Aerographic

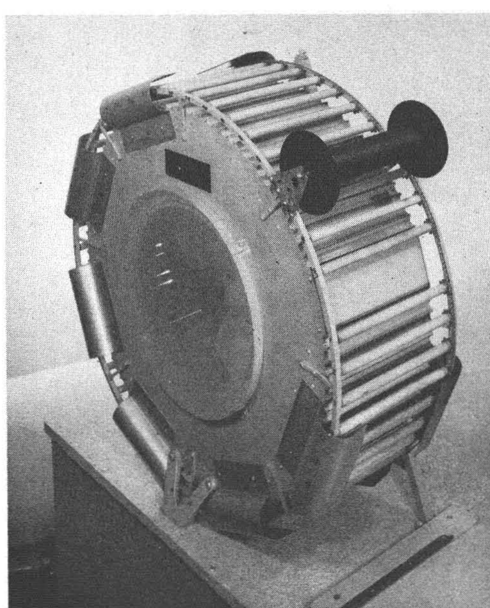

FIG. 2. Modified Type A-5 Dryer with six pairs of sheet metal baffles installed.

TABLE I
EFFECT OF BAFFLES ON DRYING RATE OF TYPE A-5 AERIAL FILM DRYER
Time Required to Reach Sensible Dryness, Seconds

Drying Air	*Kodak Special Double-X Aerial Film (Estar Base), Type SO-223**		*Kodak Super-XX Aerographic Film, Type 5425†*	
	With Baffles	*Without Baffles*	*With Baffles*	*Without Baffles*
70°F.-20% RH	55	115	55	85
70°F.-50% RH	80	160	140	150
90°F.-20% RH	45	90	40	45
90°F.-50% RH	65	110	65	85

* Gel backed side controls drying time.
† Emulsion side controls drying time.

Film, Type 5425, results from a comparatively thick emulsion layer, and the greater moisture capacity of the cellulose acetate butyrate base compared to Estar base. From these curves the moisture content for the ideal 50% RH equilibrium can be determined. Knowing the amount of water absorbed by the film in processing the drying requirement for each film may be calculated. These requirements are given in Table II. The Estar base aerial films have a much lower total drying requirement, even though they have a gel backing, than does the unbacked Kodak Super-XX Aerographic Film, Type 5425.

A further breakdown of the drying requirement for each individual layer of the films is given in Table III. The amount of water to be removed from the thicker emulsion on Kodak Super-XX Aerographic Film, Type 5425, is approximately three times that to be removed from the emulsions on the Estar base products. The drying requirements for the emulsion and gel backing layers on Kodak Special Plus-X Aerial Film (Estar Base), Type SO-135 are almost equal, as the thicknesses of these two layers are about the same. The thinner gel backing on Kodak Special Double-X Aerial Film (Estar Base), Type SO-223 lowers the drying requirement of this layer. The amount of water to be removed from the acetate butyrate base is about seven times as great as that from the Estar base.

The amount of water to be removed from the acetate butyrate base is 0.050 pounds of water per 100 square feet of film, which is only about 4% of the total drying requirement for the Kodak Super-XX Aerographic Film, Type 5425. Referring to Figure 3, only 0.120 pounds of water per 100 square feet of film are required for 50% RH equilibrium. So the quantity of water to be removed from the acetate base represents about 40% of the total moisture content of the entire dried film. Therefore, it is very important that this 0.050 pounds of water be removed from the base. Because of insufficient time, in most dryers, all of the required moisture cannot be removed from the base during the drying operation. Therefore, with cellulose acetate butyrate base films it is necessary to overdry the gelatin layers so that they may later

TABLE II
WATER ABSORPTION OF PROCESSED AERIAL FILMS

Film	*Pounds of Water/100 sq. ft. film*		
	*Wet After Processing**	*Equilibrated to 70°F.-50% RH*	*Total Dryer Requirement*
Kodak Super-XX Aerographic Film, Type 5425	1.268	0.120	1.148
Kodak Special Plus-X Aerial Film (Estar Base), Type SO-135	0.742	.056	0.686
Kodak Special Double-X Aerial Film (Estar Base), Type SO-223	.570	.042	.528

* After squeegeeing before entering the dryer.

TABLE III

DRYING REQUIREMENTS FOR INDIVIDUAL FILM LAYERS

For Equilibration to 50% RH

Film	*Pounds of Water/100 sq. ft. film*			
	Emulsion	*Base*	*Gel Backing*	*Total*
Kodak Super-XX Aerographic Film, Type 5425	1.098	0.050	None	1.148
Kodak Special Plus-X Aerial Film (Estar Base), Type SO-135	0.351	.007	0.328	0.686
Kodak Special Double-X Aerial Film (Estar Base), Type SO-223	.386	.007	.135	.528

absorb the excess moisture remaining in the base. Thus, the important point is to remove the correct total amount of water from the film during the drying operation, and the redistribution of the remaining moisture will take place automatically among the layers in the wound roll of dry film.

The water absorption of the Estar base itself during processing is very small so very little water need be removed from the base in the dryer. Therefore, with Estar base aerial films there is very little moisture redistribution between the gel layers and the base after the film leaves the dryer.

There will be some redistribution of moisture between the emulsion and gel backing layers with the Estar base films unless both layers are equilibrated to the drying air. The A-5 dryer, even after baffling, has only about ⅓ the drying capacity on the back side of the film as it does on the emulsion side. With this reduction in drying capacity the gel-backing layer, even though thinner than the emulsion layer, controls the drying rate of the film. Thus, the emulsion layer dries first and has a longer time to equilibrate to the drying air than does the gel-backed side.

The drying results at four different drying

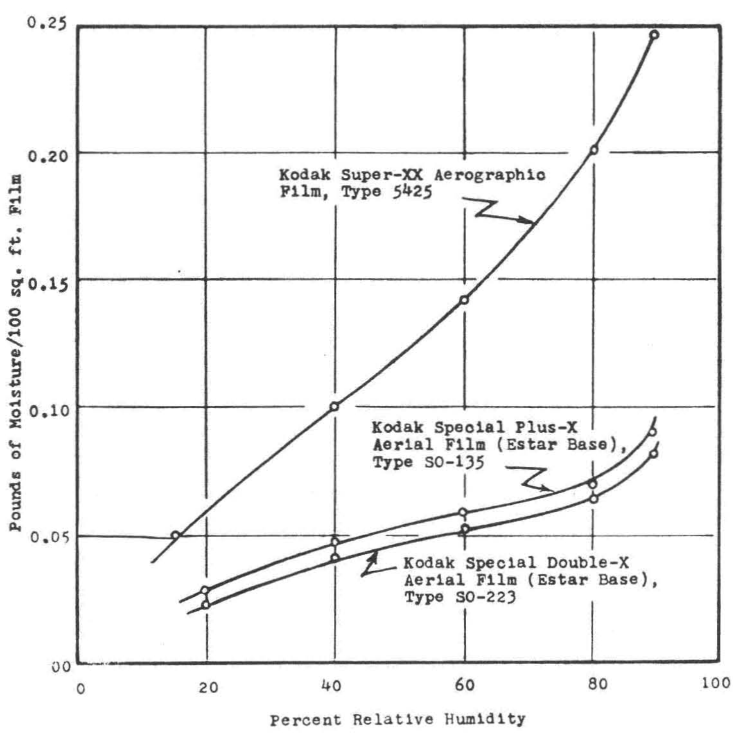

FIG. 3. Moisture Capacity of Processed Aerial Films at various relative humidities.

TABLE IV

DRYING RATE AND MOISTURE CONTENT OF DRIED AERIAL FILMS

Type A-5 Aerial Film Dryer with Baffles

Drying Air	Film Speed Ft./min.	*Kodak Super-XX Aerographic Film, Type 5425*		*Kodak Special Plus-X Aerial Film (Estar Base), Type SO-135*		*Kodak Special Double-X Aerial Film (Estar Base), Type SO-223*	
		*Dry Point**	*Film RH†*	*Dry Point*	*Film RH*	*Dry Point*	*Film RH*
70°F.-20% RH	1	8	38	10	48	10	41
	3	35	63	55	50	37	45
	6	80	85	>100	>100	72	46
70°F.-50% RH	1	30	77	45	85	20	58
	3	100	>100	>100	>100	50	65
	6	—	—	—	—	>100	>100
90°F.-20% RH	1	4	25	6	30	5	35
	3	25	55	40	33	27	38
	6	55	65	90	47	57	42
90°F.-50% RH	1	10	55	15	52	7	45
	3	41	68	52	61	32	48
	6	90	85	>100	>100	70	50

* Per cent of dryer length required for sensible dryness.
† Equilibrium relative humidity of film at dryer wind-up.

conditions are given in Table IV. These conditions were selected as being somewhat typical of indoor laboratory conditions encountered throughout the year. All of these results were obtained on the dryer with six pairs of baffles.

Operating the dryer with Kodak Super-XX Aerographic Film, Type 5425, at 3 feet-per-minute or faster at any of the drying conditions resulted in underdried film. Under these conditions the film was wound in equilibrium with 55% RH or higher. In most of these cases the emulsion layer felt dry to the touch well before it emerged from the dryer, but the emulsion was not overdried sufficiently to absorb the excess moisture remaining in the base. Most operators run the dryer as fast as they can so that the film just feels dry at the wind-up. Under these circumstances the acetate butyrate base films are probably wound in equilibrium with 85% RH or higher, regardless of the drying air condition. It was possible, operating the dryer at 70°F.-20% RH and 90°F.-20% RH at only one-foot-per-minute, to overdry the complete film.

To approach 50% RH equilibrium when drying Kodak Super-XX Aerographic Film, Type 5425, it would be necessary to adjust the relative humidity of the drying air to around 20% RH by either heating or dehumidification. The film speed through the dryer should then be set so that the emulsion surface feels dry to the touch about 25% of the way through the dryer. This will allow 75% of the drying time to overdry the emulsion and remove some water from the base. If it is necessary to heat the drying air above 90°F. to reach 20% RH, then the film speed through the dryer should be slightly increased so as not to overdry the film. Acetate butyrate base films dried using this system will be much closer to the ideal 50% RH equilibrium condition than film which is just dried to the touch as it emerges from the dryer. It will naturally require a longer time to dry a roll of film in this manner but it is believed the added benefits in physical characteristics and dimensional stability offset the increased time.

The drying of the Estar base aerial films is entirely different since the base absorbs so little water. For this reason, the Estar base films can be overdried much easier than the acetate butyrate base films. Adjusting the drying air to 50% RH around 90°F. is ideal for Estar base films. The film speed through the dryer is set so that the gel backing feels dry to the touch about half way through the dryer. Under these conditions, the emulsion and gel backing layer will both almost equilibrate to the drying air condition and with almost no water to remove from the Estar base, the entire film will be near 50% RH equilibrium at the wind-up. Using 50% RH drying air, it is impossible to overdry the film. In some localities it may be impossible to easily obtain 50% RH air because of dry atmospheric conditions. If the humidity of the air is less than 50% RH, the film speed through the dryer should be increased to move the sensible dry point of the gel-backing side nearer to the dryer exit. This will reduce the tendency to overdry the film by leaving some excess moisture in the gel backing, which will then be absorbed by the overdried emulsion layer after wind-up.

Conclusions

Drying aerial films for topographic mapping only to sensible dryness is not sufficient. Drying to 50% RH equilibrium will yield film with optimum physical properties. At this condition film distortion and dimensional changes will be minimized. This is particularly true for those distortions caused by edge conditioning of processed film wound in a roll and stored under humidity conditions different from those with which the film is in equilibrium. A 50% RH equilibrium condition is the best compromise for optimizing those other physical properties of the processed film which are greatly influenced by moisture content; curl, brittleness, static generation, ferrotyping and sticking. This ideal condition can be approached using a Type A-5 Dryer by properly adjusting the condition of the drying air and the film speed through the dryer.

Control of the moisture content of processed acetate base films is more important than with Estar base films because the latter has lower moisture capacity and greater dimensional stability. When drying acetate base aerial films it is necessary to overdry the gelatin layers so that they may later absorb the excess moisture remaining in the base.

With gel-backed Estar polyester base aerial films, provisions on the dryer for increased air flow across the back of the film will greatly increase the drying rate of the thin gel backing. On a properly baffled dryer the drying rate of gel-backed Estar base films to reach 50% RH equilibrium is equal to or faster than that for unbacked Kodak Super-XX Aerographic Film, Type 5425. The Estar base absorbs so little water in processing that after the gelatin layers are equilibrated to the drying air the entire film is nearly at the same condition.

Although proper drying of processed aerial film is important there is no substitute for thorough conditioning, handling and keeping of processed film at a controlled condition of 50% RH.

Acknowledgements

The author wishes to acknowledge the contribution of Mr. T. Anvelt who did most of the laboratory work, and also Mr. J. T. Parker under whose supervision this investigation was made.

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