PHOTOGRAPHIC MATERIALS FOR AERIAL PHOTOGRAPHY

Walter Clark
Kodak Research Laboratories

DURING the years preceding the war, the bulk of aerial photography in the world was carried out on this continent, primarily for economic purposes. Many of the negatives thus made have naturally proved of great value as the basis of wartime maps, but the great use of aerial film has come since the war, in which it is used primarily for reconnaissance purposes, but also to a rapidly increasing extent for making new maps and revising old maps of potential and actual tactical and strategic importance. With the increase in the use of aerial photography, although not mainly as a result of it, there has been an extraordinary improvement in aerial films and the other photographic materials used in conjunction with them.

Ten years ago, the type of film most used for aerial photography was that known as Super-sensitive Panchromatic Aero Film. This was a great advance over the earlier kind of film which had been in use since the last war, for it depended for its properties largely on the discovery in 1929 of new types of sensitizing dye which gave much enhanced speed. About 1930, research on sensitizing dyes developed very actively, and in a few years discoveries of great importance were made. At the same time, there was being carried out active research on the methods of making the sensitive emulsions themselves, and the progress in this field, coupled with the advances in knowledge of sensitizers, led to rapid improvements in films of all kinds, including those for aerial photography. As far as the negative was concerned, these advances were evident from shortened exposure times, greater control of contrast, improved response to red light, higher resolving power and lower graininess for increased speed, low fog and improved keeping properties, and the ability to make films particularly sensitive to special spectral regions.

Two types of film utilizing the new discoveries were introduced in 1938–39 as Kodak Super-XX Aero Panchromatic and Special Aero Panchromatic Films. (The corresponding Ansco products are Triple-S Pan and SS Pan Aero.) The Super-XX type of film was about four times as fast as the old Super-Sensitive type. The Special type was introduced somewhat later than the Super-XX in order to give higher contrast and better control of contrast in development. It had only half the speed of Super-XX, but was the film largely used for aerial photographic survey before the war. The Special film has now been dropped, because the Super-XX has been improved to the extent that it has all the desirable properties of the other, and twice the speed. The Super-XX Aero type of film resembles basically the high speed films made for general photography, but it has a higher sensitivity to red light, to permit short exposure through red filters.

During the period in which these films were being used, other types were made for special purposes. The chief of these were a fast green sensitive film, primarily for use in desert regions, and a film of moderate speed and grain and good resolving power, and capable of high contrast, known as Panatomic-X. The green sensitive film has now been dropped, since its benefits can be obtained with the faster panchromatic films and a green filter, and the slow, fine-grain film finds little use, primarily because it can only be used in good light, and in any case its low speed requires that the camera lens be used at a high aperture

which introduces aberrations which offset the advantages of its higher resolving power.

In 1941 there was introduced the fastest film yet made for aerial photography. It is known as Tri-X Aero Panchromatic, and it has twice the speeed of the Super-XX type. It is used exclusively for night photography by flash bombs, and is, in fact, too fast for day-light photography except, perhaps, for exposures made in very poor light. Photographs for survey are not usually made under these conditions.

A certain amount of film sensitive to the infrared has been used for aerial photography. When it is exposed through a deep red filter, it gives better penetration of haze than panchromatic film with a red filter, and it has been proposed for the detection of camouflage and for geological and forest survey. Ten years ago, however, infrared sensitive film for aerial photography—then known as Panchromatic K—was too low in speed for general use. Although many spectacular pictures were made with it, particularly by Captain A. W. Stevens, special precautions had to be taken to ensure adequate exposure. About 1931, great advances were made in the knowledge of infrared sensitizing dyes and they were immediately applied to astronomy and spectrography. Later, they were used in conjunction with improved emulsions to make an infrared film for aerial photography which was just about fast enough for general purposes. It was known as Eastman Infrared Aero film, Type 2. It had, however, only about one-quarter of the speed of the Super-XX type of film which was coming into use. In 1942, means were found for doubling its speed, so that the present type of Infrared Aero Film is faster through a red filter than the earlier Special Panchromatic Aero Film with no filter. Its graininess and resolving power are about the same as in the case of the Tri-X Aero Panchromatic film.

The following Table shows the speed and resolving power of the types of aerial film for black-and-white photography which have been made during the past ten years:

TABLE I

Film	*Exposure Index**	*Resolving Power†* 1000:1	2:1
Eastman Supersensitive Aero Panchromatic	24	50	30
Eastman Special Aero Panchromatic	50	50	30
Ansco SS Pan Aero	50		
Kodak Super-XX Aero Panchromatic	100	50	30
Ansco Triple-S Pan	100		
Kodak Tri-X Aero Panchromatic	200	40	22
Ansco AC Pan	200		
Kodak Infrared Aero (through Wratten No. 89A filter)	48	45	25

* The second column gives the exposure index values for use with the American Standards Association Emergency Standard Photographic Exposure Computer. They lie between the ratings which would be used with the common Weston and General Electric exposure meters.

† The resolving powers are in terms of lines per millimeter which can just be separated when photographing test objects in the laboratory having contrasts of 1000:1 and 2:1. In an aerial camera in an aircraft, all the values would probably lie between 10 and 14 lines per mm.

In spite of the film manufacturers, different users frequently worked out their own modifications of developers, usually to no advantage, and there was much confusion in some organizations. Two years ago, the United States Army Air Forces standardized their developers for aerial film. For high contrast, the developer had the characteristics of the Kodak D-19 formula. For low contrast, the Kodak D-76 formula was used. For intermediate contrast, the formula was Kodak D-76 modified by addition of carbonate and bromide. A calculator was

also worked out by the Navy Bureau of Aeronautics, for calculating the times of development with the various films with the different developers at a particular temperature.

In 1942, as a result of the activities of a committee on which the photographic industry and the Services were represented, the American Standards Association issued a Photographic Exposure Computer, in which data were included for aerial photography. The Computer provided factors for geographical latitude, lighting conditions, and type of aerial photograph, and numbers known as Film Exposure Indexes which are associated with the sensitivity and latitude of the film, its development and its intended field of use.

In 1935, the color film known as Kodachrome was made available for 16-mm. motion picture photography by the Eastman Kodak Company. As far as aerial photography is concerned, this film has been used primarily for training purposes, although some has been used for combat, record and publicity photography. It gives direct color positive transparencies. This form of the film was followed by the 35-mm. variety for miniature cameras and another type for use in 8-mm. motion picture photography. In 1938 a new variety was put out in sheet form, and quite a lot of this has been used in aerial cameras with magazines taking sheet film, and in hand-held cameras. Kodachrome film is very difficult to develop, and requires control which can only be applied in a properly equipped laboratory. It is, therefore, only processed by the manufacturer. In 1942, a notable advance was made in the form of a color film especially made for aerial photography. It is known as Kodacolor Aero Reversal Film, and has adequate contrast to overcome the flattening effects of haze. It is supplied only to the Armed Forces at the present time, in rolls which fit the standard aerial cameras, and its speed index of 40 (in the same terms as the values for films given in Table I) makes it fast enough for photography from the air in good weather. It is so made that it can be processed in the standard types of aerial film processing equipment by the user in the field. The film gives positive transparencies in color, and a special form is available, on a diffusing support, for making duplicate transparencies. Recently, certain types of color film for processing by the user have been announced by the Ansco Company.

Precision survey by aerial photography demands that the film shall undergo as little dimensional variation as possible, or, if there is variation, that it should be as nearly as possible equal in the length and breadth of the negative. This led to the introduction of the so-called "topographic" type of film support. Ten years ago, the bulk of aerial film was on a support made of cellulose nitrate, and a topographic variety of this was introduced. Later, it was found possible to make the so-called "safety" type of support of cellulose acetate having properties resembling those of the nitrate, and later a topographic safety support was introduced which was the equal of the topographic nitrate material. At the present time, safety support of the two types, called "reconnaissance" and "topographic," is used practically exclusively in this country.

Table II gives data concerning the shrinkage characteristics of Kodak Aero Film on safety support, and of Topographic Translucent Acetate Sheeting, as supplied at the present time.

For making duplicates of aerial negatives, the Ansco Corporation introduced a Direct Duplicating Film which gives a negative from a negative in a single printing and developing operation. It employs the photographic effect known as solarization. In England, it is the practice to make duplicate aerial negatives by printing onto yellow-dyed fine-grain film to give positives, and then to print from these positives on the same kind of film to give the duplicate negatives. Special

TABLE II

Approximate Shrinkage Characteristics of Kodak Aero Film and Topographic Acetate Sheeting (Safety Base)

	Reconnaissance Film, Per Cent	*Topographic Film, Per Cent*	*Topographic Translucent Acetate Sheeting, Per Cent*
Humidity Coefficient of Linear Expansion per 10% R.H. (Temporary expansion or contraction at constant temperature)			
Average of length and width	0.07	0.08	0.05
Difference between length and width	0.03	0.005	0.01
Thermal Coefficient of Linear Expansion per 10°F. (Temporary expansion or contraction at constant relative humidity)			
Average of length and width	0.04	0.04	0.04
Difference between length and width	0.015	0.005	0.01
Processing Shrinkage (Permanent)			
Average of length and width	0.10–0.15	0.05	—
Difference between length and width	0.05–0.10	0.02	—
*Processing Shrinkage plus Accelerated Aging Shrinkage (Permanent)**			
Average of length and width	0.20–0.40	0.12	0.12†
Difference between length and width	0.10–0.20	0.05	0.05

* Aging 7 days at 120°F., 20% R.H., open to the air. Test required by U. S. Army Specification No. 75-327, September 7, 1943.

† Processing omitted.

diapositive plates were worked out for making the reduced transparencies for the Multiplex. An Aero Positive Transparency film was introduced in 1942 for contact printing from aerial negatives. Such a material has a much longer scale than a printing paper, giving better highlight and shadow detail. Most practice in interpreting aerial photographs, however, is based on the use of paper prints, and the difficulty of changing in war time is probably partly responsible for the fact that the superior positive transparencies are not much used.

The printing papers for aerial photography are of the contact and enlarging types. In the former case they are generally of the types of contact printing paper which have been available for a long time, and in four contrast grades. The enlarging types have the more recently introduced kinds of enlarging emulsion, and they are also in four contrast grades.

Papers on water-resistant support were introduced by the Positype Corporation and the Eastman Kodak Company. They have the merits of rapid drying and improved dimensional stability as compared with normal paper. A new kind of paper in which the contrast of the print was varied by changing the color of a filter through which it was printed was introduced a few years ago, primarily by Ilford in England and Defender in this country. Although at the start it excited a fair amount of interest, it does not seem to be much used in the field of aerial photography.

Another product introduced recently is Topographic Translucent Acetate Sheeting. It is an improvement over the Topographic Matte Acetate Sheeting formerly in use. It is used with the Multiplex equipment for tracing detail from the projected diapositives, and resembles Topographic Safety Aero film base except that it is thicker, and that one surface is prepared to take pencil and ink and make the material translucent (see Table II for dimensional characteristics).