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LEXINGTON PROJECT REPORT

NO. 131

THE TOLERANCE OF AERIAL FILM TO NUCLEAR RADIATIONS

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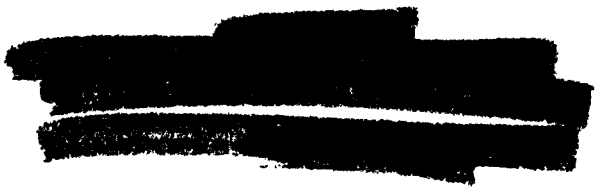


Lexington Project Report #131

Subject: The Tolerance of Aerial Film to Nuclear Radiations
Source: Clark Goodman
Date: August 20, 1948
Place: Lexington

INTRODUCTION

The principal advantage of a nuclear-powered aircraft is long range without refueling. To deliver bombs deep in enemy territory, it appears necessary to use nuclear-powered aircraft. However, aerial reconnaissance is an essential prelude. If nuclear-powered aircraft are required for bombing, in all likelihood they also would be needed for such reconnaissance. Accordingly, it is of interest to know the tolerance of aerial films to nuclear radiations. The purposes of this report are:

(a) To estimate this tolerance from data readily available,
(b) To indicate the relative importance of this tolerance in the design of nuclear-powered aircraft, and
(c) To suggest possible means of adapting aerial cameras to nuclear-powered aircraft.

SOURCES OF INFORMATION

It is likely that considerable information pertinent to the present problem has been obtained from the various atomic bomb tests and in A.E.C. laboratories. However, time does not permit a complete survey of information.

Through the assistance of Col. D. Keirn of the A.E.C. and Col. Pote of the U. S. Army Air Force, Wright Field, contact was made with the Optical Research Laboratories at Boston University. Detailed data on films and cameras were obtained from this source through the courtesy of Mr. Fred Wells, administrative assistant to the director, Dr. D. E. Macdonald. Lt. Col. R. E. Philbrick is the local research representative of the Engineering Division of Wright Field.

Dr. R. D. Evans of M. I. T. is chairman of the Subcommittee on Shipment of Radioactive Materials, of the National Research Council. This committee is studying the directly related problem of shipping radioactive isotopes in proximity to commercial photographic films. Dr. Evans kindly made available a manuscript on this subject; this has formed the basis for the bulk of the present report.

SENSITIVITY OF PHOTOGRAPHIC FILMS

1. Gamma rays (X-rays).

The response of photographic emulsions to radiation is commonly expressed in terms of H and D curves of the type shown in Figure 1. It is to be noted that these films have a base density of about 0.2, i.e., $D \simeq 0.2$ even when developed following zero exposure. To this minimum density would normally be added a small contribution for chemical fog density. Following exposure in use, the developed film usually exhibits densities of between 1 and 3, that is, within the linear portion of the H and D curve.

A general fogging corresponding to an increase of about 0.05 in base density is of no consequence in the practical use of aero film. However, at a sharp boundary, caused by shadowing, a change in density of 0.02 can be detected with a photoelectric densitometer; 0.03 can be detected by careful visual examination; and 0.05 is readily recognized visually. Until actual tests have been made on aerial photographs, the maximum permissible exposure during a flight of 24 hours' duration is assumed to be that which will cause an increase in density of 0.02 in aerial film. The same limit of exposure has been established tentatively for the shipment of radioactive materials assuming X-ray film to be located at 15 feet from the source for a period of 24 hours.

For present purposes the unpublished data on commercial films of Wilsey and of Morrison, as compiled by Evans and listed in Table 1, are sufficient. The exposure to the gamma rays of radium required to give an increase in density of 0.02 does not correlate directly with the ASA exposure index for daylight. However, it appears fairly well established that an exposure of about 50 mr would produce a barely perceptible change in base density in the most sensitive aero film, i.e., the Tri X-Pan. This value will be taken as the "tolerance level of aerial film."* It is to be emphasized that in contrast with the "tolerance level of humans", the exposure of film cannot be increased many-fold above tolerance without rendering the film worthless. Thus, if 0.1 r/day is taken, as the "tolerance level of humans", it is likely that a single exposure to 1 r/day or even 10 r/day will not produce any noticeable effect, largely because of the recovery characteristics of man. However, it is likely that 10 times the "tolerance level of aero film", for example 500 mr on Tri X-Pan would render it permanently worthless for aerial photography.

In applying this tolerance to aerial film, it is important to know the relative sensitivity of the film to the gamma rays of radium and its active deposit (on which the data are based) and the gamma rays and neutrons which will be encountered aboard a nuclear-powered aircraft. There are about

*This value is one-five hundredth of the value used for man for a single flight (Chapter IVB of the final Lexington Report).

eleven principal gamma-ray lines in the spectrum of radium and its active deposit, covering a range of quantum energies from 0.24 to 2.2 Mev. The spectrum from the nuclear reactor will probably include a fair proportion of higher-energy gamma rays, in part composed of secondary gammas from capture of neutrons in the shield and surrounding materials. However, tests by Wilsev on Eastman Blue Brand X-ray film, as shown in Table 3 indicate that the sensitivity is substantially independent of quantum energy above about 0.3 Mev. when the exposures are measured in roentgens. For this reason, it appears safe to apply without correction the data of Table 1 to the gamma rays from a nuclear reactor.

Table 1

Relative Sensitivity of Eastman Photographic Materials to the Gamma Rays of Radium.

Film	ASA Exposure Index	Relative Sensitivity to γ-rays	Exposure in mr for $\Delta D = 0.02$
Type K Industrial X-ray		1 8	8
Blue Brand X-ray		1.00	15
Super Panchro Press (Sports Type)	250	0.44	35
*Tri-X Pan	200	0.32	50
Ortho-X	125	0.32	50
Portrait Pan	50	0.16	100
*Super XX, Roll or sheet	100	----	100
Panatomic X	32	----	150
*Super XX, 16 mm (Reversal)	100	0.073	240
*Kodachrome, daylight	10	0.027	550

*These films are equivalent to the major types of films used in aerial photography, see Table 2.

Table 3

Relative Spectral Sensitivity of Eastman Blue Brand X-ray Film

Average Effective Photon Energy (in Mev.)	Exposure E in mr for D = 1.0	Relative Sensitivity K = 910/E
0.036	44.4	20.5
0.049	45.6	20.0
0.062	60.0	15.2
0.079	94.0	9.7
0.098	234.	3.8
0.127	448.	2.0
*0.3	910.	1.0
*1.8	910.	1.0

*Additional tests with unfiltered 1 Mev. x-rays and filtered gamma rays from radium gave values of E = 910 and K = 1.0 between these two photon energies.

2. Neutrons

No quantitative data on the sensitivity of aerial films to neutron radiation could be obtained from local sources, from the open literature or from the Oak Ridge National Laboratory. It appears that essentially all the film used for the measurement of neutron fluxes is of the "track" type in which knock-on protons or particles from (n,p) reactions are studied rather than changes in photographic density. Such films are far less sensitive than aerial films hence cannot be used for comparative purposes.

Practical experience with films of the aerial type has clearly shown, at least in a qualitative way, that aerial films are several orders of magnitude less sensitive to fast and resonance neutrons than to gamma rays. As a conservative estimate, it will be assumed that a D = 0.02 results in Tri-X Pan film from fast and resonance neutron beams which produce 5 r in the emulsion (assumed to be H_2O).* 5 r by volume ionization is only a little higher than the tolerance value used for man in Chapter IVB of the final Lexington Report.

EFFECTS OF COSMIC RAYS AND RADIOACTIVE RADIATIONS

The base density of film depends in part upon its age. Some general fogging results from the natural deterioration of the emulsion with time. However, an appreciable fraction of the change in base density results from "natural" radiations. The cosmic radiation at sea level has been determined by Clay to be 1.63 ± 0.05 ions/c.c. of air per second, which is equivalent to about 2 mr/month. This radiation increases with elevation and is nearly twice as great at an elevation of 1 mile (e.g., Denver or Cheyenne). The local gamma radiation, resulting from the small amounts of uranium, thorium, and potassium in all rocks, soil, and building materials, adds another 3 to 6 mr/month. Evidence supports the applicability of the Bunsen-Roscoe reciprocity law for the cumulative effect of these radiations. According to these estimates, Tri X-Pan film would show a just perceptible change in base density as the result of "natural" radiations in about one year. This effect plus the inherent chemical instability of film accounts for the customary dating of film about one year from the time of manufacture.

Because the ionizing component of cosmic radiation increases markedly with altitude, the exposure from this source would be about 0.5 mr during a 24 hour flight at 50,000 feet The terrestial radiation would be absent during a high-altitude flight.

*The (n,p) reaction in the nitrogen contained in the gelatin of the emulsion is ignored in these considerations. This effect would be quite significant for thermal neutrons, but the flux of thermal neutrons can easily be kept quite low.

From the foregoing, it is concluded that no appreciable increase in exposure results from cosmic radiation during a practicable period of flight regardless of altitude.

AERIAL CAMERAS

The arrangement of the extra gamma shielding required would depend on the particular camera used. However, some statements can be made regarding cameras. Table 4 lists the characteristics and specialized uses of a number of aerial cameras. Modifications in the design, particularly of the film magazine and mounting would be required.

The film is supplied in cylindrical rolls about 4 inches in diameter and of a length equal to the width of film used. It is customary before taking off for a mission to load the aerial cameras with sufficient film for a complete reconnaissance. The film magazines (both feed and take-up spools) would be surrounded, except for outlet and inlet slots, by a single heavy metal shield.

For purposes of computation, pure lead will be assumed. A thickness of about 1/2 foot is required to attenuate 2 Mev. gammas by 10^3. For a film 1 foot in width, the minimum shield weight would be 2500 pounds. This corresponds to about the smallest-size film used in military aerial photography. However, the weight of shield only increases approximately linearly with the width of film. Hence, the largest width film (about 3 feet)* would only require a gamma shield of about 7500 pounds.

CONCLUSIONS

1. The neutron shielding required for a manned nuclear-powered aircraft probably will suffice for photographic film used for aerial reconnaissance.

2. The gamma shielding required for a manned nuclear-powered aircraft definitely is not adequate for aerial film.

3. Gamma shielding giving an additional attenuation of about 10^3 is required for aerial film.

*Most aerial cameras employ film between 12 and 24 inches in width. However, cameras are now being used on an experimental basis that employ films as large as 36 inches in width.

4. The extra gamma shielding should be placed around a specially designed film magazine rather than around the entire camera.

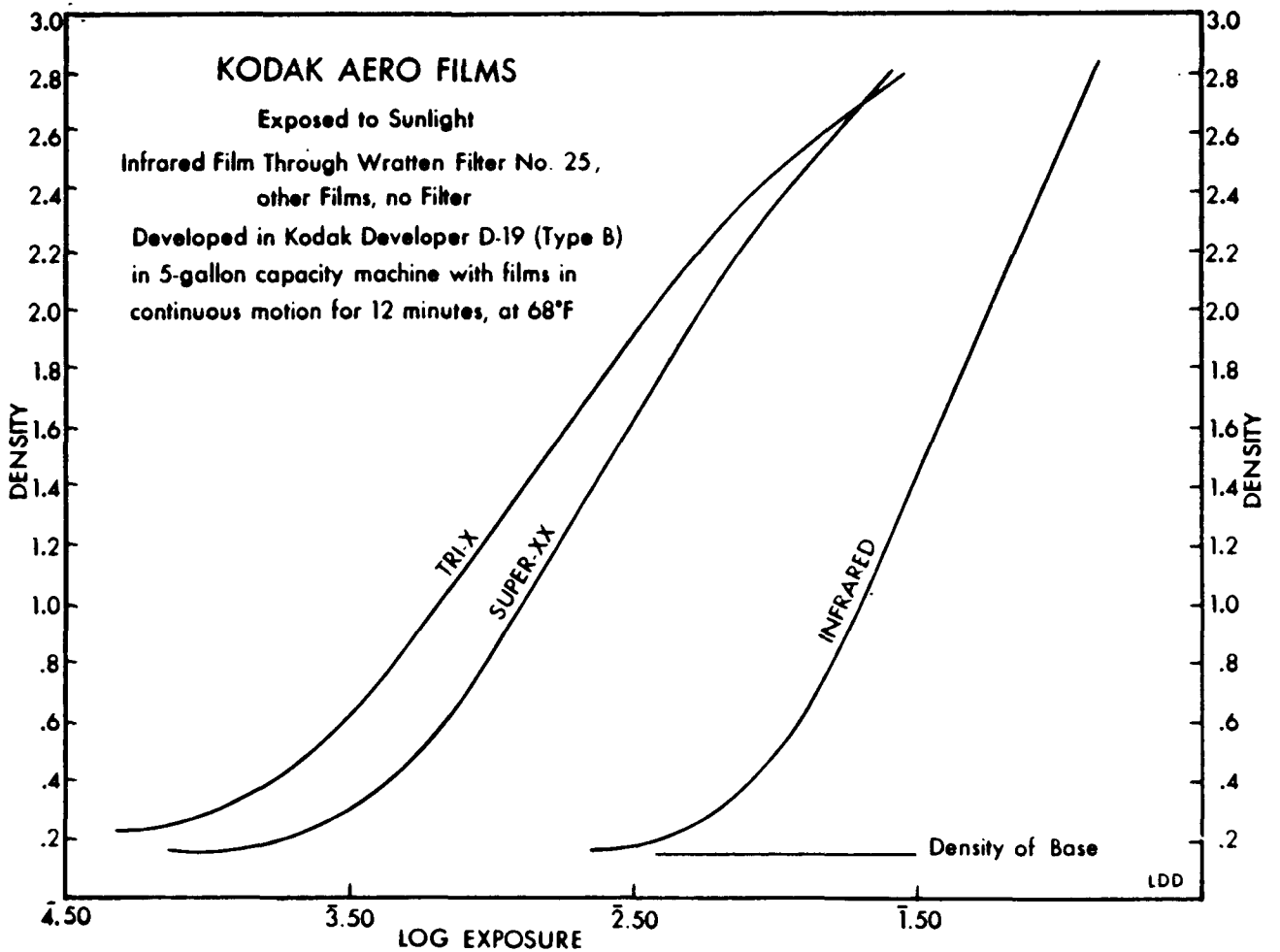
5 The weight of this gamma shielding will range from about 2500 to 7500 pounds

6. Experimental work should be done to establish the sensitivity of aerial films to neutron radiation.

Figure 1.

H and D curves for various aerial films. The exposure E is the product of illumination x time. The density D = -log T, where T = transmission of white light = transmitted illumination/incident illumination. Representative values pertinent to present considerations are:

D	0.0	0.02	0.05	0.20	1.0	2.0	3.0	4.0
o/o T	100	95.5	89.1	63.1	10.	1.0	0.1	.01



Tables 2 and 2a

Classification of Aerial Films and Descriptive Table
of Photographic Film Used by Army Air Forces
(data from Eastman Kodak Company 1947).

CLASSIFICATION OF AERIAL FILMS

AAF STOCK NO	NAVY STOCK NO.	TYPE	CLASS	EXPOSURE INDEX	MANUFACTURER'S DESIGNATION		FILM			AN SPOOL PART NO.	CAMERAS IN WHICH ROLL CAN BE USED
					EASTMAN KODAK	ANSCO	WIDTH (inches)	LENGTH (feet)	LEADER TRAILER (feet)		
	18-F-31422	1A	K	50	Infrared		7	18	3½	AN7010-1	F-1, F-14, F-25, F-56
	31537	1A	L	100	Super XX Pan	Triple S Pan	7	125	5	AN7012-1	F-56
7400 264500	31468	1A	L	100	Super XX Pan	Triple S Pan	9½	75	8	AN7013-1	K-3B, K-7C, K-17, K-18, K-19, K-22, T-5
7400 264600	31472	1A	L	100	Super XX Pan	Triple S Pan	9½	200	None	AN7014-1	K-3B, K-7C, K-17, K-18, K-19, K-22, T-5
7400 264675		1A	L	100	Super XX Pan	Triple S Pan	9½	390	8	AN7015-1	K-3B, K-7C, K-17, K-18, K-19, K-22
7400 265055		1B	K	50	Infrared		5¼	20	3½	AN7008-1	F-48, K-20, K-25
7400 265856		1B	K	50	Infrared		5½	26	None	AN7009-1	K-24 (F-24, British)
7400-265857 7		1B	K	50	Infrared		7	15	3½	AN7011-1	K-15A, K-21
7400 265858	31492	1B	K	50	Infrared		9½	75	8	AN7013-1	K-3B, K-7C, K-17, K-18, K-19, K-22, T-5
	31524	1B	L	100	Super XX Pan	Triple S Pan	5¼	9	3½	AN7008-1	F-48, K-20, K-25
7400 266400	31525	1B	L	100	Super XX Pan	Triple S Pan	5¼	20	3½	AN7008-1	F-48, K-20, K-25
7400 266410		1B	L	100	Super XX Pan	Triple S Pan	5½	26	None	AN7009-1	K-24 (F-24, British)
7400 266420	31526	1B	L	100	Super XX Pan	Triple S Pan	5½	56	None	AN7009-1	K-24 (F-24, British)
	31526-100	1B	L	100	Super XX Pan	Triple S Pan	7	121¼	3½	AN7010-1	F-8, F-11, K-10, K-15, K-15A
7400-266800		1B	L	100	Super XX Pan	Triple S Pan	7	15	3½	AN7011-1	K-15A, K-21
	31526-150	1B	L	100	Super XX Pan	Triple S Pan	7	18	3½	AN7010-1	F-1, F-14, F-25, F-56,
	31526-200	1B	L	100	Super XX Pan	Triple S Pan	7	62	3½	AN7012-1	F-14, F-25, F-56
	31527	1B	L	100	Super XX Pan	Triple S Pan	7	125	5	AN7012-1	F-56
7400-266853	31530	1B	L	100	Super XX Pan	Triple S Pan	9½	75	8	AN7013-1	K-3B, K-7C, K-17, K-18, K-19, K-22, T-5
7400-266865	31531	1B	L	100	Super XX Pan	Triple S Pan	9½	200	None	AN7014-1	K-3B, K-7C, K-17, K-18, K-19, K-22, T-5
7400-266875		1B	L	100	Super XX Pan	Triple S Pan	9½	390	None	AN7015-1	K-3B, K-7C, K-17, K-18, K-19, K-22
	31543	1B	N	200	Tri-X Pan	A C Pan	5¼	9	3½	AN7008-1	F-48, K-20, K-25
7400-266885	31546	1B	N	200	Tri-X Pan	A C Pan	5¼	20	3½	AN7008-1	F-48, K-20, K-25
7400-266920		1B	N	200	Tri-X Pan	A C Pan	5½	26	None	AN7009-1	K-24 (F-24, British)
7400-266922	31544	1B	N	200	Tri-X Pan	A C Pan	5½	56	None	AN7009-1	K-24 (F-24, British)
7400 266930		1B	N	200	Tri-X Pan	A C Pan	7	15	3½	AN7011-1	K-15A, K-21
	31547	1B	N	200	Tri-X Pan	A C Pan	7	18	3½	AN7010-1	F-1, F-14, F-25, F-56
	31549	1B	N	200	Tri-X Pan	A C Pan	7	125	5	AN7012-1	F-56
	31550	1B	N	200	Tri-X Pan	A C Pan	9½	20	None	AN7013-1	K-19
7400 266932	31551	1B	N	200	Tri-X Pan	A C Pan	9½	75	8	AN7013-1	K-3B, K-7C, K-17, K-18, K-19, K-22, T-5
7400 266945		1B	N	200	Tri-X Pan	A C Pan	9½	200	None	AN7014-1	K-3B, K-7C, K-17, K-18, K-19, K-22, T-5
7400 266955		1B	N	200	Tri-X Pan	A C Pan	9½	390	8	AN7015-1	K-3B, K-7C, K-17, K-17B, K-18, K-19, K-22

NOTE Information applying to K-17 also applies to K-17B.
Information applying to K-18 also applies to K-18A.
Information applying to K-19 also applies to K-19A, K-19B
Information applying to K-15 or K-21 also applies to K-15A
Information applying to K 15A may not apply to K-15 or K-21

DESCRIPTIVE TABLE OF PHOTOGRAPHIC FILM USED BY ARMY AIR FORCES

ARMY AIR FORCES DESCRIPTION				MANUFACTURER'S DESCRIPTION OF FILM					
				EASTMAN KODAK CO		ANSCO		DUPONT TYPES II III & VII DEFENDER TYPES V	
AAF TYPE	AAF CLASS	AAF EXP INDEX	DESCRIPTION OF FILM CLASS	FILM	CODE	FILM	CODE	FILM	CODE
IA	L	100	HIGH SPEED PANCHROMATIC	SUPER XX AERO	5225				
IB	K	50	INFRARED	INFRARED	8224				
IB	L	100	HIGH SPEED PANCHROMATIC	SUPER XX AERO	8225	TRIPLE S PAN	4241		
IB	N	200	EXTRA HIGH SPEED PANCHROMATIC	TRI X AERO	8217				
		32	AERIAL COLOR FILM	KODACOLOR AERO	8221				
II	A	50	REGULAR PANCHROMATIC	PLUS X PANCHROMATIC NEGATIVE	1231 & 5241	SUPERPAN SUPREME	353	SUPERIOR II	126
II	C	25	LOW SPEED PANCHROMATIC	BACKGROUND X PANCHROMATIC NEGATIVE	1230	FINOPAN	357	SUPERIOR I	104
II	F		SOUND RECORDING	SOUND RECORDING	1357 & 5357			SOUND RECORDING	201
II	F 1		FINE GRAIN SOUND RECORDING	FINE GRAIN SOUND RECORDING	1370			FINE GRAIN SOUND RECORDING	224
II	G		POSITIVE	RELEASE POSITIVE	1301 & 5301	POSITIVE	220 & 120	RELEASE POSITIVE	213 600 & 601
				DUPLICATING POSITIVE	1355				
				HIGH CONTRAST POSITIVE	1363 & 5363				
II	G 1		FINE GRAIN POSITIVE	FINE GRAIN RELEASE POSITIVE	1302 & 5302			FINE GRAIN PRINT POSITIVE	606
				FINE GRAIN PRINT POSITIVE	5364			FINE GRAIN RELEASE POSITIVE	225, 605 & 605C
				FINE GRAIN DUPLICATING POSITIVE	1365 & 5365			FINE GRAIN MASTER POSITIVE	228
II	J		DUPLICATING NEGATIVE	FINE GRAIN DUPLICATING NEGATIVE	1203 & 5203			FINE GRAIN DUPLICATING NEGATIVE	108
				FAST DUPLICATING NEGATIVE	1505				
II	K	12	INFRARED	INFRARED	1210				
II	L	100	HIGH SPEED PANCHROMATIC	SUPER XX PANCHROMATIC NEGATIVE	1232 & 5242				
II	M		COLOR FILM DAYLIGHT TYPE	KODACHROME	5263	ANSCO COLOR	235		
II	M 1		COLOR FILM TUNGSTEN TYPE	KODACHROME TYPE A	5264	ANSCO COLOR, TUNGSTEN TYPE	234		
II	Q	75	HIGH CONTRAST PANCHROMATIC	SHELLBURST PAN	5214				
III	A	50	REGULAR PANCHROMATIC	PLUS X PANCHROMATIC NEGATIVE	5241	SUPERPAN SUPREME NEGATIVE	253	SUPERIOR II	301
				SUPER X PANCHROMATIC REVERSAL	5256	HYPAN REVERSIBLE	293		
				UNIVERSAL TYPE SUPER X GUN CAMERA FILM	5205				
III	C	25	LOW SPEED PANCHROMATIC	PANCHROMATIC NEGATIVE	5240	FINOPAN NEGATIVE	257	REGULAR PANCHROMATIC NEGATIVE	314
III	F		SOUND RECORDING	SOUND RECORDING	5357				
III	F 1		FINE GRAIN SOUND RECORDING	FINE GRAIN SOUND RECORDING	5372				
III	G		POSITIVE	RELEASE POSITIVE	5301	POSITIVE	220	POSITIVE	600
III	G 1		FINE GRAIN POSITIVE	FINE GRAIN RELEASE POSITIVE	5302			FINE GRAIN RELEASE POSITIVE	605
				FINE GRAIN DUPLICATING POSITIVE	5365				
III	J		DUPLICATING NEGATIVE	FINE GRAIN DUPLICATING NEGATIVE	1203 & 5203			FINE GRAIN DUPLICATING NEGATIVE	308
				FAST DUPLICATING NEGATIVE	1505				
III	L	100	HIGH SPEED PANCHROMATIC	SUPER XX PANCHROMATIC NEGATIVE	5242	ULTRA SPEED PANCHROMATIC NEGATIVE	256		
				SUPER XX PANCHROMATIC REVERSAL	5261	TRIPLE S PAN REVERSAL	294		
III	M		COLOR FILM DAYLIGHT TYPE	KODACHROME	5263	ANSCO COLOR, DAYLIGHT TYPE			
III	M 1		COLOR FILM TUNGSTEN TYPE	KODACHROME TYPE A	5264				
III	M 2		COLOR FILM DAYLIGHT TYPE			ANSCO COLOR, DAYLIGHT TYPE (ACTIVITY PROCESSED)			
III	MICRO FILM		MICROFILM	RECORDAK, MICROFILE PANCHROMATIC	5202			MICROCOPY	327
				GRAFLEX PHOTO RECORD M 412	5204				
IV	A	50	REGULAR PANCHROMATIC	PLUS X PANCHROMATIC	5241 & 1021	ANSCO SUPREME ROLLFILM	164		
IV	C	25	LOW SPEED PANCHROMATIC	PANATOMIC X	5240				
IV	D	50	REGULAR ORTHOCHROMATIC	VERICHROME	1008 & 1009	PLENACHROME	161		
IV	K	12	INFRARED	INFRARED	5212 & 2044				
IV	L	100	HIGH SPEED PANCHROMATIC	SUPER XX PANCHROMATIC	5242 & 2017	SUPERPAN PRESS	167		
IV	M		COLOR FILM DAYLIGHT TYPE	KODACHROME	5263	ANSCO COLOR DAYLIGHT TYPE			
IV	M 1		COLOR FILM TUNGSTEN TYPE	KODACHROME TYPE A	5264	ANSCO COLOR TUNGSTEN TYPE			
IV	M 2		COLOR FILM DAYLIGHT TYPE			ANSCO COLOR DAYLIGHT TYPE (ACTIVITY PROCESSED)			
IV	M 3		COLOR FILM TUNGSTEN TYPE			ANSCO COLOR TUNGSTEN TYPE (ACTIVITY PROCESSED)			
IV	P		TRANSPARENCY FOR REPRODUCTION FROM AERIAL NEGS	TRANSPARENCY	O 408				
V	A	50	REGULAR PANCHROMATIC	PORTRAIT PANCHROMATIC	6114	SUPERPAN PORTRAIT	288	XF PAN	5895
				PANATOMIC X	6140				
V	B	100	HIGH SPEED ORTHOCHROMATIC	ORTHO X	6145	TRIPLE S ORTHO	281		
				SUPER ORTHO PRESS	6147				
V	D	50	REGULAR ORTHOCHROMATIC	SUPER SPEED ORTHO	6122	SUPERSENSITIVE PLENACHROME	284	XF ORTHO	6195
V	E	25	LOW SPEED ORTHOCHROMATIC	COMMERCIAL ORTHO	6107	COMMERCIAL ORTHO	208	COMMERCIAL ORTHO	5795
V	G		PROCESS	CONTRAST PROCESS ORTHO	6111	PROCESS	200	PROCESS	5195
V	H		PANCHROMATIC PROCESS	CONTRAST PROCESS PANCHROMATIC	6112	PROCESS PAN	202	PANCHROMATIC PROCESS	5495
V	K	12	INFRARED	INFRARED	6130				
V	L	100	HIGH SPEED PANCHROMATIC	SUPER XX PANCHROMATIC	6142	SUPERPAN PRESS	487	ARROW PAN	4195
V	M		COLOR FILM DAYLIGHT TYPE	KODACHROME PROFESSIONAL DAYLIGHT TYPE	6137	ANSCO COLOR DAYLIGHT TYPE			
V	M 1		COLOR FILM TUNGSTEN TYPE	KODACHROME PROFESSIONAL TYPE B	6138	ANSCO COLOR TUNGSTEN TYPE			
V	M 2		COLOR FILM DAYLIGHT TYPE			ANSCO COLOR DAYLIGHT TYPE (ACTIVITY PROCESSED)			
V	M 3		COLOR FILM TUNGSTEN TYPE			ANSCO COLOR TUNGSTEN TYPE (ACTIVITY PROCESSED)			
V	N	200	EXTRA HIGH SPEED PANCHROMATIC	TRI X PANCHROMATIC	6143	TRIPLE S PAN	295		
V	O		DIRECT COPY			DIRECT COPY	444		
V	P		TRANSPARENCY	TRANSPARENCY	O 408				
V			WASH OFF RELIEF	WASH OFF RELIEF	1515			CHROMA RELIEF	5092
								PAN CHROMA RELIEF	6492
VI	A	50	REGULAR PANCHROMATIC	PLUS X PANCHROMATIC	2019	SUPERPAN SUPREME	364		
VI	K	12	INFRARED	INFRARED	2044				
VI	L	100	HIGH SPEED PANCHROMATIC	SUPER XX PANCHROMATIC	2023	SUPERPAN PRESS	367		
VIIB	E		ORTHOCHROMATIC	KODALITH ORTHO	6557	REPROLITH ORTHO	2214	PHOTOLITH ORTHO (DUPONT	780
				KODALITH HALFTONE	6567	REPROLITH ORTHO HALFTONE			
VIIB	G		COLOR BLIND			ANSCO REPROLITH	2213	LITHO ORTHO DEFENDER	
VIIB	P		PANCHROMATIC			REPROLITH PAN	2219	REGULAR LITHO DEFENDER	

NOTE EXPOSURE INDEX FOR INFRARED FILM IS CALCULATED FOR USE WITH WRATTEN NO 25A FILTER

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Table 4

Summary of Data on Aircraft Cameras and Installations

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Camera	Use	Means of Operation	Cycling Time (Seconds)	Lenses (Focal Length Max. Aper.)	Lens Angles (Across Diagonal, Side to Side) Half Angles	Area Covered at 10,000' (Miles)	Filter Unit Supplied	Shutter Speeds (Seconds)	Type of Shutter	Type of Focal Plane	Film Magazine Used	Negative Size (Inches)	Film Load Size	Number of Exposures per Load	SPOOLS Part No.	SPOOLS Core Dia.	SPOOLS Flange Dia.	Mounts Used	Inter-valom-eter	Camera Handbooks of Instruction	Camera Spec. No.	Outline Dimension Drawing No. (On File ATSC)	Lens Spec.	Cone Spec.	Status
K 3B	Day Recon.	Manual or Electrical	6 Secs.	6"—F/6.3 8¼"—F/5.0 12"—F/5.0 24"—F/6.0	With A-5 Magazine 46½° 37° x 37° 37½° 28½° x 28½° 20° 20½° x 20½° 15° 10½° x 10½°	A-5 Magazine 2.85 x 2.85 2.07 x 2.07 1.42 x 1.42 0.71 x 0.71	Part of Cone A-5 A-5 A-6	1/50, 1/100, 1/200, 1/300 1/50, 1/100, 1/150 1/50, 1/100, 1/150 1/50, 1/100, 1/150	Between Lens	Vacuum Vacuum Open Frame	A-5 A-5A B-1	9 x 9 8 x 10	9½" x 200' 8" x 10"	250 1	AN7014-1	2½"	5⁹⁄₁₆"	A-8 A-11 A-11A A-27 A-27A	Yes	10-10-1 (1924-1930) 10-10-24 (after 1930) 10-10-26 (1932 1933)	75-23	N37G0031	75-146 75-148 75-148 75-145	75-154	Limited Standard
K 7C	Day Recon.	Manual		24"—F/6.0	22½° 10½° x 20½°	0.71 x 1 42	A-6	1/50 1/100, 1/150	Between Lens	Vacuum	A-7 A-8	9 x 18	9½" x 75' 9½" x 390'	47 245	AN7013-1 AN7015-1	2½" 2½"	4" 6⅝"	A-8 A-11 A-11A A-27 A-27A	None	10-10-20	75-52	N37G0023	75-145		Limit Standard
K 15	Day Recon	Manual		20"—F/5.6 40"—F/8.0 Telephoto	12° 7° x 10° 6° 3½° x 5°	0 47 x 0.66 0.24 x 0.33	Part of Camera	1/75 1/150 1/300	Focal Plane	Glass	Part of Camera	5 x 7	7" x 15'	36	AN7010-1	1⅝"	2⅝"	Adapter A-8 A-11 A-11A	None	10-10-31	31006	N42G2216	75-214 75-216		Limited Standard
K 15A	Day Recon	Electrical (24 volts)		40"—F/8.0 Telephoto	6° 3½° x 5°	0.23 x 0.33	Part of Camera	1/200 1/400 1/600	Focal Plane	Glass	Part of Camera	5 x 7	7" x 15'	36	AN7010-1	⅝"	2⅝"	Adapter A-8 A-11 A-11A	Yes	10-10AC-8	31006	N42G2216	75-216		Limited Standard
K 17	Day Recon	Manual or Electrical (24 volts)	6 Secs.	6"—F/6.3 12"—F/5.0 24"—F/6.0	46½° 37° x 37° 20° 20½° x 20½° 15° 10½° x 10½°	A 5 Magazine 2.85 x 2.85 1 42 x 1 42 0 71 x 0 71	Part of Cone A 5 A-6	1 50 1 100 1 200 1 300 1 75 1 150 1 225 1 50 1 100 1 150	Between Lens	Vacuum Vacuum Open Frame	A-5 A-5A A 9	9 x 9 9 x 9	9½" x 200' 9½" x 390'	250 490	AN7014-1 AN7015-1	2½" 2½"	5⁹⁄₁₆" 6⅝"	A-8 A-11 A-11A A-27 A-27A	Yes	10-10AC-9	75-94	N42J11917	75-146 75-148 75-145	75-144	Limited Standard
K 17B	Charting	Manual or Electrical (24 volts)	3 Secs.	6"—F/6.3	46½° 37° x 37°	2.85 x 2 85	Part of Cone	1 50 1 100 1 200 1 300	Between Lens	Vacuum	A 5 A 5A A 9	9 x 9 9 x 9	9½" x 200' 9½" x 390'	250 490	AN7014-1 AN7015-1	2½" 2½"	5⁹⁄₁₆" 6⅝"	A-8 A-11 A-11A A-27 A-27A	Yes	10-10AC-21	75-94	N42J11917	75-146	75-144	Substitute Standard
K 17C	Charting	Electrical (24 volts)	1¼ and 3⅓ Secs.	6"—F/6.3	46½° 37° x 37°	2.85 x 2.85	Part of Cone	1 50 1 100 1 200 1 400	Between Lens	Vacuum	A 5 A 5A A 9	9 x 9 9 x 9	9½" x 200' 9½" x 390'	250 490	AN7014-1 AN7015-1	2½" 2½"	5⁹⁄₁₆" 6⅝"	A-8 A-11 A-11A A-27 A-27A	Yes	10-10AD-7	75-94	N42J11917	75-146	75-144	Standard
K 18	Day Recon	Manual or Electrical (24 volts)	8 Secs.	24"—F/6.0	22½° 10½° x 20½°	0 71 x 1 42	A 6	1 50 1/100 1 150	Between Lens	Vacuum	A 7 A 8	9 x 18 9 x 18	9½" x 75' 9½" x 390'	47 245	AN7013-1 AN7015-1	2½" 2½"	4" 6⅝"	A-8 A-11 A-11A A-27 A-27A	Yes	10-10-28	75-92	N42J11918	75-145		Limited Standard
K 18A	Day Recon	Manual or Electrical (24 volts)	3 Secs.	24"—F/6.0	22½° 10½° x 20½°	0 71 x 1 42	A 6	1 50 1/100 1 150	Between Lens	Vacuum	A 7 A 8	9 x 18 9 x 18	9½" x 75 9½" x 390'	47 245	AN7013-1 AN7015-1	2½" 2½"	4" 6⅝"	A-8 A-11 A-11A A-27 A-27A	Yes	AN10-10AC-33	75-92	N42J11918	75-145		Standard
K 19	Night Recon	Manual and Electrical	6 Secs.	13½"—F/3.5	B-1 Magazine 25½° 16½° x 20½° A-5 Magazine 25° 18½° x 18½°	B-1 Magazine 1 12 x 1 40 A 5 Magazine 1.26 x 1.26	None	1 25 1/50 1 100	Between Lens	Open Frame Vacuum	A 5 A 5A B-1	9 x 9 8 x 10	9½" x 200' 8" x 10"	250 1 (Night)	AN7014-1	2½"	5⁹⁄₁₆"	A-8 A 11 A-11A A-27 A 27A	None	10-10AC-11	75-97	N42J11919	75-213		Limited Standard
K 19A	Night Recon	Electrical (24 volts)	6 Secs.	12"—F/2.5	B-1 Magazine 28° 18½° x 22½° A-5 Magazine 28° 20½° x 20½°	1.26 x 1 58 1 42 x 1 42	None	1 25 1 50 1 100	Between Lens	Open Frame Vacuum	A 5 A 5A B-1	9 x 9 8 x 10	9½" x 200' 8" x 10"	250 1 (Night)	AN7014-1	2½"	5⁹⁄₁₆"	A 8 A 11 A-11A A 27 A 27A	None	10-10AC-11	75-97	N42J11919	75-196		Limited Standard
K 19B	Night Recon	Electrical (24 volts)	3 Secs.	Same as K-19A	Same as K-19A	Same as K 19A	Part of Camera	Same as K 19A	Same as K 19A	Same as K 19A	Same as K 19A	Same as K 19A	Same as K 19A	Same as K 19A	Same as K 19A			Same as K 19A	None	AN10-10AC-24	75-97	N45K13203	75-196		Standard
K 20	Day Recon (Hand-Held)	Manual		6⅝"—F/4.5	26½° 17½° x 26½°	1 19 x 1 49	Part of Camera	1/125 1/250 1 500	Between Lens	Vacuum (self made)	Part of Camera	4 x 5	5¼" x 20'	50	AN7008-1	1¼"	2⅝"	Hand-Held	None	10-10AC-12 AN10-10AC-25 10-10AD-2 (F.G)	75-227	N41G6307	75-212		Limited Standard
K 21	Orientation Day and Night	Electrical (24 volts)	2 Secs.	7"—F/2.5	32° 12½° x 26½°	1.35 x 1 90	Part of Camera	1/300, 1/600 Time	Focal Plane	Open Frame	Part of Camera	5 x 7	7" x 15	36	AN7011 1	⅝"	1¹⁹⁄₃₂"	A-17 A-17A	Yes	AN10-10AD-3	75-210	N42G11921	75-197		Limited Standard
K 22	Day Recon.	Electrical (24 volts)	2 Secs.	6"—F/6.3 12"—F/5.0 24"—F/6.0 40"—F/5.0 40"—F/5.6 40"—F 8.0	A-5 Magazine 46½° 37° x 37° 28° 20½° x 20½° 15° 10½° x 10½° 9° 6½° x 6½° 9° 6½° x 6½° 9° 6½° x 6½°	A-5 Magazine 2.85 x 2.85 1 42 x 1 42 0.71 x 0.71 0.43 x 0.43 0.43 x 0.43 0.43 x 0.43	Part of Cone Part of Cone Part of Cone Part of Cone Part of Cone Part of Cone	Shutter A 1/150, 1/350 Shutter B 1 350, 1/800	Focal Plane	Vacuum Vacuum Open Frame	A-5 A 5A A 9 B-1	9 x 9 9 x 9 8 x 10	9½" x 200' 9½" x 390' 8" x 10"	250 490 1	AN7014-1 AN7015-1	2½" 2½"	5⁹⁄₁₆" 6⅝"	A-8 A-11 A-11A A-27 A-27A	Yes	AN10-10AC-13	75-221	44K26329	75-146 75-148 75-31174 75-216 75-212	75-222	Standard
K 24	Orientation Day and Night	Electrical (24 volts) and Manual	4, 10 Secs.	6⅝"—F/4.5 7"—F/2.5 12"—F 5.0 20"—F 5.6	28° 21½° x 21½° 29° 19½° x 19½° 16½° 12° x 12° 10° 7° x 7°	1.49 x 1.49 1.35 x 1.35 .79 x .79 .47 x 47	Part of Camera Part of Camera Part of Cone Part of Cone	Four Curtains a. 1/150, b 1/450 c. 1/900, d Time	Focal Plane	Glass	Part of Camera (removable)	5 x 5	5½" x 26' 5½" x 50'	55 125	AN7008-1	⅝"	2⅝"	A-17 A-17A	Yes	10-10AB-1	75-234	N45J13262	7" 75-197 12" 75-148 20" 75-215	75-240 (6⅝") 75-230 (7" 12" 20")	Standard
K 25	Day Recon	Electrical (24 volts)	1 Sec.	6⅝"—F/4.5	26½° 17½° x 21½°	1.19 x 1 49	Part of Camera	1/125 1/250 1/500	Between Lens	Open Frame	Part of Camera	4 x 5	5¼" x 20'	50	AN7008-1	1¼"	2⅝"	Special	None	10-10AC-15 AN10-10AD-6	75-218	N42D11147	75-212		Limited Standard
S 7	Day Recon. (Strip Photography)	Electrical (24 volts)		6"—F 6.3 80mm—F 6.8 (Stereo)	30½° 34½°		None		Moving Film	Roller	Part of Camera	9" x 200'	9½" x 200'		AN7014-1	2½"	5⁹⁄₁₆"	Part of Camera	None	AN10-10A-12	31355	S 7 555 Change Aerial Surveys	6" 75-146	75-425	Limited Procurement
T 5	Topographic Mapping	Manual or Electrical (24 volts)	6 Secs.	6"—F 6 3	46½° 37° x 37°	2.85 x 2.85	Part of Camera	1/50, 1/100 1/200, 1/300	Between Lens	Vacuum	Part of Camera (removable)	9 x 9	9½" x 200'	250	AN7014-1	2½"	5⁹⁄₁₆"	A-22	Built In	10-10AC-20	75-282	N42J11920	75-146		Limited Standard

Summary of Data on Aircraft Cameras and Installations

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