



United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Reston, Virginia 20192REPORT OF CALIBRATION
of Aerial Mapping Camera

December 14, 2000

Camera type:	Jena LMK 1015*	Camera serial no.:	269157D
Lens type:	Jena Lamegon PI/D	Lens serial no.:	7390027D
Nominal focal length:	153 mm	Maximum aperture:	f/4.5
		Test aperture:	f/4.5

Submitted by: Photo Science, Inc.
Lexington, KentuckyReference: Photo Science, Inc. purchase order
No. 95142, dated July 9, 2001.

These measurements were made on Kodak Micro-flat glass plates, 0.25 inch thick, with spectroscopic emulsion type 157-01 Panchromatic, developed in D-19 at 68° F for 3 minutes with continuous agitation. These photographic plates were exposed on a multicolliimator camera calibrator using a white light source rated at approximately 5200K.

I. Calibrated Focal Length: 152.295 mmII. Lens Distortion

Field angle:	7.5°	15°	22.7°	30°	35°	40°
Symmetric radial (um)	0	0	1	3	3	-3
Decentering (um)	0	1	1	3	4	5

Symmetric radial distortion parameters	Decentering distortion parameters	Calibrated principal point
$K_0 = 0.2000 \times 10^{-4}$	$P_1 = -0.2091 \times 10^{-6}$	$x_p = -0.001$ mm
$K_1 = -0.1361 \times 10^{-7}$	$P_2 = 0.2536 \times 10^{-6}$	$y_p = 0.001$ mm
$K_2 = 0.8469 \times 10^{-12}$	$P_3 = 0.0000$	
$K_3 = 0.0000$	$P_4 = 0.0000$	
$K_4 = 0.0000$		

The values and parameters for Calibrated Focal Length (CFL), Symmetric Radial Distortion (K_0, K_1, K_2, K_3, K_4), Decentering Distortion (P_1, P_2, P_3, P_4), and Calibrated Principal Point [point of symmetry] (x_p, y_p) were determined through a least-squares Simultaneous Multiframe Analytical Calibration (SMAC) adjustment. The x and y-coordinate measurements utilized in the adjustment of the above parameters have a standard deviation (σ) of ± 3 microns.

* Equipped with Forward Motion Compensation

III. Lens Resolving Power in cycles/mm

Area-weighted average resolution: 92

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	113	134	113	113	113	95	80
Tangential lines	113	113	113	95	80	67	57

The resolving power is obtained by photographing a series of test bars and examining the resultant image with appropriate magnification to find the spatial frequency of the finest pattern in which the bars can be counted with reasonable confidence. The series of patterns has spatial frequencies from 5 to 268 cycles/mm in a geometric series having a ratio of the 4th root of 2. Radial lines are parallel to a radius from the center of the field, and tangential lines are perpendicular to a radius.

IV. Filter Parallelism

The two surfaces of the Jena 405 No. 275558, and the 500 No. 51389A filters accompanying this camera are within 10 seconds of being parallel. The 500 filter was used for the calibration.

V. Shutter Calibration

Indicated time (sec)	Rise time (μ sec)	Fall Time (μ sec)	$\frac{1}{2}$ width time (ms)	Nom. Speed (sec.)	Efficiency (%)
1/125	2187	2369	7.36	1/85	80
1/175	1527	1687	5.11	1/120	80
1/250	1054	1155	3.62	1/170	80
1/350	754	823	2.53	1/245	80
1/500	564	623	1.83	1/345	80

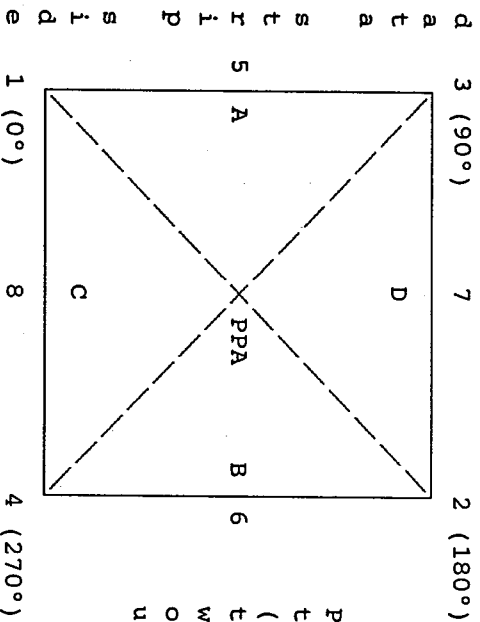
The effective exposure times were determined with the lens at aperture f/4.5. The method is considered accurate within 3 percent. The technique used is Method I described in American National Standard PH3.48-1972(R1978).

VI. Magazine Platen

The platens mounted in LMK-K 24/120 film magazines No. 266792B, No. 266799B, and No. 271753B do not depart from a true plane by more than 13 μ m (0.0005 in).

These film magazines are equipped with identification markers that will register "266792" for magazine No. 266792B, "266799" for magazine No. 266799B, and "271753" for magazine 271753B, in the film edge for each exposure.

VII. Principal Points and Fiducial Coordinates



Positions of all points are referenced to the principal point of autocollimation (PPA) as origin. The diagram indicates the orientation of the reference points when the camera is viewed from the back, or a contact positive with the emulsion up. The data strip is to the left.

	X coordinate	Y coordinate
Indicated principal point, corner fiducials	-0.008 mm	0.002 mm
Indicated principal point, midside fiducials	-0.005	0.008
Principal point of autocollimation (PPA)	0.0	0.0
Calibrated principal point (pt. of sym.) x_p, y_p	-0.001	0.001

Fiducial Marks	X coordinate	Y coordinate
1	-110.004 mm	-109.994 mm
2	109.991	110.001
3	-110.013	110.000
4	109.995	-109.994
5	-112.006	0.006
6	111.991	0.010
7	-0.011	112.005
8	0.001	-111.999

VIII. Distances Between Fiducial Marks

Corner fiducials (diagonals)	
1-2: 311.120 mm	3-4: 311.129 mm
Lines joining these markers intersect at an angle of 90° 00' 06"	
Midside fiducials	
5-6: 223.998 mm	7-8: 224.003 mm
Lines joining these markers intersect at an angle of 90° 00' 07"	
Corner fiducials (perimeter)	
1-3: 219.994 mm	2-3: 220.004 mm
1-4: 219.999 mm	2-4: 219.996 mm

The method of measuring these distances is considered accurate within 0.003 mm

Note: For GPS applications, the nominal entrance pupil distance from the focal plane is 241 mm.

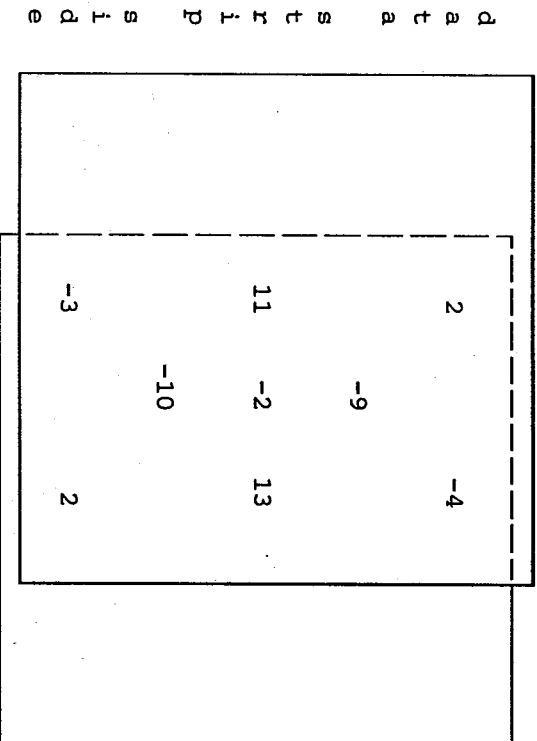
IX. Stereomodel Flatness

FMC Magazine No.: 266792B

Base/Height ratio: 0.6

Platen ID: 266792

Maximum angle of field tested: 40°



The values shown on the diagram are the average departures from flatness (at negative scale) for two computer-simulated stereo models. The values are based on comparator measurements on contact glass (Kodak Micro-flat) diapositives made from Kodak 2405 film exposures. These measurements can vary by as much as $\pm 5 \mu\text{m}$ from model to model.

X. System Resolving Power on film in cycles/mm

Area-weighted average resolution: 46

Film: Type 2405

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	57	57	48	48	48	48	40
Tangential lines	57	57	48	48	48	40	34

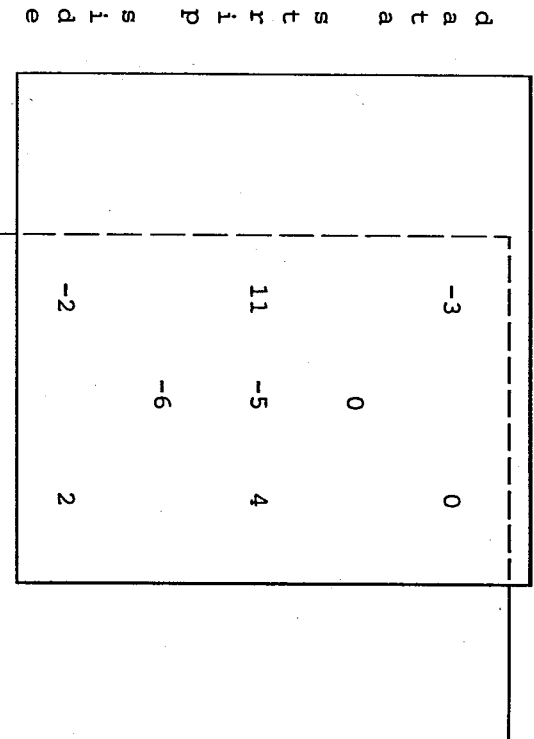
IX. Stereomodel Flatness

FMC Magazine No.: 266799B

Base/Height ratio: 0.6

Platen ID: 266799

Maximum angle of field tested: 40°



The values shown on the diagram are the average departures from flatness (at negative scale) for two computer-simulated stereomodels based on comparator measurements on contact glass (Kodak Micro-flat) diapositives made from Kodak 2405 film exposures. These measurements are considered accurate within 5 um.

X. Lens/Film Resolving Power in cycles/mm

Area-weighted average resolution: 46

Film: Type 2405

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	57	57	57	48	48	48	40
Tangential lines	57	57	57	48	40	40	34

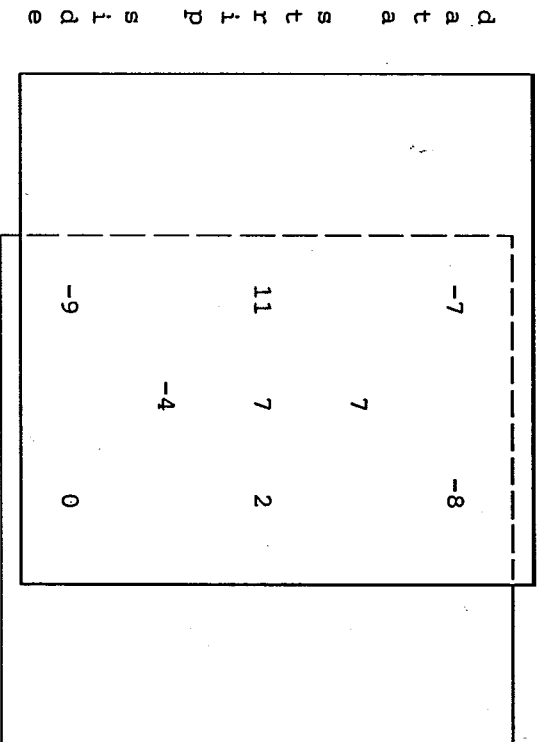
IX. Stereomodel Flatness

FMC Magazine No.: 271753B

Base/Height ratio: 0.6

Platen ID: 271753

Maximum angle of field tested: 40°



The values shown on the diagram are the average departures from flatness (at negative scale) for two computer-simulated stereomodels based on comparator measurements on contact glass (Kodak Micro-flat) diapositives made from Kodak 2405 film exposures. These measurements are considered accurate within 5 um.

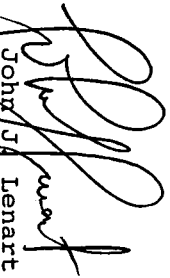
X. Lens/Film Resolving Power in cycles/mm

Area-weighted average resolution: 46

Film: Type 2405

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	57	57	57	48	48	48	40
Tangential lines	57	57	48	48	48	40	34

This aerial mapping camera calibration report supersedes the previously issued USGS Report No. OSL/2451, dated June 16, 1998.


 John J. Lenart
 Chief, Technology Operations Section
 National Mapping Division

LENS/FILM DISTORTION PARAMETERS

FMC Magazine No.: 266792B
Platen ID: 266792

Base/Height ratio: 0.6
Maximum angle of field tested: 40°

XI. Calibrated Focal Length: 152.307 mm

XII. Lens/Film Distortion

Field angle:	7.5°	15°	22.7°	30°	35°	40°
Symmetric radial (um)	0	1	3	4	3	-4
Decentering (um)	0	1	1	3	4	6

Symmetric radial distortion parameters	Decentering distortion parameters	Calibrated principal point
$K_0 = -0.3225 \times 10^{-5}$	$P_1 = -0.1064 \times 10^{-6}$	$x_p = -0.001$ mm
$K_1 = -0.1338 \times 10^{-7}$	$P_2 = 0.3310 \times 10^{-6}$	$y_p = 0.001$ mm
$K_2 = 0.9537 \times 10^{-12}$	$P_3 = 0.0000$	
$K_3 = 0.0000$	$P_4 = 0.0000$	
$K_4 = 0.0000$		

The above measurements were computed from contact glass positives made from Kodak 2405 film exposed in the magazine.

The values and parameters for Calibrated Focal Length (CFL), Symmetric Radial Distortion (K_0, K_1, K_2, K_3, K_4), Decentering Distortion (P_1, P_2, P_3, P_4), and Calibrated Principal Point [point of symmetry] (x_p, y_p) were determined through a least-squares Simultaneous Multiframe Analytical Calibration (SMAC) adjustment. The x and y-coordinate measurements utilized in the adjustment of the above parameters have a standard deviation (σ) of ± 3 microns.

LENS/FILM DISTORTION PARAMETERS

FMC Magazine No.: 266799B

Base/Height ratio: 0.6

Platen ID: 266799

Maximum angle of field tested: 40°

XI. Calibrated Focal Length: 152.304 mmXII. Lens/Film Distortion

Field angle:	7.5°	15°	22.7°	30°	35°	40°
Symmetric radial (um)	0	1	3	5	4	-4
Decentering (um)	0	1	2	3	5	7

Symmetric radial distortion parameters	Decentering distortion parameters	Calibrated principal point
$K_0 = 0.1207 \times 10^{-5}$	$P_1 = -0.3426 \times 10^{-7}$	$x_p = -0.001$ mm
$K_1 = -0.1483 \times 10^{-7}$	$P_2 = 0.4433 \times 10^{-6}$	$y_p = 0.001$ mm
$K_2 = 0.1032 \times 10^{-11}$	$P_3 = 0.0000$	
$K_3 = 0.0000$	$P_4 = 0.0000$	
$K_4 = 0.0000$		

The above measurements were computed from contact glass positives made from Kodak 2405 film exposed in the magazine.

The values and parameters for Calibrated Focal Length (CFL), Symmetric Radial Distortion (K_0, K_1, K_2, K_3, K_4), Decentering Distortion (P_1, P_2, P_3, P_4), and Calibrated Principal Point [point of symmetry] (x_p, y_p) were determined through a least-squares Simultaneous Multiframe Analytical Calibration (SMAC) adjustment. The x and y-coordinate measurements utilized in the adjustment of the above parameters have a standard deviation (σ) of ± 3 microns.