



United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Reston, Virginia 20192

REPORT OF CALIBRATION of Aerial Mapping Camera

October 1, 1999

Camera type:	Zeiss RMK A 15/23	Camera serial no.:	119015
Lens type:	Zeiss Pleogon A4	Lens serial no.:	123616
Nominal focal length:	153 mm	Maximum aperture:	f/4
		Test aperture:	f/4

Submitted by: Midwest Aerial Photography
Columbus, Ohio

Reference: Midwest Aerial Photography purchase order
No. 99-404, dated September 28, 1999.

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 multicollimator camera calibrator using a white light source rated at approximately 5200K.

I. Calibrated Focal Length: 152.927 mm

II. Lens Distortion

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

Symmetric radial distortion parameters

$$\begin{aligned} K_0 &= 0.2152 \times 10^{-4} \\ K_1 &= -0.4730 \times 10^{-8} \\ K_2 &= 0.1920 \times 10^{-12} \\ K_3 &= 0.0000 \\ K_4 &= 0.0000 \end{aligned}$$

Decentering distortion parameters

$$\begin{aligned} P_1 &= 0.3267 \times 10^{-6} \\ P_2 &= -0.2708 \times 10^{-6} \\ P_3 &= 0.0000 \\ P_4 &= 0.0000 \end{aligned}$$

Calibrated principal point

$$\begin{aligned} x_p &= 0.006 \text{ mm} \\ y_p &= -0.007 \text{ mm} \end{aligned}$$

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.

III. Lens Resolving Power in cycles/mm

Area-weighted average resolution: 79

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	113	113	95	95	95	67	57
Tangential lines	113	113	95	95	80	57	48

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 B No. 119073, the KL No. 118923, and the KL-F (36%) No. 129170 filters accompanying this camera are within 10 seconds of being parallel. This filter was used for the calibration.

V. Shutter Calibration

<u>Indicated exposure time</u>	<u>Effective exposure time</u>	<u>Efficiency</u>
1/200	3.25 ms = 1/310 s	72%
1/400	1.75 ms = 1/570 s	72%
1/600	1.17 ms = 1/855 s	72%
1/800	0.88 ms = 1/1145 s	72%
1/1000	0.70 ms = 1/1430 s	72%

The effective exposure times were determined with the lens at aperture $f/4$. 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 platen mounted in FK 24/120 film magazine No. 118784 does not depart from a true plane by more than 13 μm (0.0005 in).

The platen for this film magazine is equipped with an identification marker that will register "CZ331" in the data strip area for each exposure.

III. Lens Resolving Power in cycles/mm

Area-weighted average resolution: 80 (f/5.6)

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

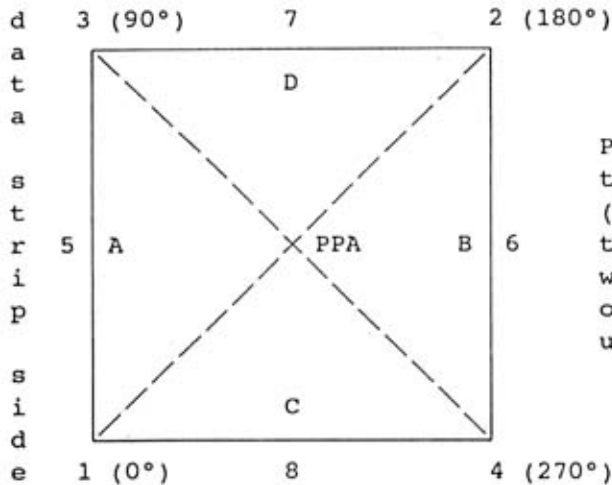
III. Lens Resolving Power in cycles/mm (f/8.0)

Area-weighted average resolution: 84

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

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.

	<u>X coordinate</u>	<u>Y coordinate</u>
Indicated principal point, corner fiducials	0.028 mm	-0.015 mm
Indicated principal point, midside fiducials	0.011	-0.008
Principal point of autocollimation (PPA)	0.0	0.0
Calibrated principal point (pt. of sym.) x_p, y_p	0.006	-0.007

Fiducial Marks

1	-104.977 mm	-105.015 mm
2	105.047	105.000
3	-104.988	104.991
4	105.038	-105.015
5	-112.990	-0.008
6	113.011	-0.007
7	0.013	112.979
8	0.009	-112.978

VIII. Distances Between Fiducial Marks

Corner fiducials (diagonals)

1-2: 297.012 mm 3-4: 297.007 mm

Lines joining these markers intersect at an angle of 90° 00' 14"

Midside fiducials

5-6: 226.001 mm 7-8: 225.957 mm

Lines joining these markers intersect at an angle of 89° 59' 56"

Corner fiducials (perimeter)

1-3: 210.006 mm 2-3: 210.035 mm

1-4: 210.015 mm 2-4: 210.015 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 250 mm with a 10 mm filter thickness. Additional filter thickness will increase entrance pupil distance by 0.34 X added thickness.

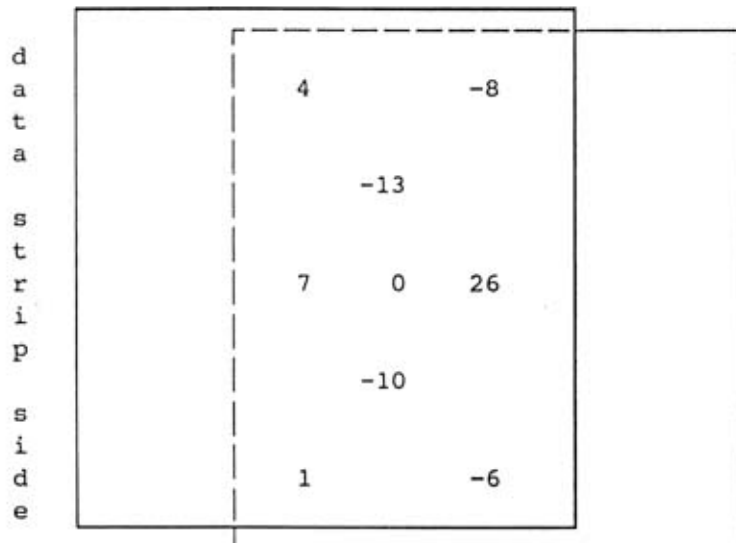
IX. Stereomodel Flatness

Magazine No.: 118784

Base/Height ratio: 0.6

Platen ID: CZ331

Maximum angle of field tested: 40°



Stereomodel
Test point array
(values in micrometers)

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: 40

Film: Type 2405

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	57	57	48	48	40	40	34
Tangential lines	57	48	48	48	40	28	28

This aerial mapping camera calibration report supersedes the previously issued USGS Report No. OSL/2214, dated July 9, 1996.

Frank C. Maccue
Frank C. Maccue
Chief, Optical Science Laboratory
National Mapping Division