United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Reston, Virginia 20192

REPORT OF CALIBRATION
of Aerial Mapping Camera

August 17, 2001

Camera type:	Zeiss RMK TOP 15*	Camera serial no.:	144117
Lens type:	Zeiss Pleogon A3/4	Lens serial no.:	144146
Nominal focal length:	153 mm	Maximum aperture:	f/4
		Test aperture:	f/4

Submitted by: Photo Science, Inc.
Lexington, Kentucky

Reference: Photo Science, Inc. purchase order
No. 95158, dated August 15, 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 multicollimator camera calibrator using a white light source rated at approximately 5200K.

I. Calibrated Focal Length: 152.874 mm

II. Lens Distortion

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

Symmetric radial distortion parameters

$K_0 = 0.7832 \times 10^{-4}$
$K_1 = -0.1425 \times 10^{-7}$
$K_2 = 0.5182 \times 10^{-12}$
$K_3 = 0.0000$
$K_4 = 0.0000$

Decentering distortion parameters

$P_1 = -0.2601 \times 10^{-7}$
$P_2 = 0.1533 \times 10^{-6}$
$P_3 = 0.0000$
$P_4 = 0.0000$

Calibrated principal point

$x_p = 0.002$ mm
$y_p = -0.002$ mm

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: 106

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

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 TOP 15 KL-F (36%) filter No. 144532, and the USGS TOP 15 test filter KL-F (60%) No. 142399 are within 10 seconds of being parallel. The USGS test filter, in conjunction with the internal "B" filter, was used for the calibration.

Indicated time (sec)	Rise time (μ sec)	Fall Time (μ sec)	½ width time (ms)	Nom. Speed (sec.)	Efficiency (%)
1/100	3910	3880	11.05	1/120	78
1/200	1898	1872	5.30	1/240	78
1/300	1277	1242	3.50	1/370	78
1/400	914	897	2.57	1/500	78
1/500	732	729	2.06	1/620	78

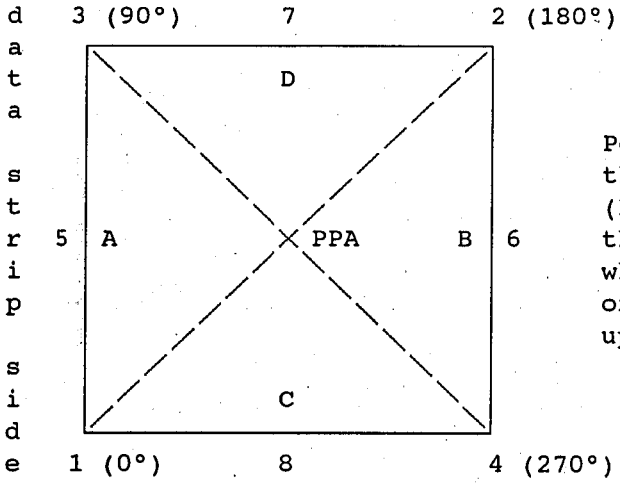
The effective exposure times were determined with the lens at aperture f/4. The method is considered accurate within 3 percent. The technique used is Method I described in American National Standard PH3.48-1972(R1978).

VI. Magazine Platen

The platens mounted in FK 24/120 film magazines No. 3653 and No. 129849, and in T-MC film magazine No. 144878, do not depart from a true plane by more than 13 um (0.0005 in).

The platen for film magazine No. 3653 is not equipped with an identification marker. The platens for the other film magazines are equipped with identification markers that will register "CZ194" for magazine No. 129849, and "144400" for magazine No. 144878 in the data strip area 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	0.003 mm	-0.005 mm
Indicated principal point, midside fiducials	-0.006	0.003
Principal point of autocollimation (PPA)	0.0	0.0
Calibrated principal point (pt. of sym.) x_p, y_p	0.002	-0.002

Fiducial Marks		
1	-113.002 mm	-112.999 mm
2	113.012	112.993
3	-112.993	112.991
4	112.997	-112.999
5	-112.997	-0.001
6	112.999	0.006
7	-0.004	113.003
8	-0.008	-113.010

VIII. Distances Between Fiducial Marks

Corner fiducials (diagonals)

1-2: 319.616 mm 3-4: 319.598 mm

Lines joining these markers intersect at an angle of 90° 00' 10"

Midside fiducials

5-6: 225.996 mm 7-8: 226.013 mm

Lines joining these markers intersect at an angle of 89° 59' 50"

Corner fiducials (perimeter)

1-3: 225.989 mm 2-3: 226.005 mm

1-4: 225.999 mm 2-4: 225.991 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 254 mm with a 10 mm filter thickness. Additional filter thickness will increase entrance pupil distance by 0.34 X added thickness.

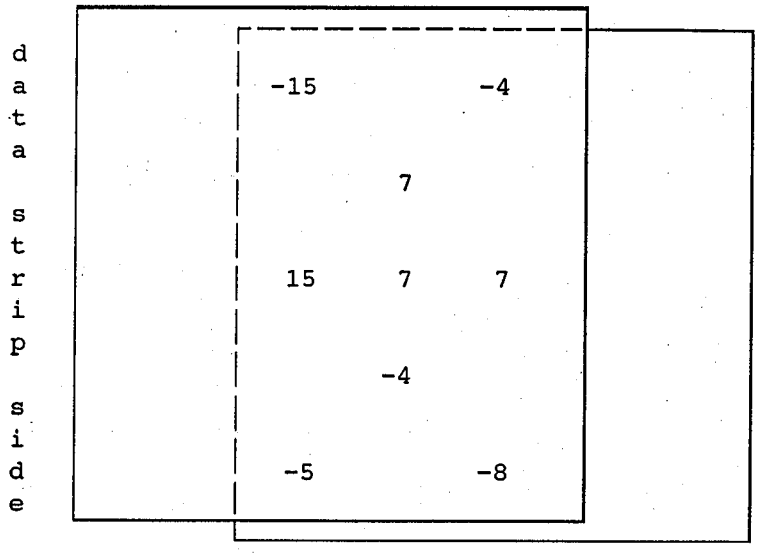
IX. Stereomodel Flatness

Magazine No.: 3653

Platen ID: n/a

Base/Height ratio: 0.6

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 ± 5 μm from model to model.

X. System Resolving Power on film in cycles/mm

Area-weighted average resolution: 43

Film: Type 2405

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

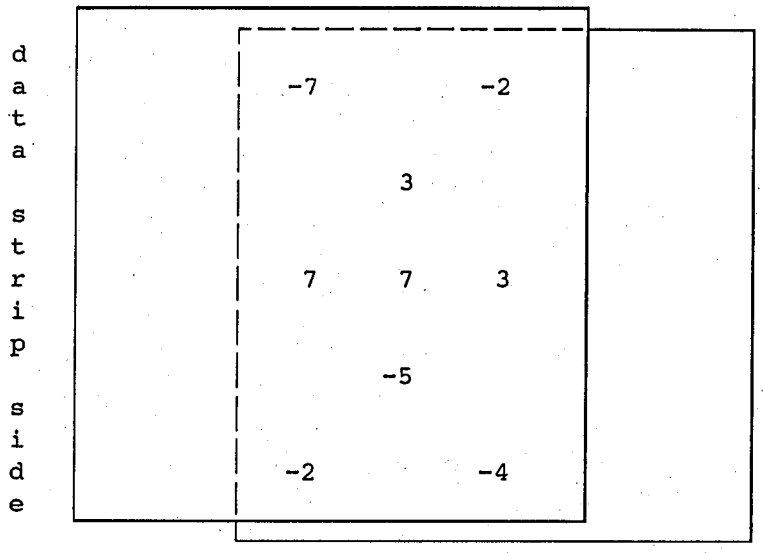
IX. Stereomodel Flatness

Magazine No.: 129849

Platen ID: CZ194

Base/Height ratio: 0.6

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 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: 51

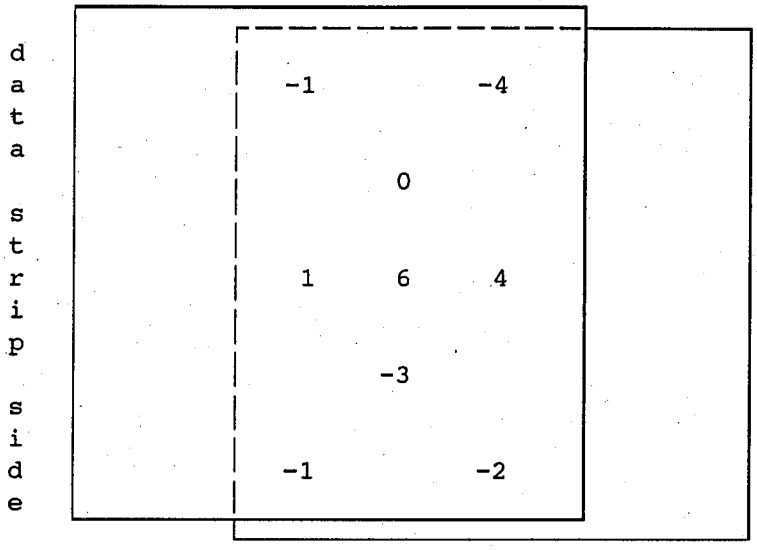
Film: Type 2405

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

IX. Stereomodel Flatness

FMC Magazine No.: 144878 Base/Height ratio: 0.6

Platen ID: 144400 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 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.

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This aerial mapping camera calibration report supersedes the previously issued USGS Report No. OSL/2472, dated August 13, 1998.

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