



United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Reston, Virginia 20192

REPORT OF CALIBRATION of Aerial Mapping Camera

November 1, 2001

| | | | |
|-----------------------|--------------------|--------------------|--------|
| Camera type: | Zeiss RMK TOP 15* | Camera serial no.: | 145844 |
| Lens type: | Zeiss Pleogon A3/4 | Lens serial no.: | 145891 |
| Nominal focal length: | 153 mm | Maximum aperture: | f/4 |
| | | Test aperture: | f/4 |

Submitted by: Midwest Aerial Photography
Galloway, Ohio

Reference: Letter of approval dated October 29, 2001,
signed by Ms. Jeannie Radford.

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: 152.992 mm

II. Lens Distortion

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

Symmetric radial distortion parameters

$$\begin{aligned} K_0 &= 0.1836 \times 10^{-4} \\ K_1 &= -0.7322 \times 10^{-8} \\ K_2 &= 0.4122 \times 10^{-12} \\ K_3 &= 0.0000 \\ K_4 &= 0.0000 \end{aligned}$$

Decentering distortion parameters

$$\begin{aligned} P_1 &= -0.2330 \times 10^{-6} \\ P_2 &= 0.2259 \times 10^{-7} \\ P_3 &= 0.0000 \\ P_4 &= 0.0000 \end{aligned}$$

Calibrated principal point

$$\begin{aligned} x_p &= 0.003 \text{ mm} \\ y_p &= -0.006 \text{ mm} \end{aligned}$$

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.

* Equipped with Forward Motion Compensation

III. Lens Resolving Power in cycles/mm

Area-weighted average resolution: 102

| 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 | 95 | 80 | 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 Zeiss TOP 15 KL-F (36%) filter No. 150025, and the USGS TOP 15 KL-F (60%) test filter 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.

V. Shutter Calibration

| Indicated time (sec) | Rise time (μ sec) | Fall Time (μ sec) | $\frac{1}{2}$ width time (ms) | Nom. Speed (sec.) | Efficiency (%) |
|-------------------------|---------------------------|---------------------------|----------------------------------|----------------------|-------------------|
| 1/100 | 3439 | 3471 | 10.98 | 1/110 | 81 |
| 1/200 | 1621 | 1655 | 5.51 | 1/220 | 81 |
| 1/300 | 1105 | 1111 | 3.60 | 1/340 | 81 |
| 1/400 | 844 | 826 | 2.71 | 1/460 | 81 |
| 1/500 | 644 | 637 | 2.16 | 1/570 | 81 |

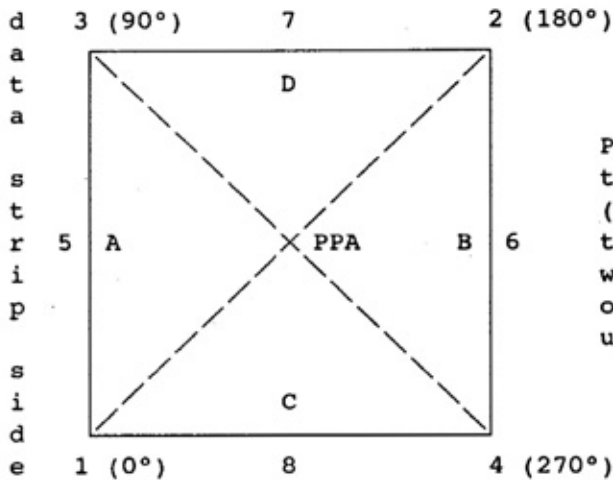
The effective exposure times were determined with the lens at aperture f/4. The method is considered accurate within 3 percent. The technique used is Method I described in American National Standard PH3.48-1972(R1978).

VI. Magazine Platen

The platen mounted in T-MC film magazine No. 145759 does not depart from a true plane by more than 13 μ m (0.0005 in).

The platen for this film magazine is equipped with an identification marker that will register "144862" 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.

| | <u>X coordinate</u> | <u>Y coordinate</u> |
|---|---------------------|---------------------|
| Indicated principal point, corner fiducials | 0.020 mm | 0.011 mm |
| Indicated principal point, midside fiducials | 0.016 | 0.010 |
| Principal point of autocollimation (PPA) | 0.0 | 0.0 |
| Calibrated principal point (pt. of sym.) x_p, y_p | 0.003 | -0.006 |

Fiducial Marks

| Fiducial Mark | X coordinate | Y coordinate |
|---------------|--------------|--------------|
| 1 | -112.982 mm | -112.982 mm |
| 2 | 113.017 | 113.000 |
| 3 | -112.980 | 113.014 |
| 4 | 113.009 | -112.982 |
| 5 | -112.985 | 0.018 |
| 6 | 113.027 | 0.002 |
| 7 | 0.019 | 113.011 |
| 8 | 0.014 | -112.980 |

VIII. Distances Between Fiducial Marks

Corner fiducials (diagonals)

1-2: 319.599 mm 3-4: 319.602 mm

Lines joining these markers intersect at an angle of 90° 00' 04"

Midside fiducials

5-6: 226.012 mm 7-8: 225.991 mm

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

Corner fiducials (perimeter)

1-3: 225.996 mm 2-3: 225.997 mm

1-4: 225.991 mm 2-4: 225.983 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.

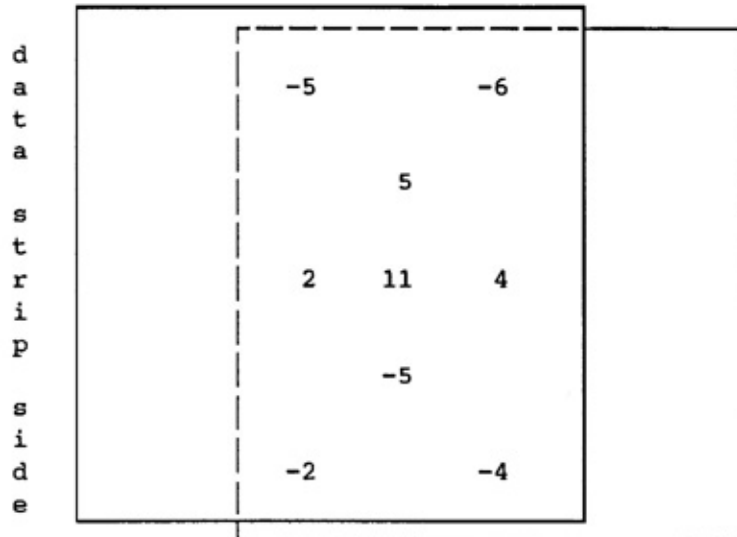
IX. Stereomodel Flatness

FMC Magazine No.: 145759

Base/Height ratio: 0.6

Platen ID: 144862

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: 50

Film: Type 2405

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

LENS/FILM DISTORTION PARAMETERS

FMC Magazine No.: 145759

Base/Height ratio: 0.6

Platen ID: 144862

Maximum angle of field tested: 40°

XI. Calibrated Focal Length: 152.985 mmXII. Lens/Film Distortion

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

Symmetric radial distortion parameters

$$\begin{aligned} K_0 &= -0.6994 \times 10^{-4} \\ K_1 &= 0.4728 \times 10^{-8} \\ K_2 &= 0.5211 \times 10^{-13} \\ K_3 &= 0.0000 \\ K_4 &= 0.0000 \end{aligned}$$

Decentering distortion parameters

$$\begin{aligned} P_1 &= 0.1277 \times 10^{-7} \\ P_2 &= 0.1475 \times 10^{-6} \\ P_3 &= 0.0000 \\ P_4 &= 0.0000 \end{aligned}$$

Calibrated principal point

$$\begin{aligned} x_p &= 0.003 \text{ mm} \\ y_p &= -0.006 \text{ mm} \end{aligned}$$

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.

This aerial mapping camera calibration report supersedes the previously issued USGS Report No. OSL/2483, dated September 18, 1998.



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