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Total System of Evaluating Aerial Survey Cameras of G.S.I.

I. Abstract

It is well known that all photogrammetric measurements are performed using photographs. Geometric accuracy and amount of information obtained by interpretation depend on the quality of the photographs. The quality of photographs is very much influenced by the quality of a camera which is used to take photographs.

Therefore it is important for a user to be able to assess a survey camera properly.

For this purpose, G.S.I. of Japan had been studying the methods of calibrating aerial survey cameras for 3 years with the cooperation of scientists and experts of universities, institutions and companies which were concerned optical instruments, photogrammetry and image technology.

Based on this study, G.S.I. is going to complete a total system of evaluating aerial survey cameras.

In this paper, the outline of the system is explained and some results of measurements are reported.

II. Items of Calibration

The following items are planned to be calibrated in the total system.

(a) Geometric optical performance of a aerial survey camera.

- (1) Distance between the fiducial marks.
- (2) Mutual position of intersecting point of the fiducial marks and the principal point of autocollimation.
- (3) Mutual position of the principal point of symmetry and the principal point of autocollimation.
- (4) Effective calibrated focal length.
- (5) Distortion.

- (6) Chromatic aberration (longitudinal aberration)
- (7) Flatness of the film surface
- (b) Image forming performance of aerial survey cameras.
 - (1) Resolving power
 - (2) M T F
 - (3) P T F
- (c) Photometric performance of a aerial survey camera.
 - (1) Exposure time
 - (2) F-number
 - (3) Spectral transmittance
 - (4) T-number
 - (5) Uniformity of image illuminance
 - (6) Flare
 - (7) Ghost
 - (8) Blue spot

III. Methods of Calibration

Methods of calibration of each item are following :

- (a) The geometric optical performance and the resolving power of a camera to be calibrated should, in principle, be examined by a collimator array or a goniometer.
The length of the picture image should be measured by a comparator with an accuracy of more than one micrometer.
- (b) Chromatic aberration should, in principle, be measured by a monochromatic filter fixed to a goniometer and by a naked eye using a micrometer microscope.
- (c) The flatness of the film surface should, in principle, be measured by moiré topography.
- (d) MTF and PTF should be measured according to the linear photometric Fourier transformation of a photo-electrically measured line spread.
- (e) The exposure time and the uniformity of image illuminance should be measured according to the measurement and calculation methods of exposure, using an instrument for measuring illuminance of the image surface.

- (f) Blue spot should be measured according to the illumination method, using an instrument for measuring blue spot.

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IV. Measurement of the Modulation Transfer Function (MTF)

The principle of the measurement of MTF of the system is based on the digital Fourier transformation of the photoelectrically measured line spread function (LSF).

An optical arrangement to obtain LSF is illustrated in Fig. 1.

A slit illuminated by the light source and optical fiber assembly is projected, by the tested lens, through a variable light bender which locates the projected slit image on the scanner when image height is changed and also through a collimator lens which makes line images on the scanner. The helical scanning slit is rotated by a synchronous motor, and spacial distribution of LSF is converted to a periodic time signal.

This signal is put into a microcomputer through an interface, and the discrete Fourier transformation by the following equation is processed digitally.

$$F(fi) = \sum_{k=1}^N L(x_k) \exp \left\{ i \frac{2\pi f j x_k}{N} \right\}$$

The processor has a display capability for LSF and MTF on a CRT and also for a X-Y recorder. (Fig. 2)

Since aerial survey cameras are usually used for infinite conjugates, MTF measurement must be done at a fixed focal plane on which the film is located. Therefore the following procedures are necessary.

(a) Image plane

Slit are made on a flat (within 5 m) glass surface. This surface is put in contact with the mechanical surface of the camera as a replacement of the pressure plate. The scanner is placed exactly at the focus of the collimator lens.

(b) Light quality

MTF is measured for the white light, rather than the monochromatic light, in a combination of a halogen lamp of 3,300 k

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- 1) Prof. Kazumi Murata and Dr. Kazuo Sayanagi were in charge of the study of this item as the committee member.

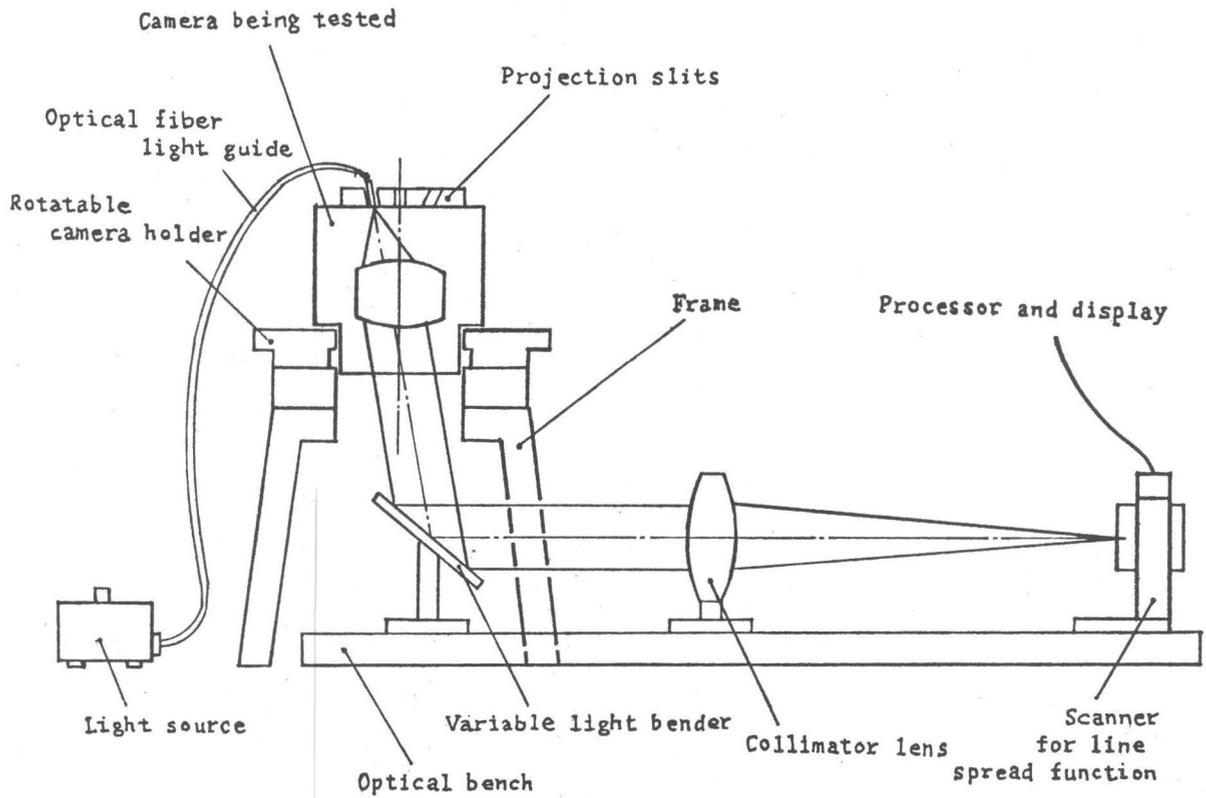


Fig. 1 Optical arrangement of the Lens Analyzer

LENS ANALYZER LA-G10

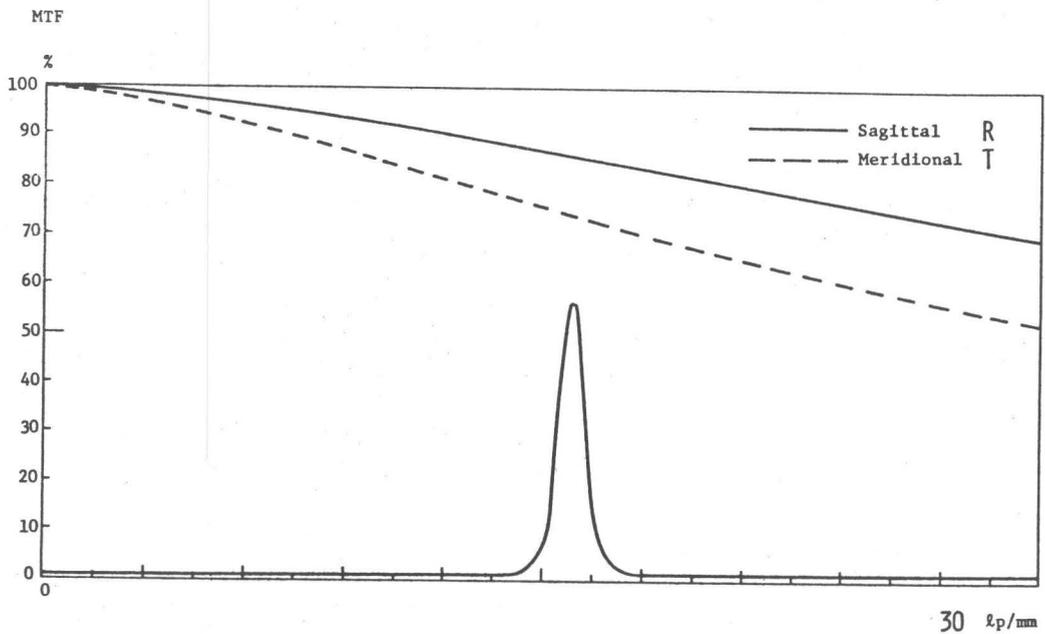


Fig. 2 Line spread function and MTF recorded on X-Y recorder

and a photomultiplier (R 372).

(c) Image height

Since the optical system has rotational symmetry, image performance has symmetric characteristics. Locations of measured points on a film plane are expressed by distances from the center of the film and are called image height.

(d) Azimuth (R, T)

MTF is tested at each image height in two slit directions, namely radial and tangential, based on the rotationally symmetrical nature of the optical system.

(e) Symmetrical deviation

Lenses deviate from the symmetrical nature of the system because of manufacturing errors. Four radial directions are chosen along semi-diagonals of the picture format to check the local effects of symmetrical deviation.

(f) Slit width

Two slits are used in this measuring system. One is used as the object (light source) and the other as the scanning slit. The width of the former is 10 m and that of the latter is 50 m. These slit widths affect blurring of LSFs to be measured. Our processor compensates for the above error in the final MTF results obtained by means of software digital calculations.

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V. Collimator Array Camera Calibrator

This instrument consists of a collimator array, a collimator supporting table, an autocollimator, an autocollimator supporting arm, a camera supporting table and 4 collimators for imaging fiducial marks.

The collimator array consists of 81 collimators. They are arranged hemispherically at every 7.5 from 0 to 60 along the planes which cross each other at 30 as is shown in Fig. 3. All collimators are installed so that their optical axes converge at a point around which the objective lenses of

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- 1) Prof. Yasufume Emori was in charge of the study of this item as the committee member

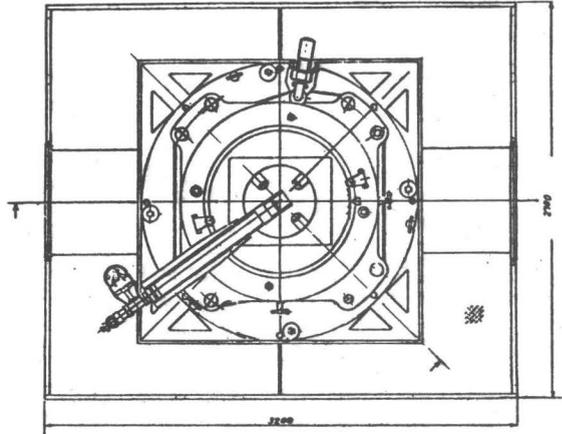
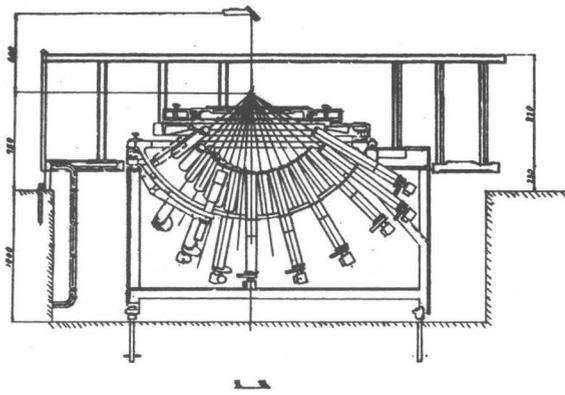


Fig. 3 Collimator Array Camera Calibrator

the collimators are set up hemispherically. The focal length of all collimators are the same. A test chart, having a cross line for measuring distortion and three bar charts for measuring the resolving power, is kept on the focal plane. (Fig. 4)

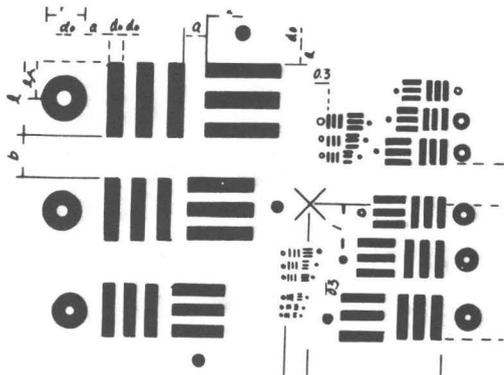


Fig. 4 Test Chart

The test chart is illuminated by the light source with a lamp of 6 V, 50 W.

Each collimator has 7 filters such as blue, green, red, infr-red, yellow, color balance and haze cut. These filters can be changed by switching on the control board.

The objective lens of the collimator is aprochromatic and insertion

of a filter does not change the focal point.

Following 5 types of camera mounts can be set on the camera supporting table : camera mount for RMK, RMKA, RC-8, RC-9 and RC-10.

VI. Results of measurments of resolving power.

Resolving power of a camera is determined visually and using MTF. In the visual test, the test chart of the collimator is imaged on a glass plate which is coated by fine graine

emulsion. After a proper photo-processing, the resolving power is determined visually under x 30 microscope.

In the MTF method, the cross point of MTF curve and the curve of the 0.03 threshold contrast of the human eye is assumed to give the corresponding resolving power.

Fig 5 shows one example of the results of the test. Resolving power is measured at the points along diagonals.

Area weighted average resolution of this camera is 25 l/mm by visual test and 17 l/mm by MTF method.

The tested camera has been used for many years in practice without any overhauling. It may be the reason why the makers data differ considerably from our results.

We, however, tested more than ten cameras and we found that resolving powers of aerial cameras are not so high as we expected.

VII. Conclusions

Aerial Survey camera must fulfill many difficult requirements concerning geometrical accuracy and quality of image.

It, however, is clear that the quality of a camera deteriorates after long service even with careful handling.

According to our experiments, the items of deterioration are not only resolving power but also flatness of the film surface during exposure, uniformity of image illuminance and so on.

And for this purpose, a standard methods of calibration and proper criterions must be determined.

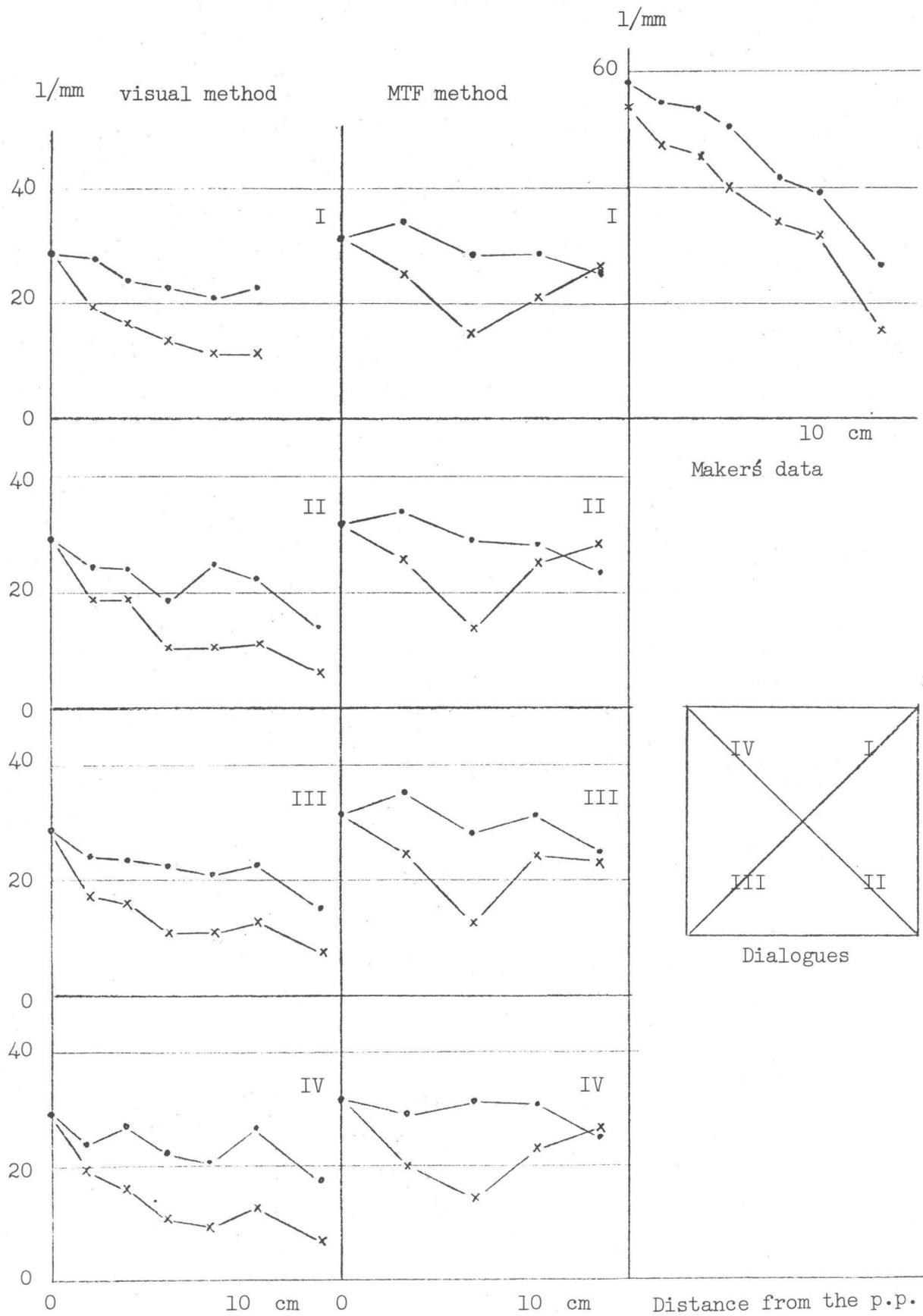


Fig. 5 Resolving Power of a camera by two methods