THE CALIBRATION OF AIR CAMERAS IN CANADA

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THIS account of the methods followed at the National Research Laboratories, Ottawa, in calibrating air cameras is presented because (a) it may be informative to those readers who, while using hundreds of air photographs, rarely come into contact with the equipment employed to originate them and (b) it is of some historical interest as a development which commenced with the pioneer work in Canadian photogrammetry on the part of the late Dr. E. G. Deville. In this latter regard, it is worthy of note, that the apparatus of these laboratories still includes the original collimators set up and adjusted by Deville some 35 years ago when he initiated laboratory methods for measuring the constants and checking the adjustments of transits, levels, terrestrial surveying cameras and other instruments. The first air camera to be calibrated in Ottawa, in 1920,[1] was measured with the same laboratory apparatus and almost by the same methods that had been applied for several years in calibrating the then well-known Deville surveying camera. These methods have been gradually developed, and the apparatus and procedure now employed for some of the essential measurements are here described.

In air or terrestrial camera calibration the most important constants to be measured—giving consideration to perspective projection rather than to purely optical or photographic characteristics—are the principal point (P.P.) and the principal distance (P.D.).

Principal Point Location

Auto-collimation affords a ready means, in most instances, for finding the P.P., and Figure 1 shows the simple set-up used with this method at Ottawa. The camera is placed, with the focal plane horizontal, on a base supported from a concrete pier on three footscrews, and having a hole near its centre. Beneath the hole in the base is an iron tray containing mercury. For the purpose of accurately levelling the focal plane, use is made of the small level seen in the picture. This is fitted with a vial of about 40″ value per division, and three hard steel balls are peened into holes in the base to give a three point support on any surface. A hard rubber handle is provided for convenience and to minimize the effect of heat from the operator's hand.

When the camera embodies a glass focal plane plate, as in the illustration, levelling is direct. For suction-back or allied types with no glass, a piece of flat glass plate must be laid on the rim or other parts defining the focal plane. In addition, cameras of this latter type must be fitted with a marker to substitute for the cross usually etched at the P.P. of glass focal plates. We have found an old transit reticle to be quite suitable for this purpose. It is fitted in a short piece of tubing soldered to a plate and has the usual opposing capstan screws for centering. The plate is shaped so that it can be attached to the camera by some convenient means, and shimmed to bring the cross lines into the focal plane. One of these auxiliary markers is seen in the picture opening of the camera in Figure 2.

In the case of the etched crosses, a reflecting eyepiece and a lamp, seen in Figure 1, permit the observer to see direct and reflected images of the cross. An

[1] Field, R. H. The first air calibration in Canada. The Canadian Surveyor. Vol. VIII-5, 1944.

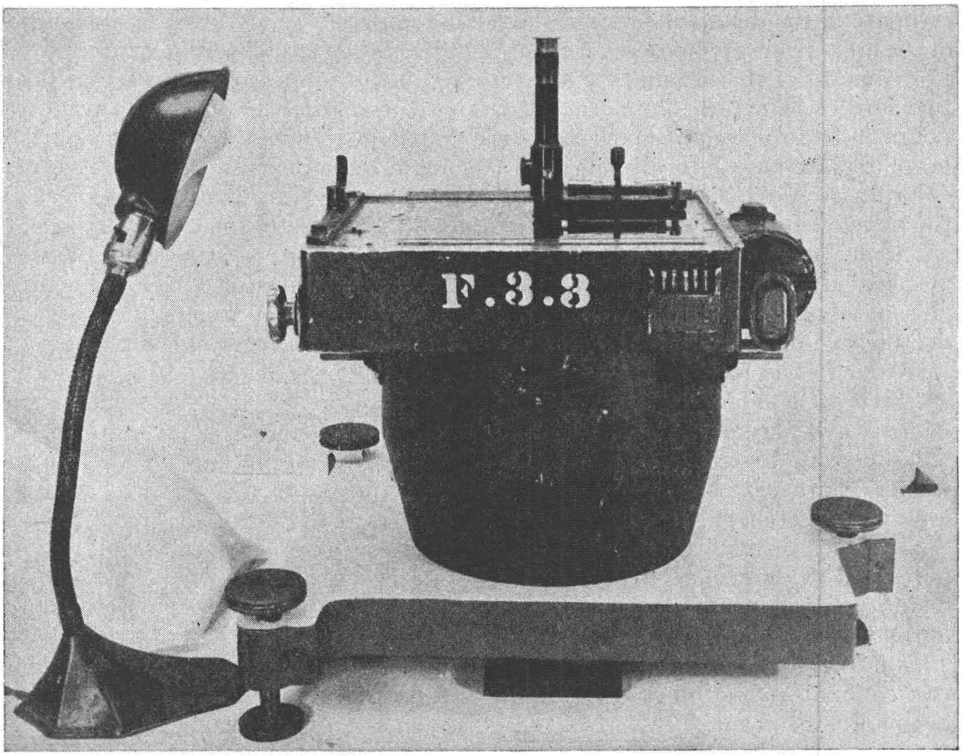

FIG. 1. Principal point location, auto-collimation method.

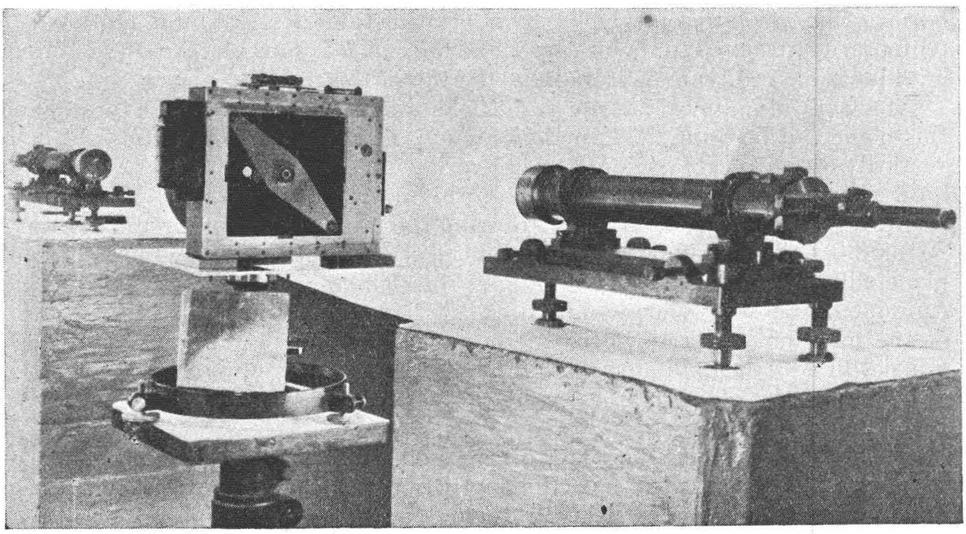

FIG. 2. Principal point location, using two collimators.

estimate of the distance between these close images is easily made if the lengths of the cross-arms are known; and that distance is twice the position error desired. For cameras of the second type the reticle capstan screws are adjusted until the two images coincide. The actual record of the relation between the principal point and the marginal markers is best found in this case by laying a photographic plate on the focal plane and flashing a light through the lens. A Mann co-ordinate measuring engine is used for measuring the required distances on the developed plate, which also may be found very useful for later reference.

Sometimes the actual location of the P.P. indicators must be restored after an accident or camera overhaul. This is a simple operation when the central cross is used. A pointed piece of adhesive paper is moved about under the reflecting eye-piece, after levelling the focal plane, until the point and its image just touch. The paper is stuck down. Four auxiliary stickers and a special jig are then used to locate four fine pencil witness marks 90° apart and each about 2 inches away from the P.P. After next removing the central pointed sticker, an etching ground is painted about the P.P. and the same jig, now located on the witness marks, is used to rule in the arms of the cross one at a time, and the cross can be etched.

In order to restore the marginal marks where there is no glass plate, it is necessary to determine the location, at the picture margins, of the images of distant points in each of two intersecting planes (usually at 90°), and both normal to the picture plane and, furthermore, containing the outer lens node. This is readily accomplished with the equipment illustrated in Figure 2. The two collimators rest on concrete piers, are directed upon one another and have been adjusted accurately horizontally by means of a geodetic level set up on the testing stand, the upper part of which can be seen between the piers.

When in use for calibrating air cameras, a metal table mounted on the skeleton base of a 12 inch geodetic theodolite is placed on the testing stand, as shown. The camera is set on the table with its lens approximately over the centre of rotation of the theodolite base at nearly the height of the common collimator axis, and, with the picture plane nearly vertical. To control the position of the camera with reference to rotation about the lens axis and the horizon line, a plate, on which a pair of adjustable level vials is mounted, is temporarily attached to the upper side of the camera. This plate and the horizon level is visible in Figure 2, just above the top of the camera.

If a front-aluminized flat mirror be held or lightly clamped in the focal plane, this plane can be brought normal to the axis of the right collimator (i.e., truly vertical) by auto-collimation and use of the theodolite foot screws. The axial level vial is then centered or read for this position. The camera can now be swung around to any position, by rotating the table, and if the level bubbles be restored to their original locations by adjusting the footscrews, the picture plane will be again vertical. Continuing the swinging until the edge of the picture opening is seen when looking into the left collimator, the correct location of the marginal mark is where the edge is apparently cut by the horizontal fiducial line of the collimator diaphragm. This is apparent from consideration of the properties of collimators—and a properly focussed camera can also be regarded as a collimator.

It is interesting to note that this method, almost as described, was in use many years before the advent of air photogrammetry for setting the collimating marks of Deville cameras. Actually the operation is a little simpler for the terrestrial cameras, in that the lens can be easily removed and a single collimator used—making the preliminary auto-collimation through the lens opening.

Terrestrial cameras, too, are fitted with permanent axial and horizon level vials.

Actually, in using the method with air cameras, it is convenient to fit the temporary diaphragm mentioned previously. Not only can the position of the P.P. be found first by the auto-collimation method (Fig. 1), and some labour saved, but during the operation of adjusting the marginal markers, the camera can be swung back at any time to check the adjustment of the axial level vial by sighting through the left collimator. Furthermore, cases have been reported[2] where, due to faulty centering of the lens components or other asymmetry, the simple auto-collimation method does not yield the true position of the image of the nadir when the picture plane of the camera is horizontal. Our experience

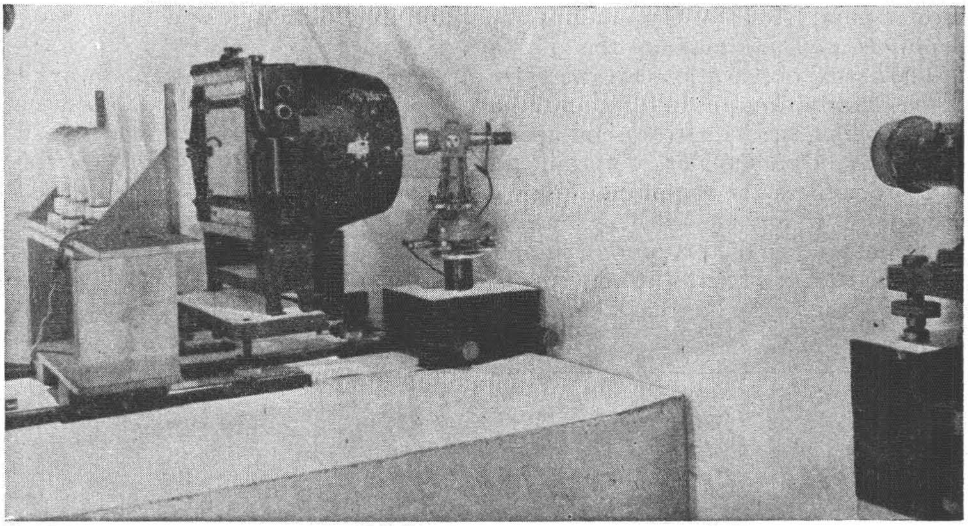

FIG. 3. Principal distance and lens distortion measurement.

has been indefinite in this respect. Where there have been appreciable discrepancies between the two methods of P.P. determination, they have usually been traced to looseness of lens components or mountings or to departures from a true plane of the glass plate or other available means of defining the actual picture plane.

PRINCIPAL DISTANCE MEASUREMENT

The apparatus employed for measuring the P.D. of air cameras is also relatively simple.[3] The actual set-up is illustrated in Figure 3, and again the collimator piers are utilized. A glass plate bearing diametral lines crossed by short lines at one centimetre intervals (which have been calibrated) is placed in the focal plane with its graduated surface towards the lens. The auto-collimation method (Fig. 1), can be used to bring the central zero mark to the P.P. before clamping the plate in position. During observations the camera is carried on a simple stand with footscrews resting on rails, and which can accommodate lenses of various focal lengths. In front of the lens a small Wild transit reading to single

[2] Hotine, Captain M., C. E. H. M. Calibration of Surveying Cameras. Stationery Office, London, 1929. P. 54.

[3] Field, R. H. A Determination of the Distortion in a Number of Air Camera Lenses. Canadian Journal Research, 10: 239–243. 1934.

seconds, is mounted on a block of cast-iron resting on two round bars fixed to the top of the pier, so that the transit can be slid in a direction approximately parallel to the picture planes. On a second pier there is a collimator just visible to the right in Figure 3 at the height of the transit telescope axis, which serves as a reference azimuth.

For adjusting the camera into position the transit telescope is levelled, directed on the collimator and then turned through 90°. By levelling and turning the camera slightly the image of the zero mark or the glass plate can be brought on to the telescope cross-lines, and the diametral line under observation on the glass plate rendered horizontal. During this and all other adjustments, where necessary the apertures of the telescope and the camera lens are maintained approximately in the centered condition with the aid of a magnifier used to view the exit pupil. A set of three lamps and a diffuser, placed behind the picture opening is used to illuminate the graduations.

The actual observations are made by directing the transit telescope through the lens on to the marks in turn, and measuring the azimuth of each with respect to the collimator. Thus the semi-apex angles of cones of base radius 1, 2–20 cm. inside the cameras are determined, and each angle yields a length for the P.D. From these the radial distortion in the picture plane is easily calculated with respect to any chosen P.D., and a value of the calibrated P.D. derived for minimum average distortion on the photographs.

In the case of cameras fitted with glass focal plane plates, this method of determining the distortion has the advantage that it includes the effect of the plate.