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PM-1 POINT TRANSFER INSTRUMENT
A NEW MODULE IN THE ZEISS SYSTEM FOR ANALYTICAL PHOTOGRAMMETRY

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1. Introduction

Aerial triangulation is a technique of which extremely wide use is presently made everywhere in the world. As computer technology, the mathematical basis and software have improved, the requirements made of the quality, speed and accuracy of the technique have increased as well. However, point transfer has proved to be a particular bottleneck in aerial triangulation. To overcome this difficulty and further advance development of the technique, CARL ZEISS of Oberkochen offers the following contributions:

- Improvement of quality and accuracy of point transfer.
- Practically error-free measurement of image coordinates.
- Continuous quality control due to on-line computation.

In doing so, the time-tried method of clearly subdividing the work into

- preparation,
- point transfer,
- measurement

has been preserved, the latter item with the aid of computer support. In detail, CARL ZEISS followed two different lines of development (Fig. 1):

1. Low-cost equipment, including
   point transfer instrument, monocomparator and desk calculator.
2. Sophisticated all-round systems, including
   point transfer instrument, stereocomparator or analytical
   plotter with minicomputer and block-triangulation programs.

This paper deals above all with the simple system mentioned under 1., focusing on point transfer. In the following, the technique of total point transfer (marking every point in every photo) and measurement in individual photos, used in that system, will be called "mono method".

2. PM-1 Point Transfer Instrument

As accuracy requirements have increased in the triangulation with artificial points, it has been found that accuracy itself is primarily a function of point transfer. As a result, it does not make sense to combine low-accuracy point-transfer equipment with costly precision measuring machines in one system. The ZEISS development therefore was aimed at creating a point transfer instrument whose production rate and accuracy would be commensurate with those of precision measuring machines.

2.1 Purpose and concept

Aerial triangulation with artificial points makes the following point-marking requirements, depending on whether the material will later be processed stereoscopically or monoscopically:

- Points have to be marked in only one photo.
- Points have to be transferred, that is, after setting a point marked in a first photo, parallax has to be cleared in a second photo and the point marked in the latter.
- Points have to be simultaneously set in a photo pair and marked.

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When dimensioning equipment ranges, allowance has to be made for the following:

- Extreme end and side laps, including 60 % side lap (Fig. 2).
- Techniques in which a point is marked in one photo and successively transferred to all other photos (Fig. 3), the first one being retained with high accuracy. This method was first suggested by van den Hout and will henceforth be called "point-by-point transfer".
- Alternative orientation of side-lap range either parallel to or across the operator's eye base.

Another important question is whether the photos are shifted over the model range either free-handedly on photocarrier plates or with the aid of a parallel-guided photocarriage (either in common or parallactically). Preference was here given to the "conventional" free-handed shifting as opposed to a cross-slide system, since the latter

- would require an x-carriage of at least 800 mm and thus give rise to considerable problems of design and operation;
- would require both the photos and the carriage to be clamped; and
- makes crosswise transfer by parallel shifting of the photos and point-by-point transfer impossible.

2.2 Design

2.21 General

In accordance with the general concept described before, a design was chosen (Fig. 4) which offers the operator a free and easily accessible work area in the form of two photoholder plates (1) resting on a casting (2) and adjustable either in common or separately by ± 15 mm in the x and y-coordinates. The measuring optical system including the measuring marks is located in the basic casting. The viewing optical system is contained in the optical-system carrier (3) projecting from the rear over the work area. The two marker assemblies (4) to the left and right of the optical-system carrier are firmly mounted on the basic casting. The basic opto-mechanical unit, and especially the marking process, are controlled and supplied with power by the control unit (5). All controls are centered on the front (6) of the machine.

2.22 Coordinate motions

The photo pair is positioned on the photoholder plates in accordance with its overlap, shifted by hand and automatically clamped by device (7), upon depression of the foot control. The central fine adjustment (8), to which the photoholder plates can be magnetically coupled either in common or separately left and right, is used for precise pointing and for clearing parallax. In the fine-adjustment range, the photoholder plates are guided parallel to the x and y-coordinates. The pointing and parallax-clearing procedure is thus equivalent to the one used in the PSK-2 Stereocomparator or the C-100 PLANICOMP.

2.23 Optical system (Fig. 5)

The photo (1) to be marked is reflected (3) and focused on an intermediate plane with a measuring-mark mirror (7) by the zoom lens (6). Four different point measuring marks of various diameters are available either as black or luminous marks.

The intermediate images are viewed through the eyepieces (10), Dove prisms (9) allowing individual or common image rotation, the latter through 90° and 180°. A focusing member (4) gives a vertical focusing range of 7 mm to allow for different plate thickness. The plane-parallel plate (5) serves to adjust the measuring mark on the marked point.

The optical system is remarkable for its high quality, its resolution going up to 120 l/mm (26x magnification).

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2.24 Marking

The artificial points are produced by a needle (Fig. 6) which has the shape of a conical frustrum. This is heated to approx. 150° C and applied to the photo with defined pressure and speed. The needle is inductively heated within approx. 2 s, high-frequency current being applied to the coil surrounding it. As the needle makes contact with the emulsion, the latter melts and is displaced towards the outside so that an annular bulge around a clear central area is obtained, which will appear as a dark ring when viewed in the measuring instrument. The mark is equally effective on film and plates and against a background or bright or dark detail (Fig. 7). Due to the smooth surface of the points, these are insensitive to dust and damage and thus can be considered permanent.

Allowance for different films and plates can be made by varying the dwell of the needle on the emulsion. At present, needles are available for points with diameters between 40 µm and 200 µm. The clamping system makes automatic allowance for film or plate thickness. To facilitate the relocation of marked points, a second, rotary tool with a fiber pen can be swung in and lowered to produce an annular mark. The point and annular marks can be made either simultaneously or separately. Marking with a fiber pen has the following advantages:

- The emulsion is not destroyed.
- The photo remains transparent even where it is marked.
- Different colors and diameters are available.
- The mark can be erased.

The technical data of the PM-1 are summarized in Fig. 8.

2.3 Accuracy

The accuracy of point transfer is a function of:

- The quality of marked points.
- The accuracy with which x and y-parallax is cleared, especially in the case of points that are already marked on one photo.
- The reproducibility of markings, that is, the coincidence of measuring mark and marked point.
- Long-time stability of adjustment of the machine.

If point quality is good, the measuring mark of the point transfer instrument or the measuring machine can be adjusted on the marked point with high accuracy. In a test made with a PK-1 Precision Comparator, for example, PM-1 points were set with an rms coordinate error of ± 0.8 µm.

The accuracy with which parallax is cleared depends both on subjective factors - such as the experience of the operator, the quality of the aerial photography or the topography - and on equipment characteristics. In the PM-1, conditions are very favorable due to high-quality optics, smooth carriage motion and image rotation through 90°. Contrast at and around the marked point is so that it has little effect on stereoscopic viewing.

As is evident from Fig. 9, the reproducibility of markings is approx. ± 1 µm. In the PM-1, reproducibility can be found by marking a point, resetting the measuring mark on the point and measuring the deviation between the new and the old positions of the photoholder plate. The reproducibility value thus found therefore also contains pointing errors.

The stability of adjustment of the machine can be checked in a similar manner. Fig. 10 shows the displacement of marked points in relation to the measuring mark, markings and measurements being made over a period of eight hours at intervals of five minutes. Particularly remarkable is the stability in the x-coordinate, which specially favors the vertical accuracy of transferred points.

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2.4 Equipment characteristics

In view of the point-transfer bottleneck in aerial triangulation and the general trend towards more effective tie-in within blocks - that is, transfer of a larger number of points - the PM-1 was, above all, designed for higher operating speed. First experience has shown that this has been attained due to

- The easy accessibility and visibility of the work area.
- Rapid free-handed shifting of photos and central location of the two fine-adjustment controls.
- Clamping of photography controlled by foot switch and rapid change-over between parallactic and common motion.

Another design specification was that the PM-1 should be universally applicable to the preparation of aerial triangulation work. This means that it should be possible to handle extreme overlap ratios, to vary the diameter of marked points whithin wide limits (40 µm to 200 µm) and to choose between point and annular marks. As a result, for example, minute natural detail can be marked and used for tie-in in combination with artificial points. Larger points without any annular mark may, for instance, be used directly for orienting aerial photography in rectifiers.

In the PM-1, a point transfer instrument has thus been created which satisfies very high requirements and lays the basis for aerial triangulation by the "mono method".

3. PK-1 Precision Comparator

The next essential component of the system is a monocomparator. The PK-1 Precision Comparator introduced by CARL ZEISS in 1976 |1| allows image coordinates to be measured with an accuracy of at least ± 1 µm |2| (Fig. 11). The accuracy of PM-1 and PK-1 thus is equivalent.

4. CAMOC Program System

Practical experience has shown that monocomparator measurement is more susceptible to point confusion, ambiguous point definition and loss of points than stereoscopic measurement. This is why the on-line computation of relative orientation and interactive error correction are of particular importance for comparator measurement. Moreover, cleared model coordinates can be computed and used as direct input for the popular technique of modelblock triangulation. In addition to the extremely farreaching program PK 1-AS for minicomputers |3|, a simple program for desk calculators is now available for this purpose, which is called CAMOC (Computer-Assisted Monocomparator Measurement).

CAMOC is based on the PRO program developed by the Institute of Photogrammetry of Stuttgart University for stereocomparators and off-line processing in medium-size computers and converted for monocomparators and on-line HP-9825 desk calculator by Chia-Yuan Chen of Taiwan. It is based on the equipment configuration shown in Fig. 12.

The program consists essentially of the following sections:

- Automatic transfer of point numbers and x,y-machine coordinates to the calculator.
- Computation of interior orientation with allowance made for film shrinkage, distortion correction and earth-curvature correction.
- Determination of identical points in the overlap area with the aid of the point numbers entered.
- Computation of relative orientation and output of residual parallax.

- Interactive error correction with correction of point numbers, elimination of points and new and repeat measurement of points, new computation of relative orientation, etc.
- Output of image or model coordinates on peripheral equipment for bundle or model-block triangulation.

The program processes up to 50 points per photo and 30 points per overlap area. The computer time for relative orientation with 12 points is approx. 30 seconds. The program thus reduces equipment outlay and offers the following advantages:

- It makes monocomparator measurement safer.
- It links model formation to the measuring instrument so that the conditions for off-line block triangulation are similar to those encountered in stereoscopic machines.

References

|1| SCHWEBEL, R.: The new PK-1 Precision Comparator, Bildmessung und Luftbildwesen 44, 147 et seq., 1976.

|2| SCHWEBEL, R.: Die Genauigkeit des Präzisionskomparators PK-1, Zeitschrift für Vermessungswesen 104, 1979.

|3| HOBBIE, D.: Interactive acquisition and editing of photogrammetric data with the ZEISS AS Program System for minicomputers, 37th Photogrammetric Week 1979, Stuttgart.

Abstract

The paper presents the new PM-1 Point Transfer Instrument by CARL ZEISS of Oberkochen. In view of the overriding importance of point transfer for the accuracy of aerial triangulation, the instrument was designed for high point quality, reproducibility of marks and operating speed. The PM-1 thus is a valuable addition to the existing ZEISS hardware and software system for analytical photogrammetry.

Das Punktübertragungsgerät PM-1

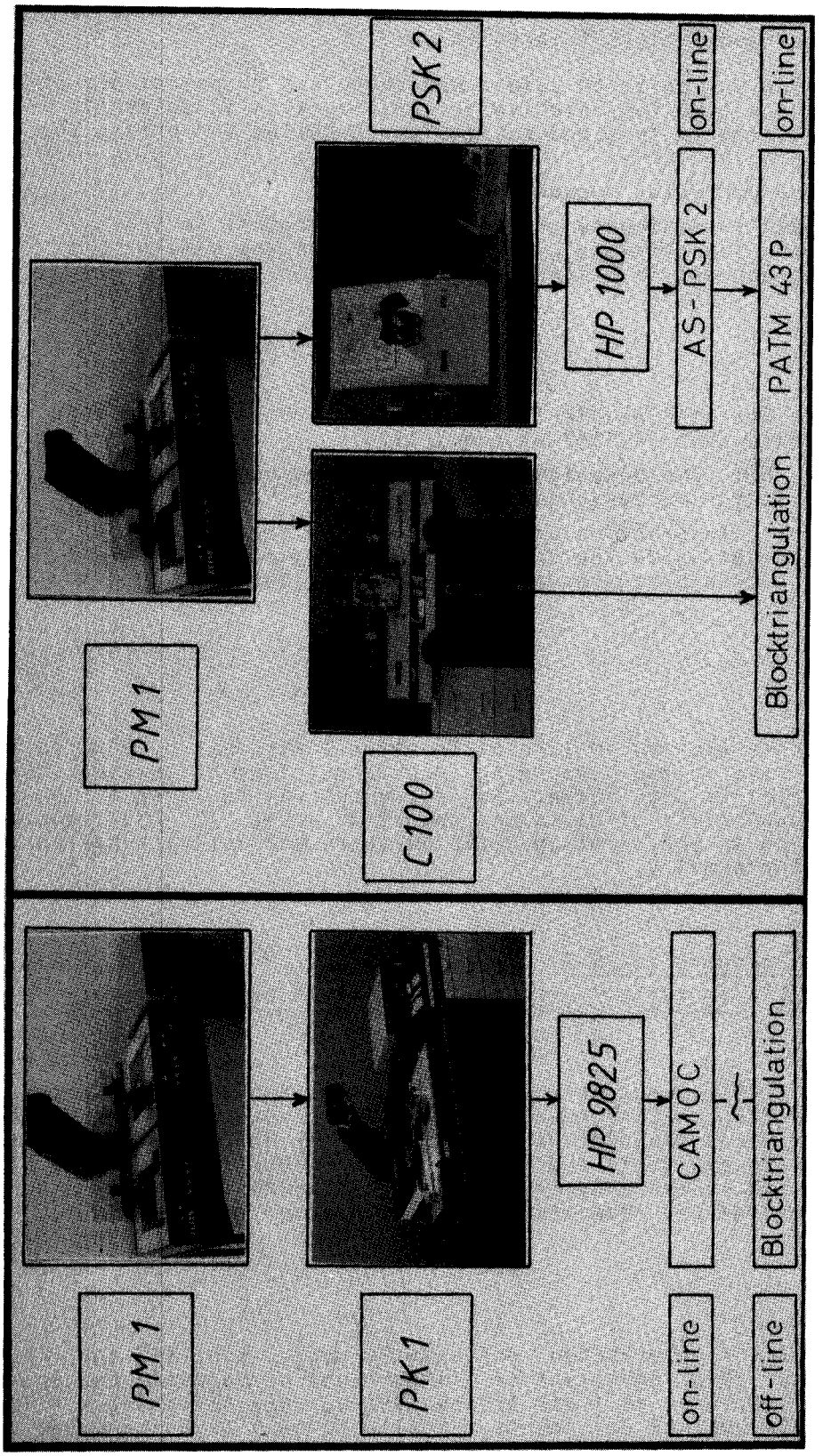
Ein neuer Baustein im ZEISS-System für analytische Photogrammetrie

Zusammenfassung

Die Firma CARL ZEISS, Oberkochen, stellt das neue Punktübertragungsgerät PM-1 vor. Wegen der grundlegenden Bedeutung der Punktübertragung für die Genauigkeit der Aerotriangulation wurde besonderer Wert auf hohe Punktqualität, Markiergenauigkeit und Arbeitsgeschwindigkeit gelegt. Das bisherige Geräte- und Software-System für analytische Photogrammetrie erhält damit die notwendige und adäquate Vervollständigung.

Résumé

La maison CARL ZEISS, Oberkochen, présente le nouvel appareil pour le report de points d'appui PM-1. En raison de l'importance primordiale du report des points pour la précision de l'aérotriangulation, on a insisté aux faits suivants: excellente qualité des points, excellente qualité de marquage et vitesse de travail. Ainsi, l'ancien système d'appareils et le système software pour la photogrammétrie analytique sont complétés de façon adéquate.


PM 1
C 100
PSK 2
HP 1000
AS - PSK 2
on-line
Blocktriangulation
PATM 43 P
on-line
PM 1
PK 1
HP 9825
CAMOC
on-line
Blocktriangulation
off-line

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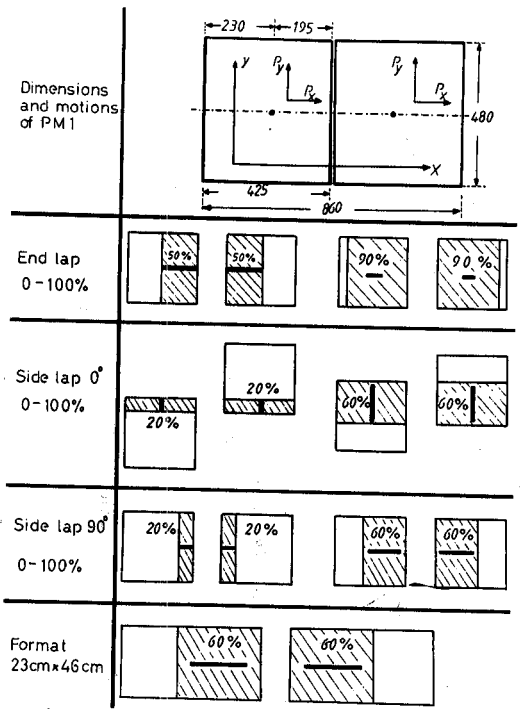

Fig. 2
Overlap ratios in point transfer.

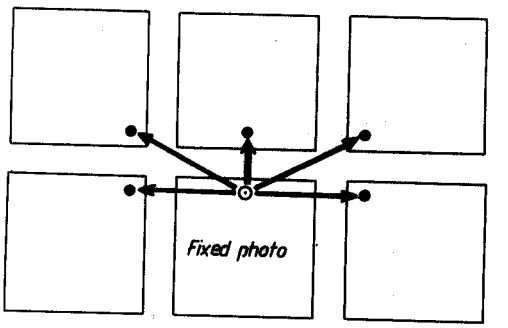

Fig. 3
"Point-by-point transfer".

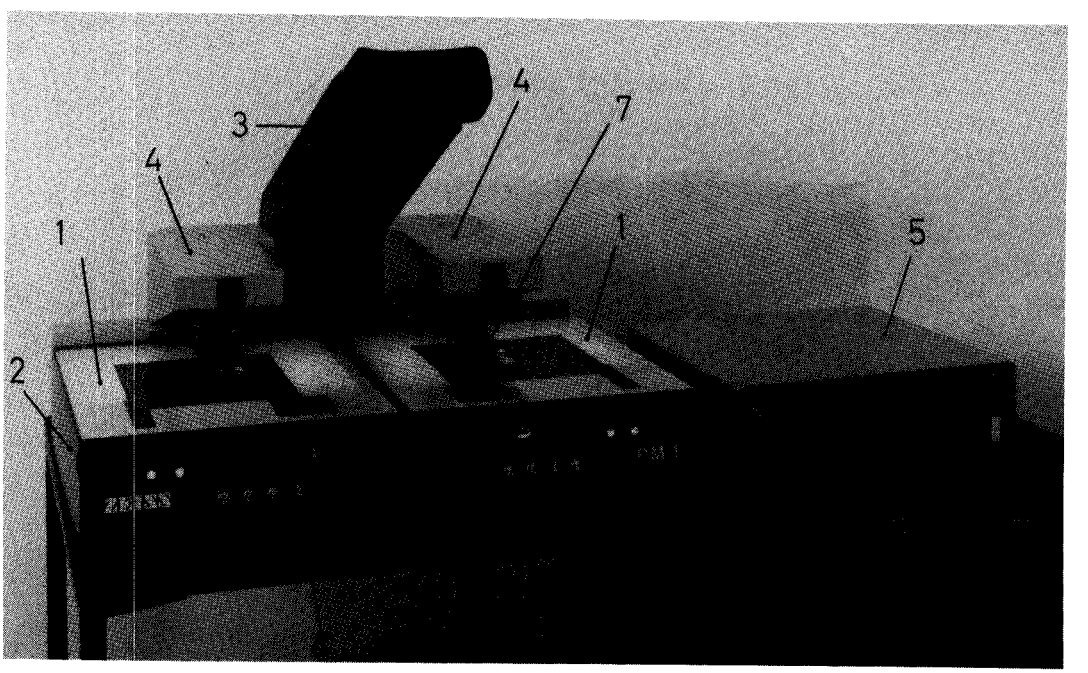

Fig. 4 PM-1 Point Transfer instrument.

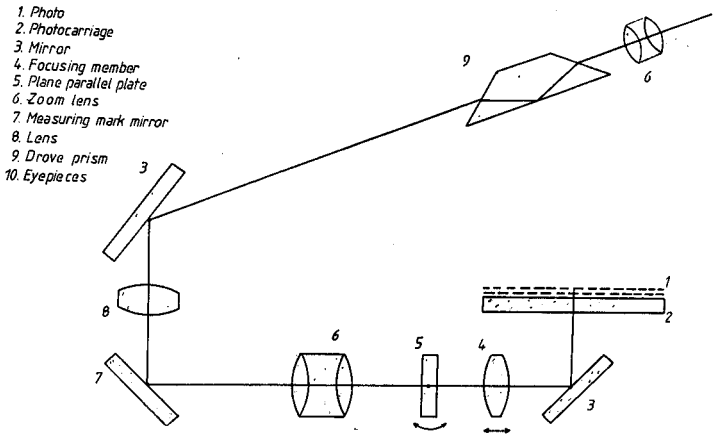

Fig. 5 Optical system.

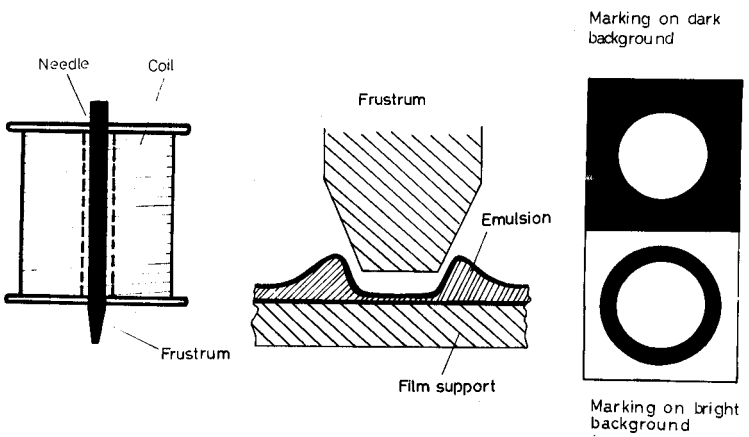

Fig. 6 Marking principle.

Fig. 7 Sample marks produced with PM-1.

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OPTICAL SYSTEM:

6.5x to 26x zoom system, independently adjustable on either side.
Field-of-view diameter 28 mm to 7 mm.
Image rotation on either side 0 to 360° (separately or in common).
Focusing for image height between 0 and 7 mm.
Max. resolution 120 l/mm.

MEASURING MARKS:

Centric luminous/black marks, switchable to 25, 40, 60 and 90 µm dia.

COORDINATE MOTIONS:

Free-handed shifting on photoholder plates 425 mm (x) x 480 mm (y).
Central fine adjustment for common and parallactic motion ± 15 mm, either left or right.

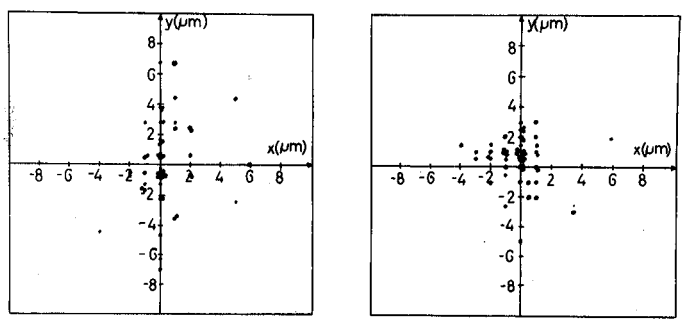
MARKING:

Point marking with heated needle.
Point diameters 40, 70, 100 and 200 µm.
Annular marks with fiber pen, 2, 4 and 6 mm dia.

DIMENSIONS AND WEIGHTS:

Point Transfer Instrument: 860 mm wide x 680 mm deep x 600 mm high. Weight: 85 kg.
Control unit: 467 mm wide x 420 mm deep x 150 mm high. Weight: 20 kg.

Fig. 8 Technical data of PM-1.



Left side: $m_x = \pm 1.3\,\mu m$, $m_y = \pm 2.7\,\mu m$

Right side: $m_x = \pm 1.8\,\mu m$, $m_y = \pm 1.5\,\mu m$

Fig. 9 Reproducibility of marks.

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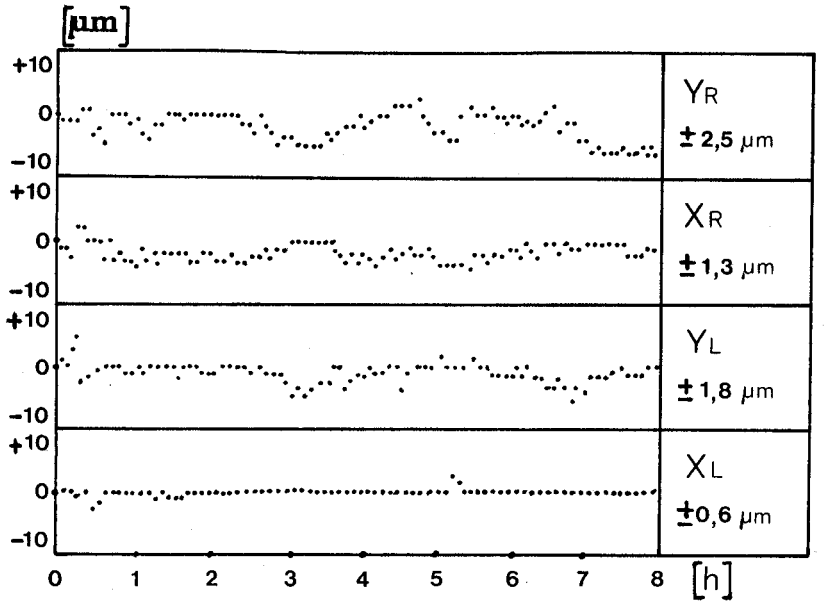

Fig. 10 Stability of adjustment in PM-1.

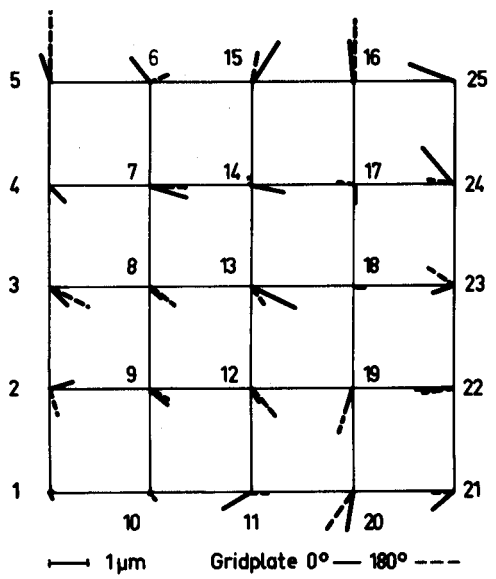

Fig. 11 Accuracy of PK-1.

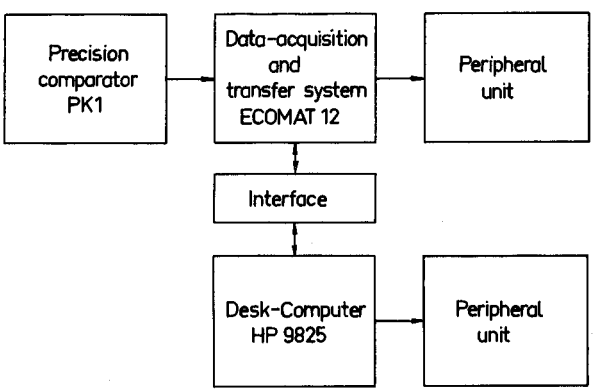

Fig. 12
Equipment configuration for CAMOC.

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