i. For 80 lines/mm. resolution, the camera window quality must be above the Standard Group M quality.

j. In consideration of the above conclusions the time is at hand when a 2 to 4 time improvement in photographic resolution and detail information can be made. With the closer tolerances and control, the mapping lens distortion calibration of below the 10 micron level becomes more meaningful and useful.

In presenting this paper, an attempt has been made to show what is believed to be what the near future holds for increasing performance in mapping and supplemental photography. It is hoped that improvement in the quality and control of the photography may help to solve other problems or, at least to open some doors for future improvements in the many areas of interest.

*The New Zeiss Stereocomparator—An Old and Reliable Principle Applied to Most Modern Techniques**

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ABSTRACT: *The paper discusses and explains the constructional principle of the Zeiss-Aerotopograph precision Stereocomparator, which differs from that of other stereocomparators presently available.*

The extremely high accuracy of this instrument is obtained on account of its far-reaching insensitivity to fluctuations of temperature and the use of extremely short measuring spindles which permit the determination of image coordinates as referred to a very precise measuring grid. The measuring process is facilitated and accelerated by a built-in automatic device, while a built-in optical system of pointers makes it easy to find the points to be measured. The Ecomat Electro-Magnetic Recording Unit which is directly connected to the instrument makes it possible to process the measuring data in any commercial automatic computer.

ON SEPTEMBER 16, 1890, Dr. Ernst Abbe held a lecture in Bremen on measuring equipment for physicists. In this lecture he outlined the principles for comparator measurement and design which up to the present day have conserved their value and importance and which have become known as the Abbe Comparator Principle.

In the aforementioned lecture, Ernst Abbe made about the following outlines:

In the design of comparators, the following two requirements must be fulfilled:

1) The measurement must in any case, both in the contact setting and the visual setting, be based on a graduation with which the distance to be measured is directly compared.
2) The measuring apparatus must by all means be so designed that the distance to be measured is the rectilinear extension of the graduation used for measurement.

It must be taken into account that these requirements apply to comparators for mere distance measurement only and require a certain modification above all in item 2), if they be applied to comparators for image measurement.

The purpose of the first requirement is to eliminate the irregular and partly uncontrollable sources of error originating in the measuring spindles. The aim of the second requirement is to make the measurement largely independent of the mechanical irregularities of the guide elements. Contrary to comparators for distance measurement, the comparator for image measurement must determine two components (x and y), so that the linear

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division mentioned under item 2) must be changed into an aerial measuring agent.

In the majority of comparators designed in the past, the Abbe principle was neglected. This was the case also in the Pulfrich comparator. In contrast thereto, the new Zeiss comparator fulfills the Abbe principle in an ideal manner.

The design of the new comparator was based also on another model which is shown in Figure 1. This is the stereocomparator after Prof. Hugershoff. In it, the plates to be measured are arranged in a vertical cross-slide system which implies three advantages:

1) The cross-slide guides used are very short.
2) As a consequence, these quides will, in operation, be deformed far less—a fact which is, by the way, not essential as far as our new comparator is concerned.
3) The instrument can thus be given a very compact shape, so that it can be kept relatively small in its outer dimensions.

This is the reason why the new Zeiss comparator also has vertically arranged diapositive plates which are displaced only in one component direction. The displacement in the other direction at right angles to the former is achieved by prisms incorporated in the observation system. On account of its relatively low weight and its reduced dimensions, the instrument is suited for table-top use.

The second requirement of Abbe's comparator principle is fulfilled even more rigorously than was ever the case in previous designs, since the measuring agent is a precision grid plate. It should be emphasized at this point that this grid plate is the only decisive measuring agent used in the comparator. The long spindles employed must be considered exclusively transport spindles which are not directly used for measurement. The instrument is so designed that the coordinate values x_1', y_1' and x_2' and y_2' are determined in each photo, such as is most convenient for the analytical processing of these data.

Owing to the fact that the precision grid which—as was mentioned already before—is in close contact with the diapositive plate representing the object to be measured, differences of temperature can be completely neglected. This pronounced insensitivity to temperature fluctuations was proved in the course of painstaking experiments in which the comparator was subjected to different temperatures. Even now it can be stated that the new stereocomparator need not be set up in an air-conditioned room with strict temperature control.

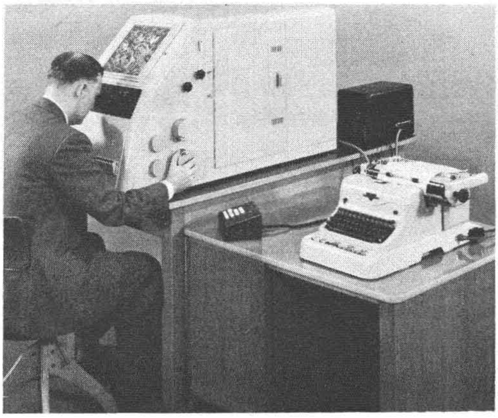

FIG. 1. The new Zeiss stereocomparator.

As was mentioned earlier, a precision grid is used as measuring agent. As in other comparator designs, the setting of the point to be measured is accomplished by a common displacement of both photographic plates and by differential displacement of the right photo. On account of the experience that the finding of a certain image point may be a very complicated and time-consuming process, the instrument was provided with an indicator in the form of a luminous point. In accordance with the x- and y-motion of the instrument, this luminous point wanders over a paper print of the left photo attached above the eyepieces and in convenient viewing range of the operator. The operator is thus able to approach a point without depending on the relatively small visual field of the eyepiece. As a consequence, the setting process is considerably facilitated and abbreviated.

When the stereoscopic setting has been completed, there is an additional possibility to eliminate any remaining y-parallaxes by optically swinging both photos and converting these y-parallaxes into apparent x-parallaxes. In keeping with the principle of the new stereocomparator, the next task is to determine the position of the focussed point with reference to the nearest grid lines. By pressing a button, the following operations are released within the comparator: The observation, in transmitted light previously used, is switched off by disconnecting the respective light source, while an observation in incident light is made possible by another light source, so that the photogram previously observed is no longer visible. Instead, only the reticle of the left photo and the grid, which was previously invisible, will appear in both eyepieces. At the same time, all drive elements of the cross-slide mechanism, i.e. of image displacement, will be locked. In addition, two electric motors will start running, which will set the reticle automatically and roughly to the nearest grid line.

Since the coincidence of the reticle with the grid line must be obtained with a high degree of accuracy, it is the intention of the manufacturer to have the final precision setting made by the operator, so as to not violate one of the basic rules of precision measurement.

In the case of fully automatic coincidence, the reticle would approach the grid line alternatively from the left or the right or from above or below, while the operator can obtain the coincidence by approaching the line always from one and the same side. Since the measuring grid has a mesh separation of exactly 1 cm. = 10 mm., and since the reticle has a 1 mm. graduation, the required maximum motion of the reticle can be limited to + and −0.6 mm. For measuring the amount of displacement of the reticle, a spindle is used whose advance is stepped down 30 times. Owing to this transmission ratio and the relatively short length of the spindle, any errors inherent in the spindle as well as differences of temperature can be neglected. Furthermore, since the operator can always work with binocular observation, even if the measuring process is carried out on one of the two photograms only, he need never close one of his eyes. Thus he can avoid eyestrain which may reduce the accuracy of the measurement.

By a renewed operation of the respective switch, the aforementioned process is repeated for the right photo, while a third operation of the switch will again switch on the transmitted light, so that the operator will again see the stereoscopic model.

At the same time, preparations are made for recording the image coordinates measured. Such a recording can be made with the aid of an Ecomat II unit, either on punched tape or punch cards. In addition, an automatic typewriter will record these values in the form of clear text. The store incorporated in the stereocomparator accepts the measured values appearing at the counters in approximately one second. During this short spell of time, the instrument is locked. Immediately afterwards, the next point may be focussed in spite of the fact that the recording operation itself has not yet been completed.

Since the coincidence of the reticle with respect to the measuring grid is obtained in a few seconds—because the rough setting to coincidence is accomplished automatically by electric motors—only very little time is lost. This slight loss of time is entirely insignificant if compared with the duration of the setting process. The setting process in turn is again considerably accelerated by the luminous point indicator already mentioned.

In principle, there is also a possibility to use reseau photography instead of the measuring grid in the stereo-comparator. Detailed investigations on this point are still underway.

The test measurements made to date have proved that the instrument must be counted among the group of high-performance stereocomparators and that the accuracy to be obtained is far below the limit given by the photograph itself. I will disclose only the following data:

The measuring grid can be manufactured with an accuracy of one micron, while the mean error of coincidence is of approximately the same magnitude. Interchangeable eyepieces with a magnification of 8 times, 12 times and 16 times permit a far-reaching adaptation to existing problems.

In conclusion I call attention to the fact that an additional paper on this new instrument prepared by Prof. Dr. Schwidefsky will appear in the special issue of the German journal *Bildmessung und Luftbildwesen* on the occasion of the International Congress of Photogrammetry in London.