A NEW TWO-CIRCLE GONIOMETER

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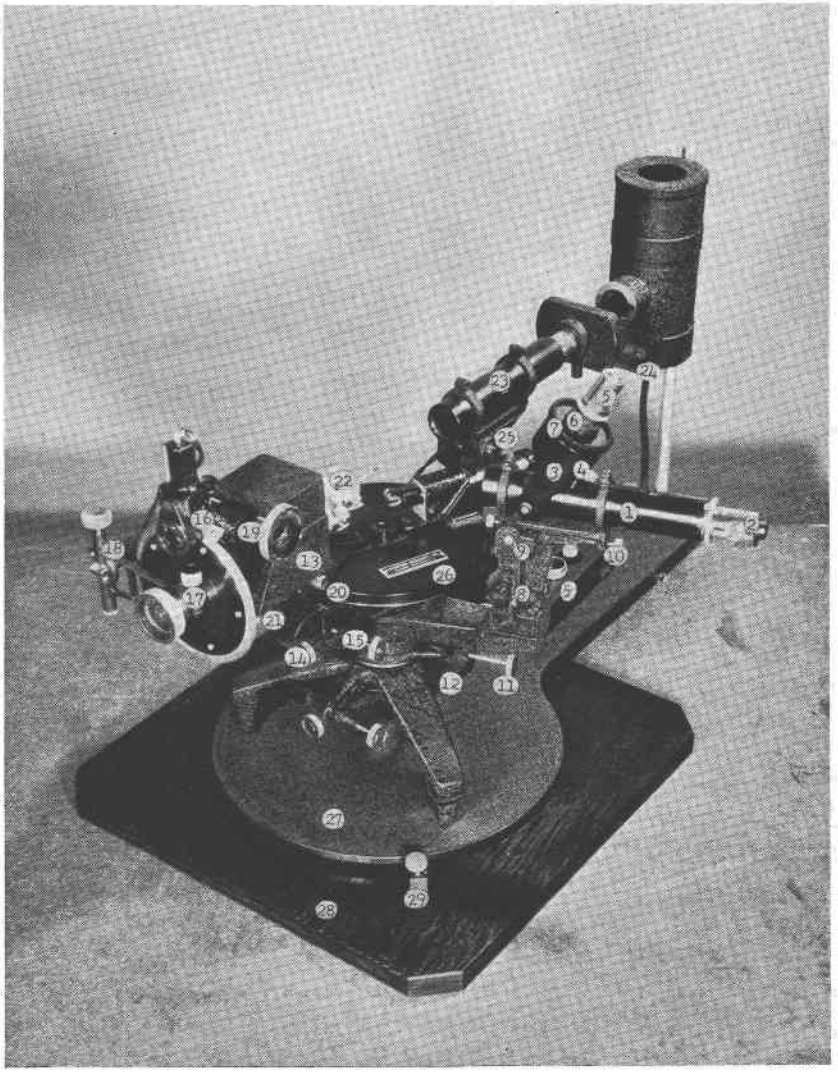
With the rapid growth of crystallography as a science a pronounced need for an adequate two-circle goniometer has been strongly felt in the United States. This need has been met in part by two new commercial sources, the principal difficulty with these sources being their high cost. Most university funds are limited to such a degree that the purchase of two-circle goniometers costing $1500–$2000 is prohibited. This high cost problem was first met by Dr. Cutler West and Mr. A. S. Makas (*Am. Mineral.*, **32**, 692, 1947) of Polaroid Corporation by making a model similar to that of Goldschmidt, using a Spencer spectroscope with its horizontal graduated circle as a base instrument.

The adaptation proved quite satisfactory, and the author decided to follow their suggested course of action. A two-circle goniometer was constructed according to my specifications by Laboratory Associates, 60 White Street, Belmont, Massachusetts. The original intention was that the work was to be restricted to the one instrument, but when it was discovered that the price of the instrument was notably less than other models available, it was decided that Laboratory Associates would make the model available at the standard price of $1,000.00. Since the instrument carries several innovations over the Goldschmidt goniometer, it was decided that colleagues in the field of crystallography might like to have similar instruments constructed or would like to purchase the goniometer from Laboratory Associates. A description of the instrument is given herewith.

Microscope-Telescope Unit. One outstanding feature of the goniometer is the character of the microscope-telescope tube. In the following discussion the numbers in parenthesis will refer to correlative numbers on the accompanying figure. The telescope tube (1) with eyepiece (2) is a regular part of the base spectroscope instrument. The magnification of the eyepiece is about 10×. The telescope, with which the reflected signal from the crystal is seen, is converted into a microscope for actually viewing the crystal by rotating the objective holder or nosepiece (3) into axial conjunction with the telescope. An adjustment in the vertical plane is provided by a screw (4). The objectives (5) are simple 48 mm., 32 mm., and 16 mm. microscope objectives. They are provided with adapters (6) for the varying focal length of the lenses, cutting the necessary amount of focusing to a minimum. When focusing is necessary, it is obtained by turning the ring-screw device (7) on the nose-piece. The 16 mm. objective with a magnification of 10X is best used on very small crystals, since the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total magnification with this objective and eyepiece combination is about 100X.

Such a high magnification has been unknown in goniometers up to the present time. The goniometric study of crystals under this magnification provides much needed information concerning etch figures and growth accessories, and their reproduction on photographs will be a simple matter. Orientation of very small crystals for x-ray analysis is also facilitated. One difficulty with the high magnification, however, is the closeness of the objective to the crystal. This is best obviated by mounting the crystal on a slender glass rod which will not strike the objective when high polar angular values are being obtained or by using a special crystal mounting rod which has been developed for the purpose. This rod is the usual type of brass rod into which a small hole is bored in one end. Into this hole a phonograph needle is inserted by the blunt end, and the crystal is mounted on a minute quantity of wax at the point of the needle. Wax is generally more satisfactory than collodion or Duco, since it not only is completely adequate for holding very small crystals, but it also permits the manipulation of the crystal after mounting. Laboratory Associates will supply the bored brass pins in any length which is desired. There is no interference between crystal and objective when signals and angles are being observed, for the nosepiece is lifted and out of the way.

The microscope-telescope tube is mounted on an upright post (8) with horizontal adjusting screws (9) and with a tilting screw (10) to bring the tube into alignment. The entire unit may be rotated around the vertical central axis of the instrument, and a lock screw (11) with fine adjustment (12) is provided. When the instrument is to be used only as a two circle goniometer, the fine adjustment screw should be removed after the proper position of the unit has been fixed; this precaution precludes any inadvertent change in the chosen position of the unit. The provision for rotation around the vertical axis is desirable in case the instrument should get out of adjustment or in case minimum deviation work, with liquids in hollow prisms mounted on the goniometer head, is desired. The author has already made an adapter for this purpose, and it saves the purchase of a one-circle goniometer.

Vertical Circle Unit. The vertical circle unit is mounted in a chuck (13) which is directly tied in with the horizontal circle, the movement being controlled by a lock screw (14) and a fine adjustment screw (15). The vertical circle is engraved by C. L. Berger and reads clockwise and counter clockwise. The vernier (16) is very easily read at a distance of six inches from the circle, due to the presence of a suitable lens and adequate lighting. The vertical circle is equipped with lock screw (17) and fine adjustment screw (18) and is mounted on a simple microscope tube

(19) with rack and pinion back and forward movement of about $1\frac{1}{2}$ inches. The tube is also equipped with horizontal adjustment screws (20) and tilting screw (21) for alignment. The goniometer head (22) which is not an official part of the goniometer is detachable. If desired it may be supplied by Laboratory Associates or may be procured separately from Otto von der Heyde or Charles Supper who supply such heads with their Weissenberg equipment.

Signal Unit. The collimating tube (23) is that of the Spencer spectroscope with the slit unit omitted. In place of the old spectroscope slit a five signal target (24) has been introduced. The target is made photographically; the individual signals are obtained by sliding the target horizontally, the construction of the slide being such that each signal is centered automatically. The five signals are: the large maltese cross, the small maltese cross, the vertical bar, the horizontal bar, and the pin point. The entire collimating tube may be aligned with horizontal screws (25) and with a tilting screw. The light source is a 100 watt lamp of the narrow, vertical four helical filament type. There is a condensing lens inside the light housing which focuses the incandescent filaments on the front lens of the collimator, giving maximum illumination.

Horizontal Circle. The horizontal circle (26) is that of the Spencer spectrometer. The present spectrometer scale reads backward for goniometric purposes, making impossible the direct determination of polar angular values, but it is hoped that this may be corrected through special specifications to the American Optical Company. The reading of the horizontal scale, although reversed at present, is extremely easy, as it is well illuminated, and the focal length of the reading lens is about six inches.

The entire instrument is mounted on a metal base (27) which may be rotated upon a wooden base board (28), with a lock screw (29) to hold it in any particular position. Rotation of the entire instrument enables the ready reading of the vertical circle scale when the polar angular readings are small.

The advantages of the instrument, then, are: high magnification, intense light source, flexibility of adjustment of all parts, ready reading of the scales, simplicity of manipulation, and comparatively low cost. Angular readings are to one minute, and the over-all accuracy of the instrument leaves nothing to be desired. One disadvantage, as compared with the Goldschmidt instrument, is that there is no provision for the blacking out of reflections from different parts of the reflecting face. This may be corrected in later models.

The author wishes to acknowledge his debt to many others in the planning and building of this instrument. Of course the basic plan is that

of Goldschmidt. The use of the Spencer spectroscope was conceived by Dr. West, and several other features of the instrument were developed in principle by West and Makas. The optics were largely developed by Mr. Kenyon Zaph of the Optical Research Laboratory of Boston University, and the actual engineering and designing has been the work of Mr. Harry Gewertz of Laboratory Associates. The specifications for construction and a critical examination of the utility and engineering of the various parts have been the author's principal contributions.