SETTING A GIVEN DIRECTION PARALLEL TO THE AXIS OF A GONIOMETER HEAD

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Abstract

Certain problems require that an unusual crystal direction rather than an ordinary crystal axis be made parallel the axis of the goniometer head. This is the case when a triclinic crystal is worked out by the precession method; it is also not uncommon in crystal structure or disorder studies. The stereographic technique here described permits easy visualization of the situation in any individual case, whether working with a euhedron and the optical goniometer or an anhedron and purely x-ray techniques. The method makes an unusual application of the stereogram since the principle employed involves the use of small circles not parallel to the equator of the stereonet.

The introduction includes a description of the goniometer head, together with brief remarks on crystal mounting and handling on the optical goniometer. The next section outlines the method of preparing a stereogram showing the necessary minimum data to obtain the new arc readings when the desired crystal direction is parallel the axis of the goniometer head. This is followed by a section explaining the theory of the method. Brief general remarks conclude the paper.

Introduction

A goniometer head is a gadget which supports a crystal in suitable orientation on some axis of an optical or x-ray goniometer. For ordinary work it is desirable that this instrument (Fig. 1) includes two sledges and two arcs. The arcs permit circular movements in the planes determined by the axis of the head (shown by a line terminated by an arrow at each end near the top of the figure) and the direction of motion of each of the sledges. The arcs have a common center; the radius of the small arc S of the instrument shown is about 23 mm.; that of the large arc L is about 35 mm. The sledges (Sl_L parallel the large arc and Sl_S parallel the small arc) allow movements in two mutually-perpendicular directions, both normal to the axis of the head.

The crystal may be mounted on the head as follows. A small cork with a hole bored in it is used to support a brass rod about one cm. long in vertical position; this rod is of a size to fit a hole in the flat end of the S arc. A short glass capillary tube is fastened in parallel position to the upper end of the brass rod by means of a thermoplastic cement (such as Cementyte C), or by a mixture of about 50-50 beeswax and rosin, or even by Apiezon sealing compound or a gob of plasticine. Now put a blob of Apiezon N grease or Duco cement on the end of the glass capillary and place one end of the crystal in this. The crystal may be picked up with a match stick which has a pointed tip of plasticine stuck on one end of it. Working under the binocular the crystal may be lined up so that the desired zone is approximately parallel the glass capillary. When the cement has set, it may be advisable to add a bit more of it at the glass-crystal contact to make a firm union. The cork may now be inserted in a glass vial to protect the crystal while setting continues for a few hours.

Using pointed pliers to hold the brass rod, the crystal may be transferred to the goniometer head and adjusted in azimuth under the binocular so that the desired directions are parallel the sledges. The set-screw clamping the brass rod in the end of the goniometer head is then tightened when the part of the crystal through which the x-ray beam should go is at the center of the arcs; this is 12 mm. beyond the flat end of the small arc for the instrument shown in Fig. 1.

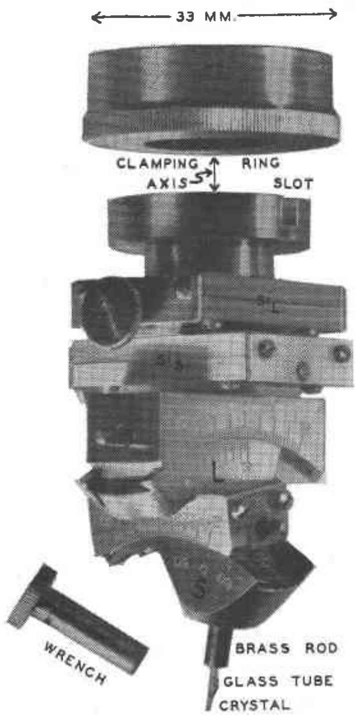


FIG. 1. The goniometer head, with crystal attached. The clamping ring normally covers the slot in the ring-base. L = large arc, S = small arc, Sl = sledges (parallel L or S respectively).

The head is now fastened to the optical goniometer where its orientation is fixed by the slot in the ring-base which engages with a pin on the goniometer axis. The slot is shown in Fig. 1, although it normally would be hidden by the clamping ring had this not been detached from the ring-base when the photograph was taken. The crystal is now adjusted on the optical goniometer so the desired direction, generally the [*c*]-axis, is parallel the goniometer axis (axis of the *V*-circle of the Goldschmidt two-circle instrument). The technique required to accomplish this is in the text-books. When oriented, the *S* and *L* readings are noted. These are recorded as right (*r*) or left (*l*) as seen when looking from the crystal towards the goniometer head. This position is adopted because it is the normal one used in viewing a crystal and its gnomonogram or stereogram, assuming the (+) end of the axis (which is set parallel to the axis of the goniometer head) is the one extending out from the head; the one pointing towards the observer in this case. Thus the readings for the head shown in figure 1 are $L=10°00'\ l$ and $S=20°00'\ r$; it is unfortunate that the numbers engraved on the arcs are upside down from this point of view. The goniometric readings for the various faces on the crystal may now be obtained and from these a gnomonogram may be prepared and the face-poles indexed, at least in preliminary fashion. Of course on this the $\phi=0°$ azimuth (generally the direction of [*b**]) may be shown; also the positions of the *L* and *S* arcs, and which side of each is the engraved one.

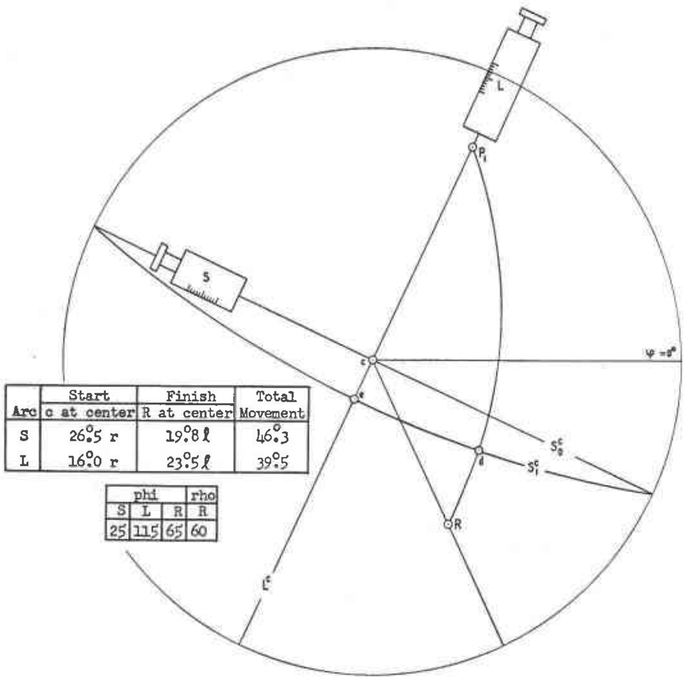
Tilting the Arcs to a New Position

This problem is most easily grasped from the working of an actual example. Suppose that it is desired that a random direction *R* be made parallel the axis of the goniometer head. *R* may represent [*c**] of a triclinic case in a typical precession camera problem, or it may represent some zone [*u v w*] in a rotation-oscillation problem. In any case the position angles for *R* may be obtained from the gnomonogram just prepared.

Figure 2 is a stereogram to fit a case in which the [*c*] -axis of a crystal is parallel the axis of the goniometer head when the arc readings are $S=26\overset{\circ}{.}5\ r$ and $L=16\overset{\circ}{.}0\ r$. Also from the gnomonogram mentioned it may be ascertained that $\phi_S=25°$ and $\phi_L=115°$ with the engraved side of *S* towards $\phi=115°$ and that of *L* away from $\phi=25°$. It will be noted that normally these ϕ readings would be close to 0° and 90°, but a completely general case is here assumed. The problem is to make *R* parallel the axis of the goniometer head where $\phi_R=65°$ and $\rho_R=60°$.

The stereogram shows the cyclographic projection of *R*, as well as L^c (the cyclographic projection of the large arc) and S^c. Note that L^c is fixed, but that S^c is represented by a series of great circles having a common diameter while the *S* arc is being tilted by movement of the *L* arc. In short any movement of *L* also moves the whole *S* arc (see Fig. 1) but the reverse is not true. When $L=16°0\ r$, then in Fig. 2 the cyclographic projection of the S arc is at $S_1{}^c$, the first or starting position of S^c. This is 16° off $S_0{}^c$, the position of S^c when the reading on the L arc is 0°; i.e., in the stereogram $c\ e=16°0$. Note that r or l is plotted while facing towards the engraved side of the arc concerned.

Let P_1 be the pole of $S_1{}^c$. Pass a great circle through P_1 and R locating d on $S_1{}^c$; this great circle (like all those through P_1) is normal to $S_1{}^c$. Measure $d\ R(=23°5)$ and $d\ e(=46°3)$. Then the required tilts on the



Arc	Start c at center	Finish R at center	Total Movement
S	26°5 r	19°8 l	46°3
L	16°0 r	23°5 l	39°5

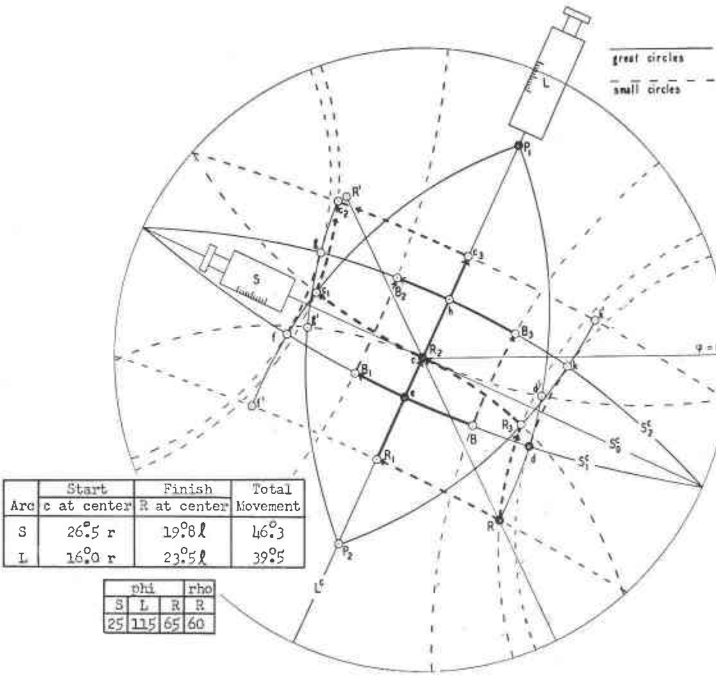
phi			rho
S	L	R	R
25	115	65	60

FIG. 2. Stereogram to explain motion of R (a random direction) to c in terms of arcs L^c and $S_1{}^c$, the cyclographic projections of L and S (the latter in its first position). P_1 is the pole of $S_1{}^c$.

two arcs to place R at the center of the stereogram (so that it is parallel to the axis of the goniometer head) are 46°3 on the S arc and 39°5 (16°0 +23°5) on the L arc. This leads to final arc readings of $S=19°8\ l$ and $L=23°5\ l$. Using a meridian stereonet with a radius of 20 cms. (the writer has one of these mounted on a sheet of bakelite) this problem may be solved quickly to the nearest 0°1 or 0°2. Of course in actual practice the great circle P_1R is not drawn; in fact only a small part of $S_1{}^c$ need be traced, and along this a tick locates d.

Explanation of the Method

If B is located on S_1^c so that $e\,B = 26^\circ\!.5$ (the first reading on the S arc) as is shown on the stereogram of Fig. 3, it represents the cyclographic projection of the brass rod; i.e., it is a normal to the flat end of the S arc in its first position. As S is moved $46^\circ\!.3$ from $26^\circ\!.5\ r$ to $19^\circ\!.8\ l$, B moves to B_1; as L is moved $39^\circ\!.5$ from $16^\circ\!.0\ r$ to $23^\circ\!.5\ l$, B_1 follows a small circle normal to S_1^c and so goes to B_2. Or if L is moved before S, B goes to B_3, then to B_2. $B_3\,B_2$ defines S_2^c, the second or final position of S^c, where $ch = 23^\circ\!.5$.



Arc	Start c at center	Finish R at center	Total Movement
S	26°.5 r	19°.8 l	46°.3
L	16°.0 r	23°.5 l	39°.5

phi			rho
S	L	R	R
25	115	65	60

FIG. 3. Stereogram as in Fig. 2 showing in addition the small circles along which R, B (the brass rod; see Fig. 1), and c travel while tilting the two arcs. S_2^c is the second position of the small arc; its pole is P_2.

If one now mentally passes a great circle through B and R, and thinks of R as being tied by a rigid pin $B\,R$ to B, then as B moves to B_1, $B\,R$ becomes $B_1\,R_1$; likewise it becomes $B_3\,R_3$, and from either B_1 or B_3 becomes $B_2\,R_2$. However this is more simply carried out in terms of a rigid pin $d\,R$ which is normal to S_1^c, and which goes to $e\,R_1$ or $k\,R_3$ and thence to $h\,R_2$. Similarly a pin like $e\,c$ goes to $f\,c_1$ or $h\,c_3$ and thence to $g\,c_2$; this is simpler than to imagine a pin $B\,c$ going to $B_1\,c_1$ or $B_3\,c_3$ and thence to $B_2\,c_2$.

The details of construction are as follows: d, k, f, and g lie along small circles 46°.3 from but parallel to L^c; d and f lie along S_1^c while k and g are on S_2^c. R, R_1, and f' lie along great circles through P_1 and d, e, and f, respectively, at 23°.5 from the latter; they establish a small circle $R\ R_1\ f'$ parallel to but 23°.5 from S_1^c; this is the 82° small circle of the stereonet, counting down from its poles. Of course to draw this circle the center of the tracing paper can no longer coincide with the center of the stereonet. Similarly d', c, and c_1 are on great circles through P_1 and d, e, and f, respectively, at 16°.0 from the latter; they fix the 61° small circle parallel to and 16°.0 from S_1^c. Likewise R_3, R_2, and g' are on great circles through P_2 (the pole of S_2^c) and k, h, and g, respectively; they define small circle $R_3\ R_2\ g'$ parallel to and 23°.5 from S_2^c; this is the 49° small circle. Also k', c_3, and c_2 are on great circles through P_2 and k, h, and g, respectively; they determine the 83° small circle parallel to and 16°.0 from S_2^c. The four small circles here described which are parallel to S^c in either its first or second position, represent the paths of R or c as tilt occurs on S.

The point R' lies on diameter $c\ R$; moreover, R and R' are equidistant from c. It will be noted that while tilting along the two arcs causes R to move to R_2, it results in c going to c_2 and not to R'.

General Remarks

This stereographic technique, besides permitting a ready solution with satisfactory accuracy of what at times may be an obstinate little problem, has the added advantage of such graphical methods that it permits easy visualization of the set-up. Thus from quick inspection of a hastily-drawn small stereogram ($r=5$ cms.), one can decide whether it is possible to orient a given direction of a crystal without first remounting it. While the arcs of the head shown in Fig. 1 are graduated to only 20° each way, by making use of the vernier graduations it is possible to tilt up to 31° each way, though with reduced accuracy of reading. If the crystal must be remounted, one gets a good picture of how this should be done.

Of course it is not necessary to have a euhedron or subhedron to make use of the method described. One may orient and prepare an indexed gnomonogram (similar to the first level of the reciprocal lattice to a suitable scale) by purely x-ray techniques, rather than by the use of the optical goniometer as here outlined in the Introduction. Thus from an x-ray picture of any orientation in which two or three directions can be recognized, one may use the method to compute the new arc settings for any desired orientation.

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