

March 16, 1948.

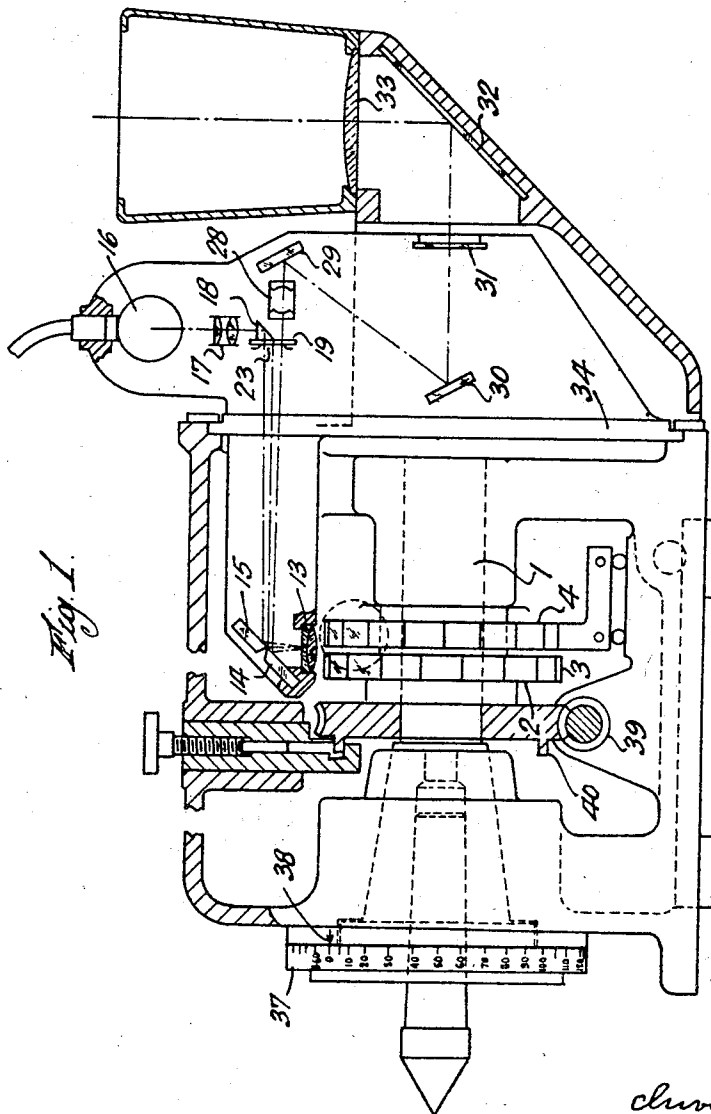
J. H. DOWELL ET AL

2,437,807

OPTICAL PROJECTION DIVIDING HEAD

Filed Dec. 19, 1944

5 Sheets-Sheet 1



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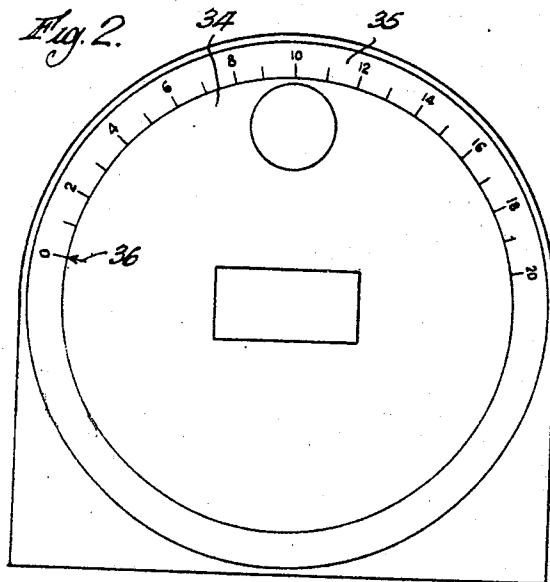
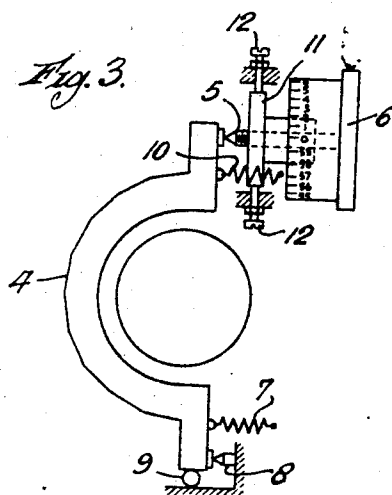
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5 Sheets-Sheet 2



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Fig. 4.

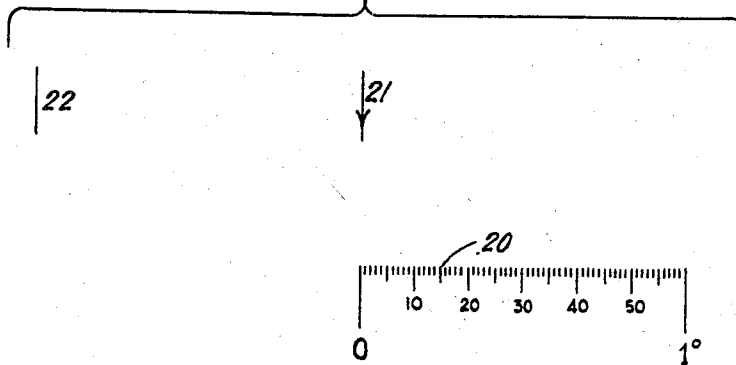


Fig. 5.

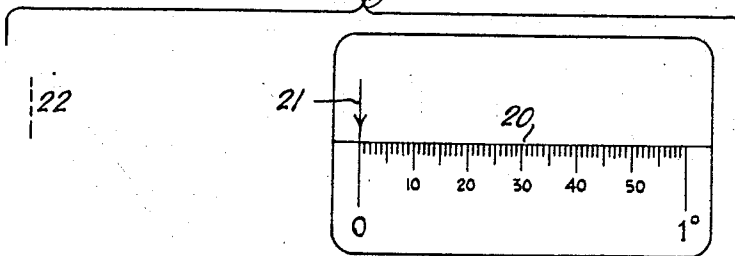
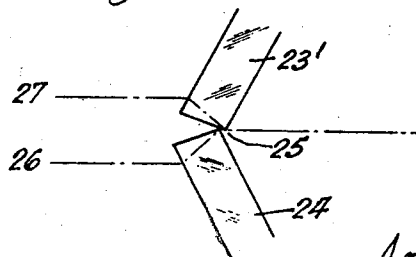


Fig. 6.



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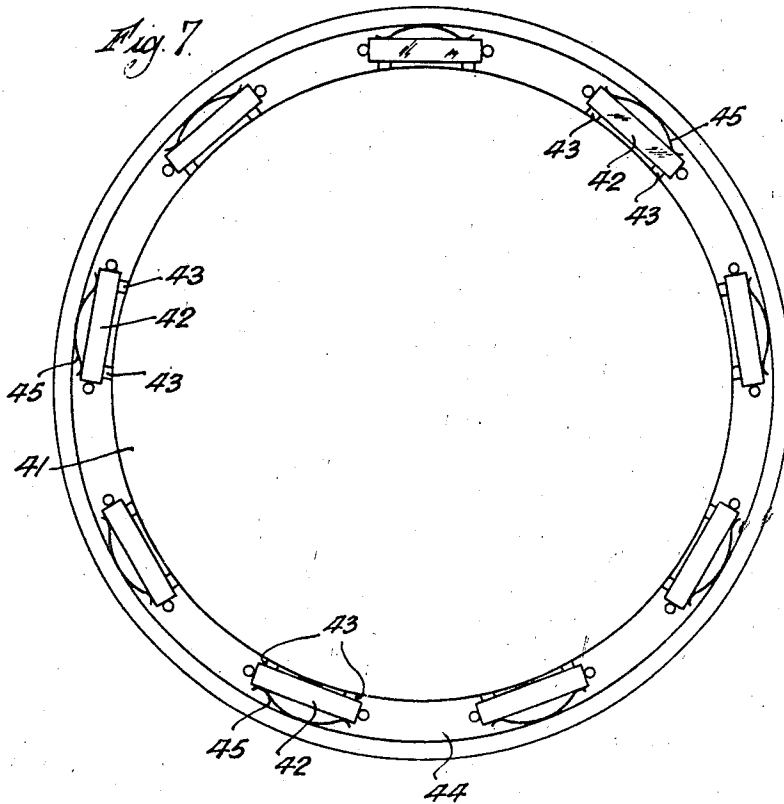
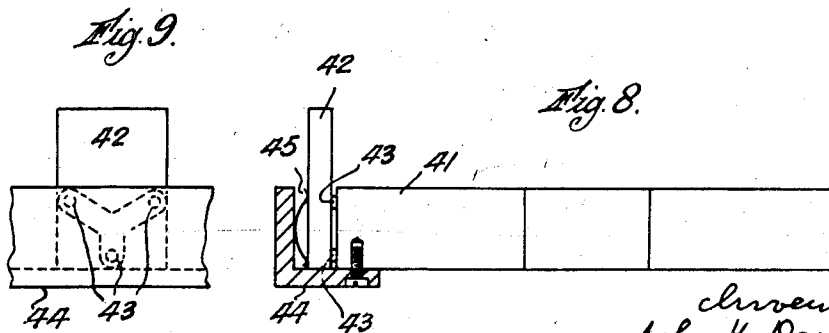
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5 Sheets-Sheet 4



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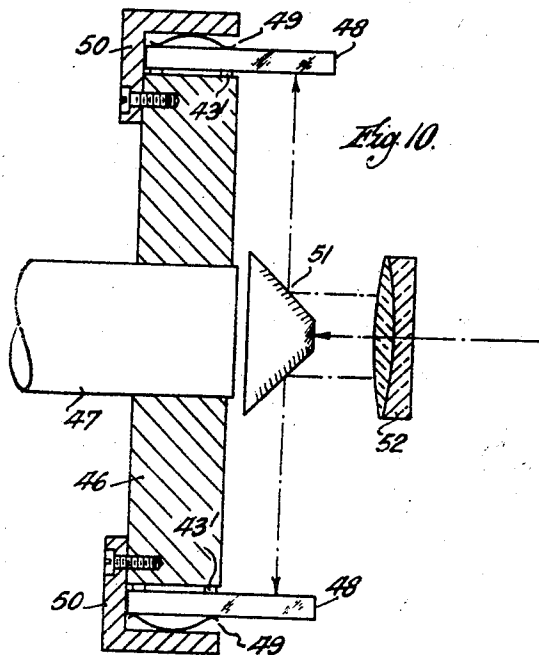


Fig. 10.

Fig. 11.

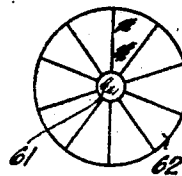


Fig. 12.

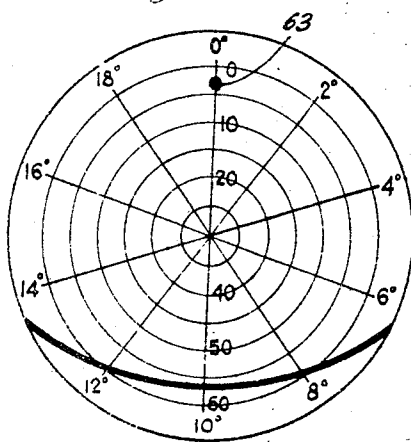
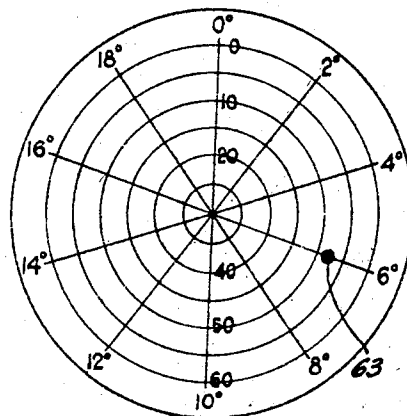


Fig. 13.



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UNITED STATES PATENT OFFICE

2,437,807

OPTICAL PROJECTION DIVIDING HEAD

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Application December 19, 1944, Serial No. 568,874
In Great Britain November 8, 1943

4 Claims. (Cl. 88-24)

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This invention relates to optical dividing heads or the like. The ordinary form of dividing head or table or the like consists of a divided circle mounted on a spindle on one end of which are means for mounting the work to be divided.

Dividing heads or tables are used for gear cutting, grinding spline shafts and other operations when it is required to turn the work through a known angle or series of angles for successive machinery operations, or for testing purposes when the piece to be tested is mounted on the spindle of the dividing head, or alternatively a divided circle is mounted on a machine for the purpose of testing its accuracy of angular setting. Such devices will hereinafter be referred to as dividing machines. The divided circle is usually of metal or glass and divided in angular measurement, the position on the angular scale being set by means of a microscope. Dividing machines of this kind are satisfactory where moderate precision is sufficient but when a precision higher than about one minute of angle is required practical difficulties are encountered; for example, mounting of the divided circle so as to be concentric with the axis of rotation and in dividing and reading the divisions with the necessary accuracy. Even when an engraved circle is mounted concentric it may become eccentric due to uneven wear of the spindle in course of time.

According to the present invention the angular setting or measuring means comprises a polygonal arrangement of reflecting surfaces combined in relative rotatable relationship with an auto-collimating device mounted so as to gauge the normality, or approximation to normality, of any reflecting surface brought into its field. The auto-collimating device may be of the type such as is known as Angle Dekkor, and which is described in "Machinery," November 24 and December 15/32 and November 30/33. Alternatively an auto-collimating device as described in application No. 13,403/42 may be used.

In one form of the invention the polygon may consist of a disc of steel, glass or other material, round the circumference of which a number of equally spaced optical flat faces are polished. An auto-collimator is arranged normally to the polished faces of the polygon so that when the polygon is rotated until the parallel light projected from the auto-collimator is approximately normal to the reflecting face of the polygon the light projected from the auto-collimator will be reflected back into the objective of the auto-collimator and so form an image in the eyepiece

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field of an index line or scale in the focal plane of the auto-collimator objective. If therefore the polygon is slowly rotated the image of the index line or scale will pass across the field of the auto-collimator eyepiece and can be set on a fixed scale or cross line and so define the exact angular position of the polygon for each of its reflecting faces. The angle through which the polygon is turned to bring each alternative face normal to the collimator depends only on the angle to which each of the faces of the polygon are inclined to each other and is independent of the distance of the faces from the axis of rotation, and thus eccentricity in the mounting is of no importance so far as the accuracy of angular rotation is concerned, nor will the accuracy be dependent upon wear of the spindle provided the bearings are in proper adjustment to remove play and this presents no special difficulty. It will be appreciated that, as an alternative arrangement, the auto-collimating device may be mounted on the spindle of the dividing machine whilst the polygon is fixed approximately on a common axis.

It will be clear that the angle to which this simple arrangement can be set is limited to the number of faces which are polished on the polygon and if, for example, a setting of every 2° is desired, 180 faces would be required on the polygon. Subdivisions of 2° could be provided for by means of a scale or image of a scale in the eyepiece field of the auto-collimator. The middle reading of this scale would most conveniently correspond with the position in which light coming from the auto-collimator is normal to the face of the polygon, the two extreme positions of the scale reading 0 and 2° will then correspond to an inclination of the polygon face of 1° to the normal position, or alternatively by mounting the auto-collimator so that it can be rotated about an axis approximately in line with the spindle axis on which the polygon is mounted and its angular position indicated by a scale so that it can be set by an amount necessary to include the range of subdividing required.

To prepare a polygon with so many polished faces as 180 with the necessary precision would, however, present great difficulty, but, according to this invention the number can be very greatly reduced by employing a second polygon or other arrangement of mirrors so as to form an optical vernier, the vernier polygon being fixed or capable of rotation over a small range of angle about an axis approximately common to that of the dividing machine spindle.

The two polygons can be arranged with a common axis so that light from the auto-collimator will fall on the reflecting faces of both polygons, and the auto-collimator is also arranged so that it can be rotated approximately about the same axis as the spindle on which the polygon is mounted so that by rotating the auto-collimator its optical axis can be brought normal to any of the faces of the fixed or adjustable vernier polygon. The number of reflecting faces on the moving polygon and on the fixed or adjustable vernier polygon are chosen so that by rotating the auto-collimator so as to be normal to each of the faces of the fixed or adjustable vernier polygon in turn subdivision of the angle between the faces of the moving polygon can be obtained by bringing the collimator image formed by light reflected from one of the faces of the moving polygon into coincidence with the collimator image formed by light reflected from one of the faces of the fixed or adjustable vernier polygon. By repeating this process with respect to successive faces of the respective polygons there will be obtained progressive increments of the subdivision of the angle.

The number of reflecting faces on the polygon mounted on the spindle and the fixed or adjustable vernier polygon will always be different and preferably so chosen that the total number of reflecting faces is the minimum number necessary to give the desired interval of angular movement. This will be the case when the difference between the angle of adjacent faces of the polygon mounted on the spindle and the angle of adjacent faces of the fixed or adjustable vernier polygon is equal to the desired subdivision of the angular interval of the fixed polygon. For example, if an interval of 2° is desired, the polygon mounted on the spindle may have 20 reflecting faces and the fixed or adjustable vernier polygon 18 reflecting faces so that the total number is 38 reflecting faces.

The number of reflecting faces on the vernier polygon can be further reduced to nine since the angle included by nine of the reflecting faces of the vernier polygon is equivalent to the angle included by ten of the reflecting faces of the polygon mounted on the spindle, the second nine reflecting faces of the vernier polygon therefore repeat the same angular coincidence of the first nine reflecting faces and thus by making the vernier polygon a segment with nine reflecting faces complete subdivision can be obtained, the collimator being returned to the first position on the vernier polygon for each successive subdivision of 20° .

The total number of reflecting faces is therefore reduced to 29, a number which can be manufactured to high precision of angle without undue cost.

An alternative method of construction may be employed in the case of a polygon in which diametrically opposite reflecting faces are parallel in which the polygon consists of a disc or ring on the circumference of which are mounted plane mirrors with reflecting faces on both sides and so arranged that the mirrors project beyond the width of the polygon. The mirrors would preferably be located on a triangular support constituted by three small raised areas on the circumference of the disc having their surfaces optically polished in one plane so that each plane formed by the surfaces of one group of raised areas will be inclined at the desired angle to the plane of the adjacent group. Since the mirrors have re-

fecting surfaces on both sides they can receive light from the autocollimator either from a direction towards the centre of the disc or in a direction from the centre of the disc towards the circumference of the disc, and if the mirrors are arranged round one half of the circumference it will be clear that for one half revolution light will be reflected by the outer reflecting faces and for the other half revolution by the inner reflecting faces, since opposite faces are parallel to each other. In this way the number of angles to be optically worked on the disc is halved. The additional work of providing the plane parallel mirrors is relatively small and so the highly skilled work required to produce the angles between the raised areas on the disc to the required precision is approximately halved and the manufacturing time of the polygon as a whole is much reduced.

This construction may be adopted for both the polygon which is mounted on the spindle of the dividing machine and the vernier polygon when it includes 360° for the purpose of reducing the number of mirrors, provided diametrically opposite reflecting faces are parallel, that is, if the number of mirrors is an even number. In cases where one of the polygons has an odd number of mirrors the full number of mirrors will be required and it is preferable to use a solid polygon.

Accordingly, in the case where an interval of 2° is desired, the total number of mirrors for the two polygons can be reduced to 19.

Instead of using mirrors with two reflecting faces, mirrors projecting beyond the width of the polygon may be used which have a reflecting surface only on the inside face. In this case a series of mirrors may be arranged within the ring to form a conical polygon whose faces in addition to being inclined at equal angles to each other are all inclined at an angle of 45° to the spindle axis, and the axis of the auto collimator may then be arranged to be approximately in line with the spindle axis, so that light projected from it falls on all the mirrors of the conical polygon and is turned through 90° and directed towards the reflecting surfaces of the mirrors mounted on the moving polygon. Light will be reflected back by one of these mirrors when the light is contained in a plane normal to the polygon mirror and to one of the fixed mirrors inclined at 45° .

If the number of mirrors in the outer ring and conical group of mirrors respectively are chosen as before to give a vernier setting to obtain subdivisions of the angle between successive mirrors of the polygon mounted on the spindle a large number of angular settings can be obtained with a small number of mirrors, with the additional convenience that the auto collimator is fixed.

In any of the above arrangements instead of the ordinary form of auto collimator a projection system may be employed, so that the index lines or scales by means of which the setting is made are projected on to an opaque or transparent screen.

To obtain greater precision in any of the above examples the light may be directed on to the reflecting face of the polygon at an angle so that it will be reflected normally towards a stationary mirror and so be reflected back along its own path to the polygon and then be returned to the autocollimator.

Under such conditions the light will be deviated through twice the angle for a given angular movement of the polygon as compared with the

angle through which the light would be deviated if it is reflected back once from the reflecting face of the polygon and so approximately twice the precision is obtained provided the surface of the mirrors are of sufficient optical precision.

The autocollimator used in conjunction with the polygon may be further modified in order to make the indication more accurate and convenient to read.

In the ordinary form of autocollimator a slit may form the reference line and be placed at the focal plane of the collimator objective and displaced to one side of the optical axis. After reflection from the face of the polygon and vernier polygon the light will form images of the slit in the focal plane on the opposite side of the optical axis from the object. When the faces of the main and vernier polygon are exactly in the same plane the images of the slit formed by light reflected from each of the two faces will be superimposed. As, however, it is not easy to determine the exact point at which the two slit images exactly overlap it is preferable to modify the instrument to displace the images along their length so that they are end to end when the two reflecting surfaces of the polygons are in one plane, and the slit images appear as though they were one long image, a setting which can be made with great precision. The endwise displacement of the image can in one method be produced by deflecting prisms between the collimator objective and the reflecting faces of the polygon. Optical means may also be employed in order to produce a good division between the two adjacent ends of the slit images in known manner, as for instance two thick glass plates inclined at an angle to each other, the edge of one plate being slightly behind the other which has a very fine edge polished on it and which forms an almost invisible dividing line between the two fields so that the ends of the slit images will appear exactly to meet each other without overlap.

The exemplary forms described above have been given to illustrate the principle of the invention and it will be appreciated that other forms may be adopted to give similar results.

The invention is exemplified by the accompanying drawings in which:

Fig. 1 illustrates one form of dividing head in sectional elevation;

Fig. 2 is an end view of a detail of Fig. 1;

Fig. 3 is an end view of another detail of Fig. 1;

Figs. 4 and 5 illustrate respectively a scale and an image thereof;

Fig. 6 is a section of a detail of the device, in a modified form;

Fig. 7 is an end view of an alternative form of polygonal reflecting surfaces;

Fig. 8 is a sectional view of Fig. 7;

Fig. 9 is a plan view of a detail of Fig. 7;

Fig. 10 is a side view of another alternative form of polygonal reflecting surfaces;

Fig. 11 is a front view of a detail of Fig. 10;

Figs. 12 and 13 illustrate scale images produced according to the arrangement in Fig. 10.

Referring first to Fig. 1, 1 is the spindle of the dividing head on which is mounted the polygon 2 on which are polished 18 faces on the circumference 3, each at 20° angle to each other.

The vernier semi-polygon 4 is mounted adjacent to the polygon 2 and means are provided for imparting a small amount of angular movement by the micrometer screw 5 and drum 6 more clearly shown in Fig. 3. The vernier polygon is

held by spring pressure 7 against two locating pins 8 at the bottom, the weight being supported by balls 9.

The upper end is held by spring pressure 10 against the micrometer screw 5. The micrometer screw 5 is mounted in the supporting nut 11 which is provided with screws 12 to enable the distance between the axis of the micrometer screw and the supporting pins to be accurately adjusted so that the engraved drum 6 will give the desired subdivision, in this case subdivision of one minute of angle corresponding to one revolution of the drum.

Referring back to Fig. 1 13 is the object glass of the autocollimator, 14 and 15 are mirrors by which the light is turned in an approximately horizontal direction. Light enters the autocollimator from the lamp 16 and condenser lenses 17 and is turned by the prism 18 by which the light is directed onto the pair of mirrors 14 and 15. Cemented to the prism is a plate 19 on which is engraved a scale including a range of 2° arranged as illustrated in Fig. 4. One part of the scale 20 includes a range of 1° divided in minutes of angle. Above this scale are two lines 21 and 22. Line 21 is an extension of the 0 line of scale 20 and the other corresponding to 1° distant from it to the left hand side. Light passes through the plate 19 on to the mirrors 14 and 15 through the objective 13 and on to the reflecting surfaces of the polygons 2 and 4 by which it is reflected back. The mirror 14 is so inclined that the light falling on the polygon 2 is returned to the aperture 23 in the plate 19 and forms an image of the scale lines 21 and 22 with the end of the lines just coming to the centre line of the aperture as shown in Fig. 5. In a similar manner the mirror 15 is inclined so that the image of the scale 20 is formed, by reflection from polygon 4, in the aperture 23 with the ends of the line coincident with lines 21 and 22 or with a slight overlap or alternatively known optical devices may be used to produce an almost invisible dividing line, as for instance a pair of thick glass plates shown in side view in Fig. 6, in which 23' and 24 are the two thick glass plates, 24 being slightly behind plate 23' so that the almost invisible dividing line is formed by the sharply polished edge 25 of plate 23', the adjacent ends of the engraved lines of scales 20, 21 and 22 being formed by the rays 26 and 27 respectively.

When the light falling on the polished face of the polygon and vernier polygon are at the zero setting of the scales the line 21 as seen in the aperture 23 is coincident with the first division of the scale 20 as illustrated in Fig. 5 the line 22 not being visible in the aperture.

Behind the aperture 23 a projecting lens 28 collects the light which then passes on to the mirrors 29 and 30 by which the light is brought approximately central to the axis of the dividing head spindle 1. The light is then directed on to the diffusing screen 31 on which an enlarged image of the scales in the aperture 23 are formed. This image is again enlarged by the magnification lens 33 which also serves to collect the scattered light and direct it towards the eye of the observer situated at approximately normal reading distance, that is about 10 to 12 inches distance.

The entire autocollimator, illuminating system, projection lenses and screen are mounted together on the plate 34 which is capable of being rotated approximately about the same axis as the dividing head spindle, its position (see Fig.

2) being indicated by the scale 35 and index 36, the scale in this example being divided in 1° divisions from 0 to 20°. The mirror 32 and magnifying lens 33 preferably do not rotate with the autocollimator, but are arranged at a convenient angle for observation.

A scale 37 divided in 1° divisions is mounted on the dividing head spindle, preferably on the front of the main housing. This scale is required for rough preliminary setting and need not be divided to a high precision. The setting of the scale readings are indicated by the index 38.

In setting the dividing head spindle to any desired angular amount, the spindle is turned to read to the nearest scale division by reference to the scale and index 37 and 38. The plate 34 is then turned to the corresponding reading to the nearest 1° division in each range of 20° of scale 37, for example if scale 37 is set to 165° the plate 34 is turned until the index 36 reads a division 15° of scale 35.

On looking into the observation screen 31 the scale lines of 21 and 22 images may both appear in the field of view or only one of them. By means of a slow motion device on the dividing head spindle e. g. a worm 39 and worm wheel 40, the spindle is turned until the line 22 is exactly coincident with the line 0 of scale 20. If the desired setting includes minutes, the spindle is turned until the index line 22 is in coincidence with the corresponding number of minutes on the scale 20; if, however, seconds of angle are also included in the required angle, the drum 6 is first turned to read the required number of seconds the inclination of the vernier polygon so imparted causing the scale image 20 to move a corresponding amount to the right. The dividing head spindle is then turned by the slow motion device until the index line 22 corresponds to the required number of minutes of angle.

For setting to an angle of even number of 1° division setting would be made by the index line 21 instead of the index line 22 but in all other respects the procedure would be the same.

It will be apparent that the precision of setting depends upon the relative setting of one of the index lines 21 or 22 in register with the scale 20 and so inaccurate movement of the plate 34 carrying the collimator and viewing system does not affect the result.

In the above example an alternative construction for the polygon may be employed in which a metal disc 41, Figs. 7 and 8, has locating faces at 40° to each other preferably each locating face consisting of three small areas 43 as shown in plan view in Fig. 9, so as to reduce the amount of work required to produce flat surfaces and to give geometric location for the mirrors 42. The mirrors are retained on the locating areas by springs 45 and the spring supporting ring 44. The mirrors are polished on both faces and may be of stainless steel or other suitable metal or of glass, quartz or fused silica, coated with a highly reflecting medium such as rhodium, chromium or aluminium.

Since light is reflected from both surfaces of the mirrors it will be clear that when the autocollimator axis is normal to the outer face of one of the mirrors the light is reflected from the other surface of the mirror, but when the autocollimator is between two adjacent mirrors with its axis normal to the inner face of the mirror on the opposite diameter, light will be reflected back from the inner face of this mirror. In this way the number of locating plane faces required

for the polygon is reduced to half the number required with a solid polygon, and since plane parallel mirrors can be manufactured to a high precision by comparatively unskilled labour the amount of highly skilled labour is reduced since there are only half the number of planes inclined to each other at high precision of angle as compared with a solid polygon.

It should be noted that this arrangement is preferably adopted when half the total number of reflecting faces required is an odd number, as otherwise the mirrors cannot be arranged equally spaced round the diameter of the disc.

An alternative arrangement may be employed in which a polygon of the above kind with mirrors overlappin the edge of a metal disc is employed, but in this case with the full number of mirrors equally spaced round the circumference and the light will be reflected from the inner face only. The vernier polygon will in this case consist of mirrors or reflecting faces polished on a solid metal polygon with the reflecting faces inclined at 45° to the axis of the dividing head spindle as illustrated in Fig. 10 and front view Fig. 11. The polygon 46 is attached to the dividing head spindle 47 and has a number of equally spaced plane faces each consisting of three raised areas 43 on which the mirrors 48 are located and retained by the spring 49 and retaining ring 50.

The conical vernier polygon 51 is mounted approximately central with the axis of the spindle 47 and the autocollimator objective 52, preferably with means of imparting a small amount of angular movement as for instance the arrangement with a micrometer screw and drum illustrated in Fig. 3 so that small angular division can be recorded.

In the centre of the conical vernier polygon a small area 61 is polished normal to the axis of the autocollimator, or slightly inclined to normal, so that some of the light coming from the autocollimator is reflected back by it, and so enables a fixed reference scale image to be formed on the projection screen.

The objective 52 is large enough in diameter to illuminate the whole of the conical polygon 51 so that when any one of the polished faces 62 and the polished face of one of the polygon mirrors 48 are perpendicular to a common plane, light will fall normally on the reflecting surface of the polygon mirror 48 and be returned back to the objective. The optical arrangement of the illuminated scale and projecting system may be similar to that illustrated in Fig. 1 the mirrors 29 and 30 being arranged to bring the light and projecting screen at a convenient angle for observation, but in this case the autocollimator and projection system are stationary so that the scale 35 Fig. 2 must be replaced by an alternative arrangement. One method which may be employed depends upon the optical effect produced by the combination of the conical vernier polygon 51 and the polygon mirror 48. The scale images as viewed on the projection screen will remain in a given direction irrespective of which of the faces 62 of the conical vernier polygon or polygon mirrors 48 are transmitting the light forming the scale image, for example if the scale image is arranged to be viewed with the dividing lines in a vertical direction, they will remain in a vertical direction for all orientations of the polygon 46 for which one of the mirrors 48 is in a position to reflect back light from any one of the faces of the conical vernier polygon, but if the

polygon 46 is moved slowly across one of the positions when light is reflected back to form a scale image, the scale image will pass across the projection screen in a direction parallel to the reflecting face of the polygon mirror 48 from which the light is being reflected, and since the reflecting plane of this mirror will then be perpendicular to a common plane to that of the plane of the reflecting face 62 of the conical polygon, it is clear that the scale will move across the field of the projection screen in directions corresponding to the relative angular interval of the reflecting faces to each other, for example, if the conical vernier polygon has 10 faces 62 at 36° to each other, the scale image will move across the field of the projection screen in one of 10 different angular directions each 36° apart depending upon which face of the conical polygon is transmitting the light forming the scale images. The projection screen may be of circular form as in Fig. 12 and the fixed or reference scale, formed by light reflected from the central polished face 61 on the conical vernier polygon, consist of a series of concentric circles, the intervals between each adjacent circle corresponding to one subdivision, as for instance one minute of angle, and a series of fine radial lines numbered to correspond to every 2° in this example. The scale image produced by the light reflected from a pair of reflecting faces of the polygon 46 and conical vernier polygon consists of a single small circle or disc 63 and a large circle of diameter representing 1° in this case, preferably slightly smaller in width than the interval between successive circles on the fixed scale, as shown in Fig. 12. For the sake of clearness only 12 divisions each representing five minutes of angle are shown in the illustration, but in this example there would be usually 60 divisions each representing one minute of angle.

In the zero position of the spindle of the divided circle the small circle or disc 63 would appear at the top of the fine line engraved 0 between the outer pair of scale circles as in Fig. 12, and for any movement of the polygon 46 within the range over which the light is reflected between the first pair of reflecting faces on the polygon 46 and conical vernier polygon the indicating circle or disc will travel along the fine line marked "0." If the polygon is turned so as to bring another pair of reflecting faces into the beam of light, for example in the 6° position the circle or disc 63 will travel along the line marked 6° (Fig. 13). If the reading required is an odd number of degree divisions readings are made on the outer indicator ring which will appear in the field when the small ring or disc completes the first degree of movement in the same way as the two lines 21 and 22, Fig. 5, indicate the reading in the first example.

Instead of the polygon 46 being attached to the dividing head spindle, the conical vernier polygon may be attached to the spindle and the polygon 46 fixed, but in this case the central reflecting polished face would be a separate mirror and remain fixed.

What we claim is:

1. In a dividing machine, a light source; a collimating device positioned to receive light from said source and including an objective; means providing an index line in the focal plane of said objective; an arrangement of reflecting surfaces together constituting a first polygon; means

mounting said polygon and said collimating device for relative rotation and with said polygon in the path of parallel light projected from said collimating device; a second arrangement of reflecting surfaces constituting a vernier polygon; means mounting said vernier polygon in the path of parallel light projected from said collimating device, the means mounting said collimating device and said vernier polygon providing for relative rotation between said collimating device and said vernier polygon; a device for viewing an image at the focal plane of the objective, said first polygon and said vernier polygon being arranged so that parallel light projected from said collimating device is received angularly by surfaces of said polygons and so that light projected from said collimating device will be reflected back into said objective to form, at the focal plane of the objective, an image of said index line formed by light reflected from one of the faces of said first polygon and an image of said index line formed by light reflected from one of the faces of the vernier polygon; and an indexing device for effecting relative rotation between said first polygon and said collimating device and between said two polygons to move the image of said index line formed by light reflected from said face of said first polygon across the field of said collimating device, and thus to define the angular position of said first polygon relative to said vernier polygon.

2. A dividing machine as claimed in claim 1 in which at least one of said polygonal means comprises a carrier and mirrors mounted in angular spaced relationship around the circumference of the carrier so as to overlap an edge of the carrier.

3. A dividing machine as claimed in claim 1 in which at least one of said polygonal means comprises a carrier and mirrors mounted in angular spaced relationship around the circumference of the carrier so as to overlap an edge of the carrier, the mirrors being each supported on three spaced flat surfaces of the carrier.

4. A dividing machine as claimed in claim 1 in which at least one of said polygonal means comprises a carrier and mirrors mounted in angular spaced relationship around the circumference of the carrier so as to overlap an edge of the carrier, the mirrors being each reflective on two parallel opposite faces.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
432,621	Holz	July 22, 1890
1,421,523	Mechau	July 4, 1922
1,854,760	Paulson	Apr. 19, 1932
2,059,753	Scott et al.	Nov. 3, 1936
2,086,391	Poole	July 6, 1937
2,253,795	List	Aug. 26, 1941
2,288,243	Hyde	June 30, 1942

FOREIGN PATENTS

Number	Country	Date
338,206	Germany	June 15, 1921