

May 19, 1953

C. W. KEUFFEL ET AL

2,638,814

REFLECTING TELESCOPE

Filed March 26, 1947

3 Sheets-Sheet 1

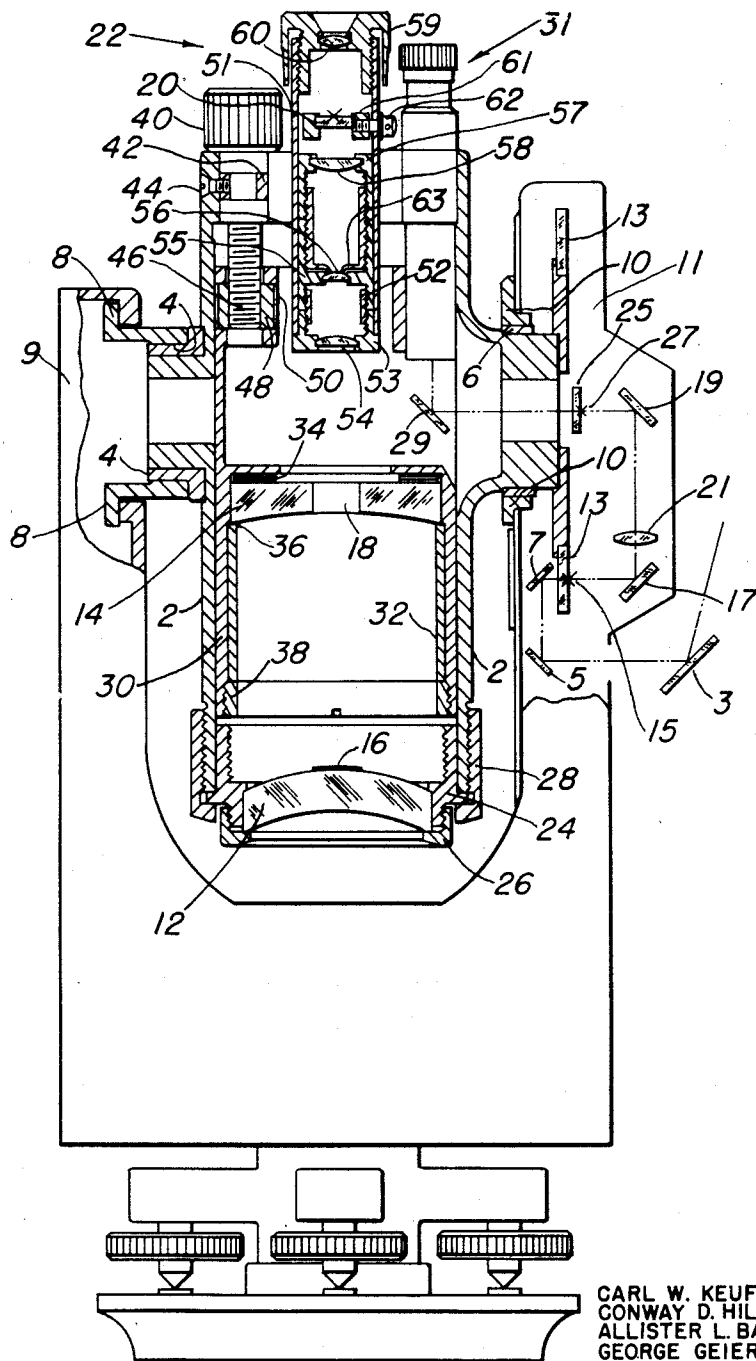


Fig. I

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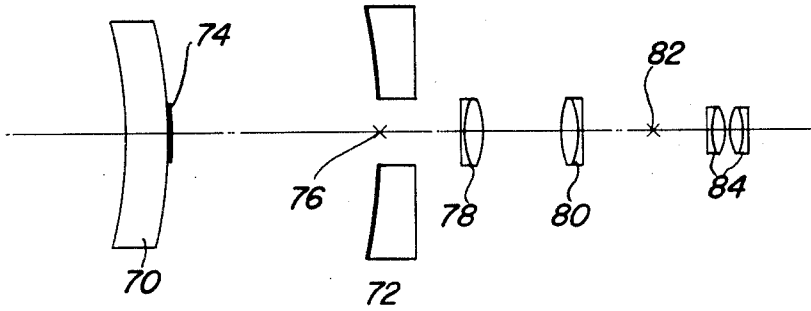


Fig. II

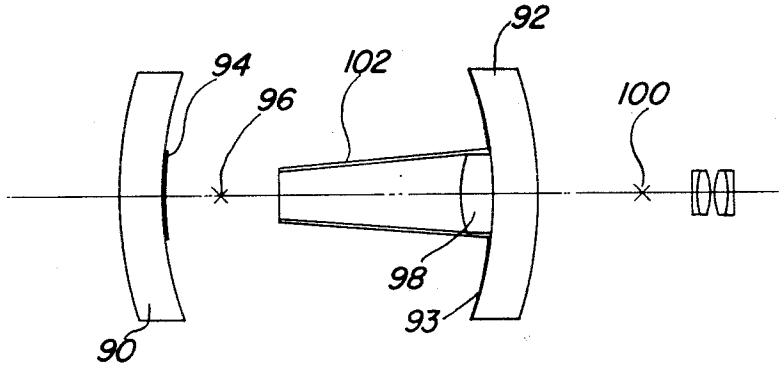


Fig. III

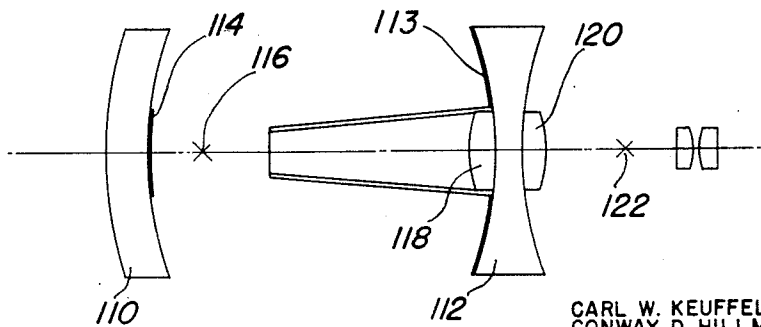


Fig. IV

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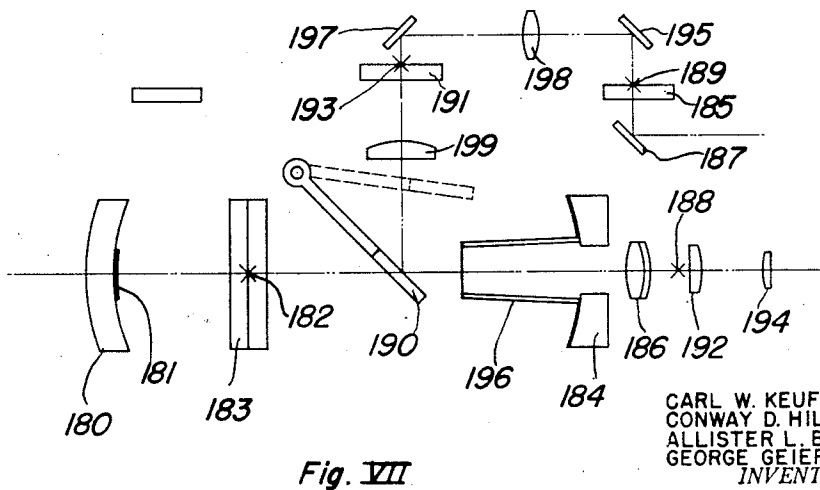
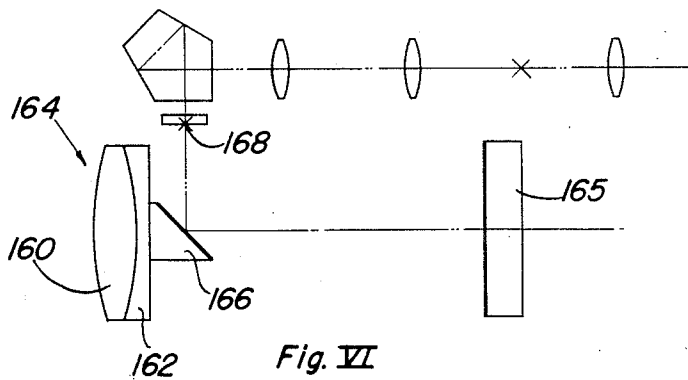
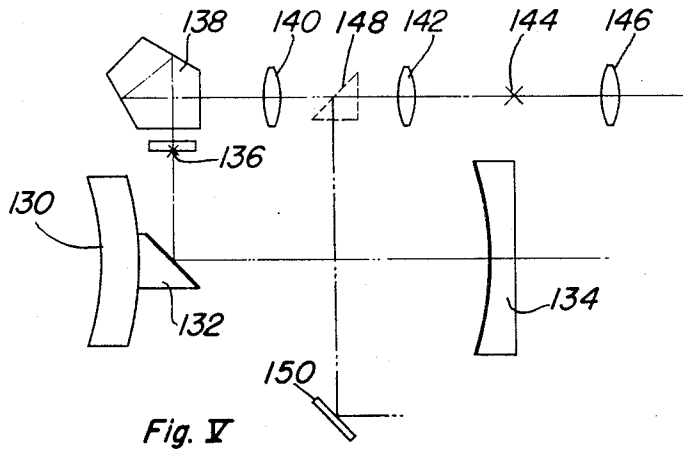
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3 Sheets-Sheet 3



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2,638,814

REFLECTING TELESCOPE

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Application March 26, 1947, Serial No. 737,348

3 Claims. (Cl. 88—32)

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Surveying instrument telescopes are usually required to have a magnification of about 18 to 40 power. In order to achieve these magnifications and have good light gathering capacity without too much loss in definition because of aberrations, it is ordinarily necessary to make the telescope quite long. It has been found that by making use of spherical reflecting surfaces as well as refracting surfaces it is possible to use shorter lengths for the same magnification while maintaining the light gathering capacity and securing definition equally as good as in the ordinary refracting type telescopes known in the art. In some cases it may be desirable to use spherical reflecting surfaces of infinite radius or plano surfaces.

This new system can also be used to increase the light gathering capacity of telescopes of a given length and magnification without reducing the definition or they can be used to improve the definition of telescopes of given length, magnification and aperture. The new shorter surveying instrument telescopes forming this invention make it possible to design surveying instruments which are more compact and therefore easier to handle and carry and less ungainly in appearance.

Another requirement of surveying instrument telescopes is that they should be capable of being focused from infinity down to about 5 ft. target distance. Methods of doing this have been devised for the reflecting telescopes herein described and are an important part of the invention.

A third requirement of surveying instrument telescopes is that a reticle should be provided at a focal plane, so that the image of a target is seen through the telescope as if superimposed on the reticle and the reticle markings can be set on any desired point of the target for the purpose of reading angles between points etc. The reticle may also be provided with stadia lines for determining distances from the instrument to a graduated rod held at some distant point.

The principal object of the invention is to provide a telescope for a surveying instrument which is shorter than those usual in the art but which has good light gathering capacity and definition and suitable magnification by including at least one spherical reflecting surface and providing the telescope with focusing means and a reticle for setting on distant targets, stadia rods or the like.

The method by which this and other objects of the invention are achieved will become more evident from the following description taken in connection with the accompanying drawings in which:

Figure I is a view in elevation of a surveying instrument with the telescope and an optical sys-

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tem for reading the protractor for vertical angles shown in vertical section.

Figure II is a diagrammatic view of a different embodiment of the optical system of Fig. I and which could be used for the telescope.

Figure III is a diagrammatic view of an optical system for a telescope in which the meniscus lens and reflecting element with attached parts form an erecting system with a simple eyepiece.

Figure IV is a diagrammatic view of an alternative optical system similar to that shown in Fig. III but having improved oblique chromatic aberration.

Figure V is a diagrammatic view of an optical system for a telescope in which the eyepiece is not coaxial with the meniscus and spherical reflector and which makes it possible to read a scale through the telescope eyepiece when desired.

Figure VI is a diagrammatic view of an optical system for a telescope using a conventional type objective in combination with a plano reflector in order to shorten the length of the telescope.

Figure VII is a diagrammatic view of an optical system for a telescope showing a system having an eyepiece coaxial with a meniscus, an optical system for reading a protractor for vertical angles and a movable reflector which can be used for reading the protractor when desired.

Referring to Fig. I, the main casting 2 forms the outer shell of the telescope. It is provided with cylindrical bearing surfaces 4 and 6, which fit inside the bearing surfaces 8 and 10 attached to the standards 9 and 11. The telescope is turned in these bearing surfaces when changing the vertical angle or in transiting.

The meniscus lens 12 and the reflector 14 act together as the objective. The inside central part of the meniscus is provided with a round spot of reflecting material 16 such as aluminum. The aluminum or other front surfaced mirrors may be made by deposition in a vacuum. Light passes through the meniscus lens 12 to the reflector 14, which in this embodiment is a glass element provided with a reflecting material such as aluminum on its front surface, and which reflects the light to the reflecting spot 16, which in turn reflects it through the light transmitting area 18 which in this embodiment is a hole xxx in the reflector 14, whence it passes through the eyepiece 22 and the reticle 20. The meniscus lens is designed (by known methods) so as to balance the spherical aberration of the reflector 14 and reflecting spot 16 without adding appreciable chromatic aberration.

The meniscus lens 12 fits into the meniscus lens mount 24 and is held in place therein by the meniscus lens cap 26, which screws over the meniscus lens mount 24. The meniscus lens

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mount 24 fits inside the main casting 2 and is held in place by the meniscus mount cap 28 which screws over the main casting 2.

The reflector 14 fits inside the reflector draw tube 30 and is held against the spacer 32 by the spring washer 34 which acts between the reflector draw tube 30 and the reflector 14. The spacer 32 is a very accurately machined part having an aligning surface 36 in a plane perpendicular to axis of the telescope so that the front reflecting surface of the reflector 14 which is aligned thereby is centered with the axis of the telescope. The ring 38 screws inside the reflector draw tube 30 and holds the spacer 32 against the reflector 14 so that the proper adjusted spacing is maintained between the reflector 14 and the meniscus 12.

The reflector draw tube 30 is actuated by the focusing knob 40 for focusing the telescope. Motion of the focusing knob 40 parallel to the axis of the telescope is prevented by the ring 42 which is fastened to the main casting 2 as by the screw 44. The focusing knob 40 turns the focusing screw 46 which is threaded to act in the self-aligning nut 48. The self-aligning nut 48 is circular in cross section taken parallel to the axis of the focusing screw 46 and fits in a circular hole 50 drilled perpendicular to the axis of the focusing screw 46 in the reflector draw tube 30.

This focusing arrangement provides a method which maintains the reflector 14 centered on the telescope axis. This is of primary importance in a telescope for a surveying instrument because one of the principal purposes of a surveying instrument is to obtain a definite line of sight to a target which can be read with respect to the graduated limbs or protractors of the instrument.

The eyepiece 22 is essentially a standard four lens erecting eyepiece with an achromatic eye lens. It fits in a coaxial sleeve forming part of the main casting 2 which centers it with the axis of the telescope and the rest of the optical parts. The position and size of the diaphragm 63 between eyepiece lenses 56 and 58 in the previous case is such as to make the opening in the diaphragm 63 an exact or slightly smaller image of the reflecting spot 16 by the first lens 54 and second lens 56 of the eyepiece. This is done to eliminate unwanted oblique rays of light which otherwise could pass directly through the meniscus lens 12 and the hole 18 and on through the eyepiece.

For this embodiment the reticle 20 is provided at the focal plane between the third eyepiece lens 58 and fourth lens 60 of the eyepiece instead of in the more usual place at the focal plane between the objective and first lens of the eyepiece. This is done in order to simplify the mounting of the reticle which would be somewhat difficult at the latter focal plane because it would have to be mounted within the movable reflector draw tube 30.

The elements of the eyepiece 22 are all held together by the main eyepiece tube 51. The four eyepiece lenses 54, 56, 58 and 60 are mounted in their mounts 53, 55, 57 and 59. The first, second and third eyepiece lenses 54, 56 and 58 and the diaphragm 63 are assembled as a unit and slide into the main eyepiece tube 51 until the shoulder on the mount 53 for the first eyepiece lens comes against the end of the main eyepiece tube 51. The diaphragm 63 screws inside the mount 55 for the second eyepiece lens. The third eyepiece lens mount 57 then screws over an extension of the diaphragm 63 which serves to join the mounts 55 and 57. The joining tube 52 screws inside the

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mount 55 for the second eyepiece lens on the opposite side of the second eyepiece lens 56. The mount 53 for the first eyepiece lens is then screwed over the joining tube 52 to complete the assembly of the three eyepiece lenses 54, 56 and 58 and the diaphragm 52.

The mount 59 for the fourth eyepiece lens screws inside the main eyepiece tube 51. This thread also serves as a means of focusing the fourth eyepiece lens 60 on the reticle 20. The reticle 20 is mounted in the reticle mount 61 which is held in position inside the main eyepiece tube 51 by screws 62. These screws 62 also serve for adjusting the position of the reticle 20.

To the right of the eyepiece 22 in Fig. I an auxiliary eyepiece is shown within the scale reading eyepiece tube 31. This eyepiece may be used for reading the graduated protractors in instruments having an optical system for reading the protractors. In the latter case the focusing knob 40 and the auxiliary eyepiece situated on both sides of the main eyepiece 22 give a symmetrical appearance to the eye end of the telescope.

Depending on variations in the rest of the surveying instruments or in the characteristics desired, variations of the telescope described above are possible within the scope of the invention. For example, the method of focusing could be changed to one in which the reflector 14 remains fixed and the entire eyepiece 22 is moved for focusing. This would require a greater focusing movement which might interfere with transiting the telescope but in cases where this was not important a more sensitive focusing method would be provided. In cases where no auxiliary eyepiece is needed focusing of the reflector 14 could be accomplished by a knurled knob rotatable around the outside of the eyepiece 22. This might provide a smooth movement with less danger of tilting the reflector 14.

Instead of the concave meniscus shown in Fig. I it would be possible to use a meniscus convex to the target by cementing an element on the inside surface of the meniscus at the center in order to provide the necessary convex reflecting surface. In case an erecting telescope was not necessary a simpler eyepiece such as a Ramsden eyepiece could be combined with the reflector and meniscus shown in Fig. I or with the one just described.

A system for obtaining an erecting telescope without an ordinary four lens eyepiece is shown in Fig. II. Light passes through the meniscus 70 to the reflector 72 which reflects it to the reflecting spot 74 which in turn reflects it to a focal plane 76. The first erector 78 changes the light into parallel or nearly parallel rays which are imaged by the second erector 80 at the focal plane 82. From here the light passes through the eyepiece 84, consisting of two achromatic lenses. A reticle could be provided at either of the focal planes 76 or 82. The system would preferably be focused by moving the first erector 78. Focusing in this manner would not change the image quality because of the parallel rays between the first and second erectors 78 and 80.

Figure III illustrates an optical system for a telescope which gives an erect image with a simple eyepiece and without erectors. Light passes through the meniscus lens 90 to the front reflecting surface 93 of the reflector element 92 which is provided with a reflecting coating. This reflecting surface brings the light from the target to a focus at focal plane 96. The light passes on to the reflecting spot 94 which reflects the light in almost parallel rays to the auxiliary

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lens 98. The light passes through this lens 98 and the reflector 92 to a focal plane 100. The auxiliary lens is cemented to the reflector element 92 at a central clear spot. The first surface of the auxiliary lens 98 and the last surface of the reflector element 92 act as a single lens and bring light to a focus at the focal plane 100. The meniscus is designed to eliminate the net spherical aberration of the reflector 92, the reflecting spot 94 and the combined lens formed by the auxiliary lens 98 and the second surface of reflector 92 without introducing appreciable chromatic aberration.

The focusing of this telescope is accomplished preferably by moving the auxiliary lens 98 and the reflector 92 together by an arrangement for example as shown in Fig. I. The elimination of unwanted light is somewhat more difficult in this embodiment but can be accomplished for example by the conical tubular diaphragm 102. The elimination of this unwanted light could be simplified if the system were designed so that the distance from the focal plane 100 to the reflector 92 was greater in proportion to the distance between the meniscus 90 and the reflector 92, so that the light passing through the meniscus around the reflecting spot 94 and directly through the auxiliary lens 98 could be more easily diaphragmed before entering the eyepiece without interfering with essential rays.

Other variations of this embodiment are also possible. For example a system may be designed having a light transmitting area through the reflector 92 without the auxiliary lens 98 or a meniscus concave to the target could be used if a concave reflector were cemented centrally to the inside surface thereof. If a hole is provided in the reflector 92, a positive lens could be provided in or near this hole but not attached to the reflector. This lens might then be used for focusing the telescope by moving it instead of the reflector.

A further variation of this embodiment is shown in Fig. IV, in which the oblique chromatic aberration has been corrected by adding one more element and making the reflector element of flint glass. Light from the target passes through the meniscus 110 to the front reflecting surface 113 of the reflector 112 which brings it to a focus at the focal plane 116. The light passes on to the reflecting spot 114 provided on the inside surface of the meniscus 110 which reflects the light in nearly parallel rays. The auxiliary lenses 118 and 120 are cemented centrally to the first and second surfaces of the reflector 112 and form a cemented triplet with the central portion of the reflector 112, which brings the light to a focus at the focal plane 122, whence it passes through the reticle and eyepiece. This system is preferably focused by moving the reflector 112 with the attached lenses 118 and 120. The unwanted light can be eliminated by the methods discussed in connection with Fig. III.

In Fig. V a system is shown having the eyepiece axis displaced from the line of sight. Light from the target passes through the meniscus 130 to the reflector 134. The reflector 134 forms an image on the reticle 136, the direction of optical path being changed by the reflector 132 cemented to the inside surface of the meniscus 130 at its center. The rays diverging from the reticle 136 pass through the penta prism 138 to the first erector 140 which sends them forth in substantially parallel form. The second erector 142 brings them to a focus at the focal plane 144.

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The target superimposed on the reticle is seen through the eyepiece 146.

The meniscus 130 is designed to neutralize the spherical aberration of the reflector 134 without introducing appreciable chromatic aberration. The erectors and eyepiece are designed to minimize aberrations in the ordinary manner. The penta prism 138 is used instead of a simple reflector or right angle prism to obtain an unverted image.

This system has the advantage of providing an erecting telescope in which the space between the meniscus and the reflector almost equals the length of the telescope. Therefore an exceptionally large aperture is possible with high magnification and freedom from aberrations. No problem of eliminating unwanted light exists in this embodiment since it is automatically eliminated when the direction of the optical path is changed by the reflector 132.

Focusing may be accomplished in this embodiment by moving the reflector 134.

The motion of the reflector can easily be accomplished without danger of tilting because of the absence of the eyepiece which makes it necessary to move the reflector from one side as in Fig. I. If the reticle were placed at the focal plane 144 instead of as shown, focusing could also be accomplished by moving the first erector 140.

If it is desired to use a telescope as shown in this embodiment of the invention in a surveying instrument provided with optical means for reading the protractors, it would be possible to read them through the same eyepiece 146 by providing a movable prism 148 shown in dotted lines between the erectors 140 and 142. When looking at the target this prism would be moved out of the optical path and when looking at the protractor scales it would be moved in the optical path to pick up parallel rays coming through a prism or reflector 150 from the scale reading system and projected through the space between the meniscus 130 and the reflector 134.

By adding two more reflectors or prisms between the second erector and the eyepiece focal plane it is possible to make the eyepiece coaxial with the axis passing through the center of the meniscus 130 and the main reflector 134.

The embodiment shown in Fig. VI uses a conventional type objective of crown and flint glass in combination with a plano reflector. This type makes it possible using a crown-flint objective lens to get a longer focus objective within the same space. The objective 164 is made up of the objective crown 160 and the objective flint 162 which are cemented together. The objective 164 images the target at 158, the direction of light being reversed by the plano reflector 165 and thrown perpendicular by the 45° reflector 166. From this point on the optical system may be as shown in Fig. V.

This system could be focused by moving the reflector 155.

This embodiment could also be modified by reflecting the light back along the optical axis from a reflecting surface provided on the inside surface of the objective thence through a hole in the reflector 165.

The reflecting surface on the inside of the objective lens may be easily accomplished by adding a reflecting spot to that surface of the objective or by cementing a small reflector at the center of this inside surface.

Fig. VII shows another system in which the same eyepiece can be used for finding the target

and reading protractors. The light from the target passes through the meniscus 180 and the glass plate 183 on which the reticle 182 is provided to the reflector 184 which focuses it on the reticle 182. The light again passes through the glass plate 183 to the reflecting spot 181 provided on the inside surface of the meniscus 180. The rays returning from the reflecting spot 181 through the glass plate 183 are nearly parallel and are brought to a focus by the auxiliary lens 186 at the focal plane 188. The target image superimposed on the reticle is viewed through the eyepiece made up of the first eyepiece lens 192 and the second eyepiece lens 194.

To read the protractors, the movable reflector 190 is moved to the position shown by the full lines, blocking off the light returning from the reflecting spot 181 and throwing the nearly parallel rays coming from the scale reading system onto the auxiliary lens 186 which brings the scales to a focus at the focal plane 188 so they may be seen through the eyepiece. One manner in which such a scale reading system could be constructed is shown diagrammatically at the top of Fig. VII. Light which can be brought into the instrument in any convenient manner is directed to pass through the glass protractor 185 by the reflector 187 to illuminate a portion of the protractor scale 189. This portion of the protractor scale 189 is imaged onto one surface of the reticle 191 superimposing it on the index mark 193, by means of the reflectors 195 and 197 and the lens 198. The light diverging from the reticle 191 passes to the lens 199 which sends it forth in substantially parallel form to the lens 186 when the movable reflector 190 is in position for reading the scale.

This description of the scale reading system is given here just to illustrate one way in which the same eyepiece may be used for both the telescope and the scale reading system of a surveying instrument. Obviously, a system similar to that shown in Fig. VII having a movable reflecting element, may be used with a conventional type telescope in order to make it possible to use the same eyepiece for both the telescope and scale reading systems in a theodolite.

In Fig. I a scale reading system is shown in diagrammatic form in which different eyepieces are used for the telescope and scale reading system. In Fig. I, light is thrown into the instrument by the reflector 3. The reflectors 5 and 7 direct this light to pass through the glass protractor 13 illuminating a portion of the protractor scale 15 provided thereon. This portion of the protractor scale 15 is imaged by the reflectors 17 and 19 and the lens 21 onto one surface of the reticle 25 which is provided with an index mark 27. The reflector 29 directs the rays of light diverging from the reticle 25 onto the eyepiece lenses not shown but included within the scale reading eyepiece tube 31.

The telescope in Fig. VII may be focused either by moving the reflector 184 or the auxiliary lens 186. It is necessary as in some other embodiments to provide means such as the conical diaphragm 196 for blocking out the unwanted light.

One mechanical method of focusing was shown in Fig. I in which a screw was used for moving the reflector. The fineness of thread used on such a screw can be widely varied depending on the focusing motion required. It is also possible to use other mechanical methods for focusing. For example, for longer motions a rack and pinion can be used. A spiral cam which can be rotated

about an axis fixed to the main telescope tube may engage and slide a pin attached to the reflector mount and extending through a slot in the telescope tube to the cam to focus the telescope.

The following tabulation shows two representative systems according to this invention.

Fig. I system

OBJECTIVE			
R	n	V	d
Radius	Index of Refraction	Dispersion	Separation
-41.88	1.517	64.5	8.5
-47.46	1.000		50.0
-130.74	1.000		50.0 (mirror)
+47.46	1.000		77.8 (mirror) dia. =11
EYEPIECE			
Plano	1.617	55.0	5.0
-9.14	1.000		2.0
Plano	1.617	55.0	16.2
-9.87	1.000		1.5
+12.20	1.617	55.0	25.1 (.8 from surface to diaphragm having 2.23 dia.)
Plano	1.000		2.5
Plano	1.523	58.6	5.4
Plano	1.000		1.7
+9.87	1.5725	57.4	14.7
-7.08	1.689		2.0
-299.5			30.9
			1.0

Fig. IV system

ERECTING OBJECTIVE

R	n	V	d
+55.80			
+46.06	1.649	33.8	15.3
-145.75	1.		105
-46.06	1.		105 (mirror)
+49.99	1.		102 (mirror)
-145.75	1.517	64.5	3
+38.10	1.649	33.8	3
-38.64	1.517	64.5	3
			25.82
EYEPIECE			
Plano			41.1
-9.25	1.523	58.6	2.5
+8.00	1.		6.5
Plano	1.523	58.6	2.0

We claim:

1. In a sighting instrument, a telescope comprising a meniscus lens having spherical surfaces to transmit light rays from an object, an element beyond said meniscus lens having a spherical reflecting surface to bend said rays of light back toward said meniscus lens and a central light transmitting opening, a reflecting surface on the center of the inside spherical surface of said

meniscus lens for reflecting the light from said spherical reflecting surface back toward the central light transmitting opening in said reflecting element, said meniscus lens and reflecting surfaces making up an objective combination which forms an image of the object, a first plano convex lens beyond said reflecting element, a second plano convex lens beyond said first plano convex lens, a diaphragm beyond said second plano convex lens having an opening no greater than the image of the reflecting surface on the center of a spherical surface of said meniscus lens formed by said first and second plano convex lenses to block out light rays passing through the meniscus lens beyond the reflecting surface thereon and through the light transmitting opening in said reflecting element and which pass on through said first and second plano convex lenses, a third plano convex lens beyond said diaphragm, a reticle beyond said third plano convex lens, an eye lens beyond said reticle, said three plano convex lenses and said eye lens forming an erecting eyepiece combination for viewing the image formed by the objective combination, all of said lenses, said reflecting element, said diaphragm and said reticle being centered on a single optical axis and means for moving at least one of the optical parts with respect to the others while maintaining the moving part centered on the optical axis to focus rays of light from the object on said reticle and form an image of the object on the reticle.

2. In a theodolite having standards mounted for rotation about a vertical axis, a telescope mounted for rotation about a horizontal axis with respect to said standards comprising a barrel shaped housing, a meniscus lens mounted in one end of said barrel shaped housing and having spherical surfaces to transmit light rays from an object, an eyepiece mounted in the other end of said barrel shaped housing on the same optical axis as said meniscus lens, a draw tube mounted within said barrel shaped housing between said meniscus lens and said eyepiece, said draw tube fitting accurately within said barrel shaped housing so that it can only move parallel to the optical axis of said meniscus lens and eyepiece, an optical element having a spherical reflecting surface and a central light transmitting opening mounted within said draw tube and centered on the optical axis of said meniscus lens and said eyepiece, said reflecting surface reflecting light rays passing through said meniscus lens back toward said meniscus lens, a reflecting surface on the center of a spherical surface of said meniscus lens for reflecting the light from said spherical reflecting surface back toward the central light transmitting opening in said reflecting element, said meniscus lens and reflecting surfaces making up an objective combination which forms an image of the object, an extension on said draw tube extending toward the eyepiece end of said barrel, a knurled knob at the eyepiece end of said barrel shaped housing for moving by rotation thereof said draw tube through said extension in a manner which will not transmit strain to said draw tube to bring the image formed by the objective combination into the focal plane of said eyepiece and a reticle at a focal plane of the optical system.

3. In a sighting instrument, a telescope comprising a meniscus lens having spherical surfaces of radius R_1 and R_2 to transmit light rays from

an object, an element beyond said meniscus lens having a spherical reflecting surface of radius R_3 to bend said rays of light back toward said meniscus lens and a central light transmitting opening, a reflecting surface conforming to the radius R_2 on the center of the inside spherical surface of said meniscus lens for reflecting the light from said spherical surface back toward the central light transmitting opening in said reflecting element, said meniscus lens and reflecting surfaces being in axial alignment, substantially in accord with the following table, in which V is the reciprocal dispersion ratio commonly found in optical glass catalogues.

Radius of Curvature	Thickness and Separation	Refractive Index, N_D	V
$R_1 = -41.88$	8.5	1.517	64.5
$R_2 = -47.46$	50.0	1.000	
$R_3 = -130.74$	50.0	1.000	
$R_2 = +47.46$	77.8	1.000	

a four lens erecting eyepiece and a reticle in axial alignment with said meniscus lens and reflecting element and means for moving at least one of the optical parts with respect to the others while maintaining the moving part centered on the optical axis to focus rays of light from the object on said reticle and form an image of the object on the reticle.

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