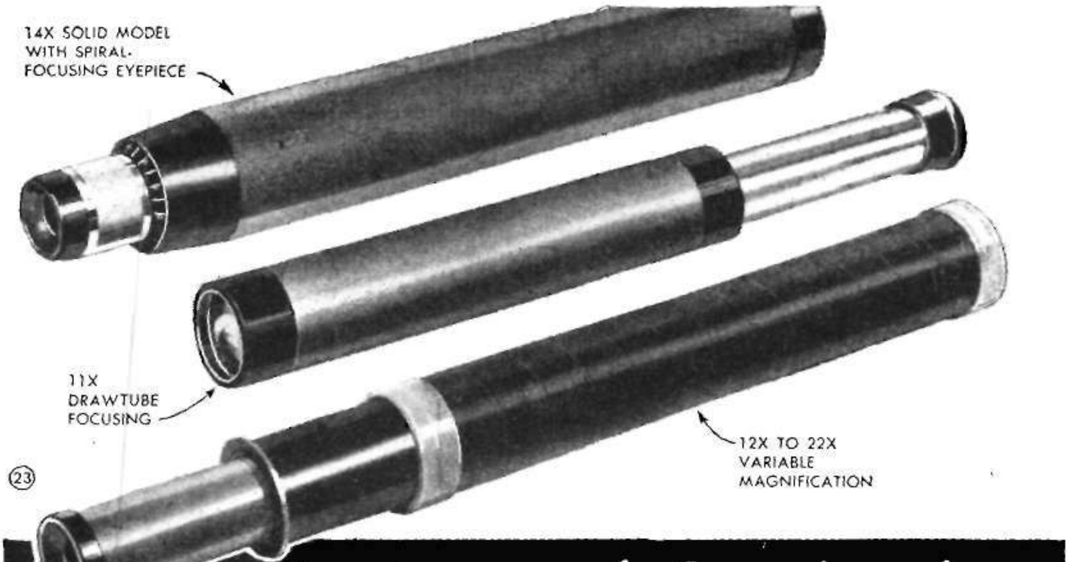


(23)

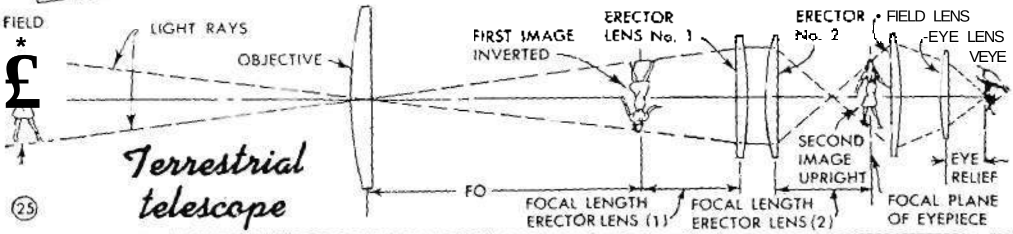
Design and Construction

(24)

IMAGE SIZE (40° APPARENT FIELD)			
M	Factor	M	Factor
8X	.087	17X	.042
9X	.077	18X	.038
10X	.070	19X	.036
11X	.063	20X	.035
12X	.058	21X	.033
13X	.054	22X	.031
14X	.049	24X	.029
15X	.047	26X	.026
16X	.044	28X	.024

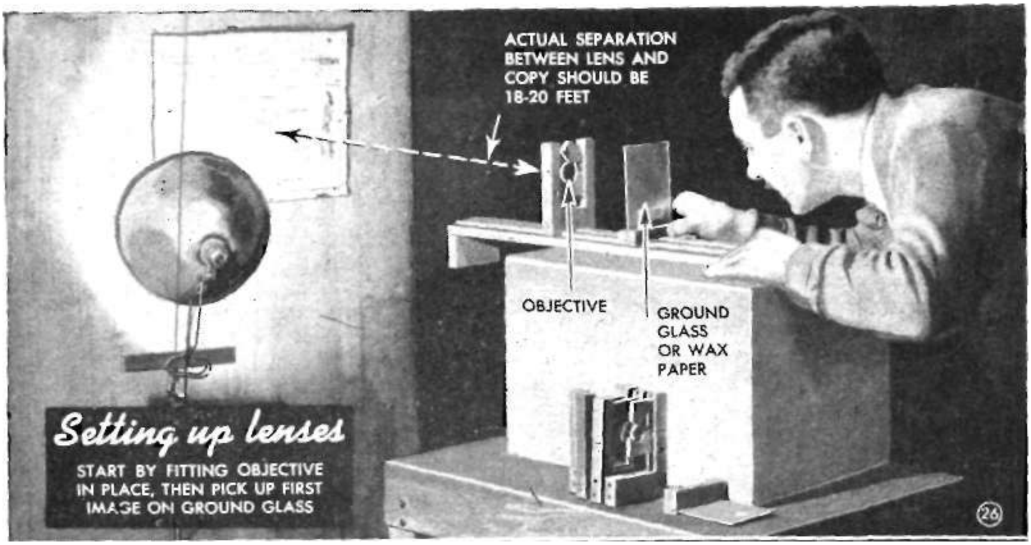
IF YOU made one of the telescopes described last month, you already are familiar with the basic information necessary to construct a terrestrial telescope, which is one for viewing objects on land. Obviously, it must show an upright image, and in order to do this with the astronomical telescope already described, it is necessary to add two lenses between the objective and eyepiece, as in Fig. 25. This type of erecting system permits added magnification through the erectors.

Normal lens system: This also is shown in Fig. 25. The field lens and eye lens making up the eyepiece are the same as for the astronomical telescope, and



(25) *Terrestrial telescope*

	CHARACTERISTIC	NORMAL VALUE	HOW CALCULATED	EXAMPLE: 11X (from text)
1	Equivalent focus of objective	1 to 3 times focal length of objective	FO times erector magnification	132 × 2 = 264 mm.
2	Erector magnification	1X to 3X	E-2 ÷ E-1	80 ÷ 41 = 2X
3	Magnification	13 times DO (in inches)	FO or equivalent FO divided by FE	264 ÷ 24 = 11X
4	First image size	1/4" to 3/4"	Value from Fig. 24 times FO	.063 × 5.18 = .326 = 5/16"
5	Exit pupil	2 to 5 mm. (3/32" to 3/16")	DO ÷ M	32 ÷ 11 = 3 mm.
6	Eye relief	3/16" (min.) to 1"	Measure direct	5/8" scant
7	Luminosity	10 to 100%	$(DO \div 5)^2 \div M^2$	$(32 \div 5)^2 \div 11^2 = 36 \div 121 = 30\%$
8	Field in yds. at 1,000 yds.	10 to 90 yards depending on magnification	Read value from Fig. 24 as yards (see text)	63 yards (see text)

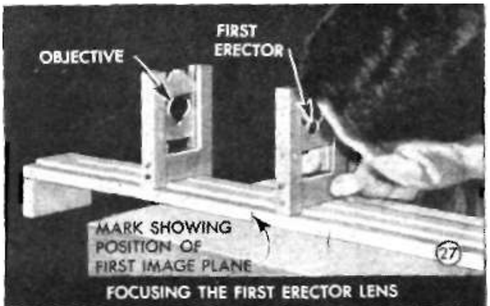


d TELESCOPES PART 2 Bf Sam Bwwn

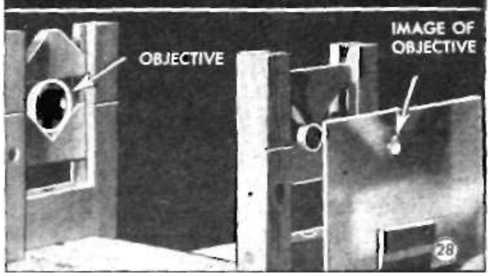
can be Huygenian, Ramsden or Kellner as previously described. The one shown here is a Ramsden. The eyepiece together with the two erectors make an erecting eyepiece, and all four lenses are mounted at a fixed spacing in the draw tube. Fig. 25 shows erectors of equal focal length, spaced at their focal lengths from the two image planes. With this setup, the erectors give unity magnification; that is, they add nothing to the magnification of the system.

Designing- your own scope: The best way to make a scope is to design and test your own. First, select suitable lenses, Fig. 32, and run through the simple calculations and other data. Then make a layout, tracing the light rays and, at the same time, check the system on the optical bench. This procedure, using tne 11X scope shown in Fig. 23 as an example, will be described in detail. Preliminary calculations are given in the right-hand column of the table.

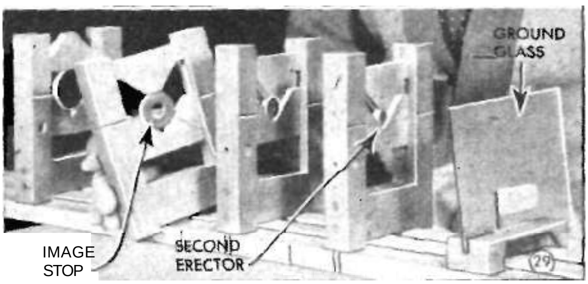
Making the layout: Start the layout as in Fig. 30, drawing a centerline and a line indicating the diameter of the objective. Set up the objective on an optical bench, with test copy about 20 ft. away. Take a piece of ground glass and pull it back from the objective until you. get the imago In sharp focus, Fig. 26. This image marks the first image plane. Measure the distance from objective to image plane and make a corresponding line on your layout. Next, set up the first erector lens and move it back and forth



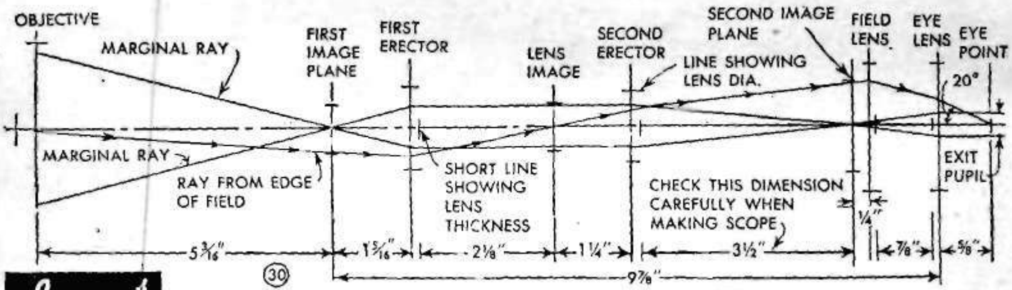
FOCUSING THE FIRST ERECTOR LENS



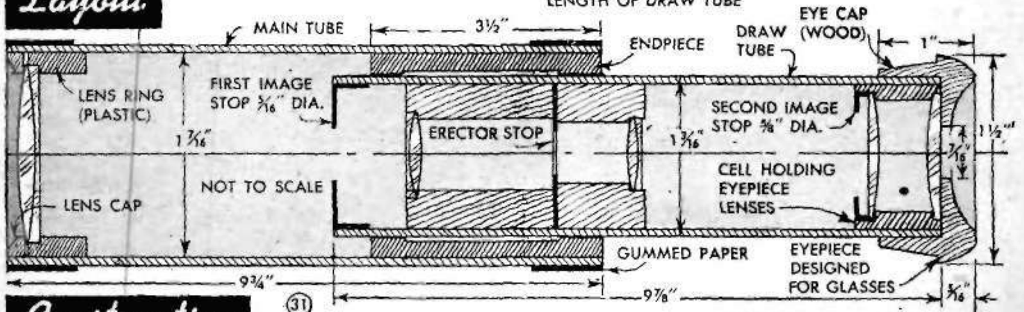
LENS IMAGE PICKED UP ON GROUND GLASS



FIT SECOND ERECTOR . . . fIND SECOND IMAGE PLANE



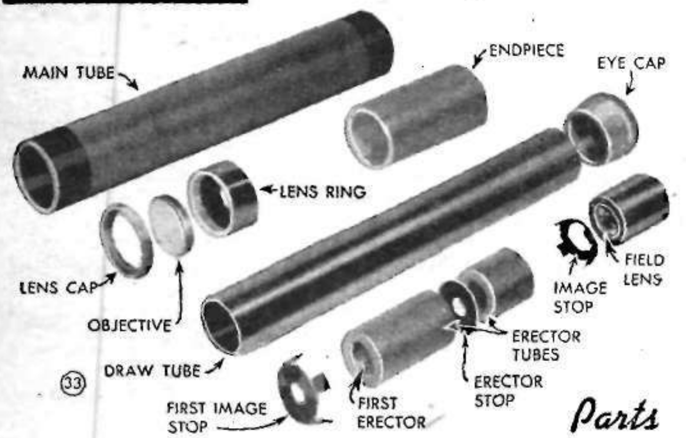
(30) Layout



(31) Construction

(32) **Lenses**

	Inches		MM.	
	Dia.	F.L.	Dia.	F.L.
Objective	1 1/4	5 3/16	32	132
E-1	5/8	1 5/8	15	41
E-2	1/2	3 1/8	12	80
Field	7/8	1 5/16	22	32
Eye	7/8	1 5/16	22	32
See right col. Fig 25 for other data				



(33) Parts

11X Terrestrial

This typical scope, ideal for hunting or observation, is used to show method of setting up and checking lens systems.

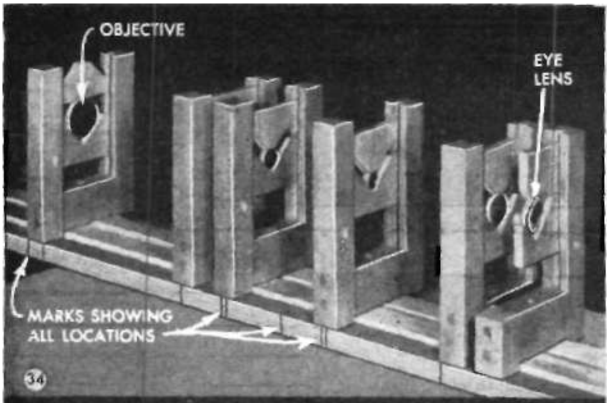
until you get the copy in sharp focus, Fig. 27. Then measure the distance from image plane or objective and mark on the layout.

Size of image: Find 11X magnification in Fig. 24, and opposite this read the factor, .063. Apply calculation No. 4, Fig. 25; the answer is ';k in., which is the size of the image at the first image plane. Mark the diameter on the layout.

Tracing the light rays: Now, you can draw the light rays from objective to first <_-i^io.-, Pip;. 20, using only three rays to represent the extremes, thus emln»ia«8 all of the many light rays which pass through-the telescope. The pair of marginal rays comes to a focus at the center of the image plane and continues until it strikes the first erector. The other ray is from the extreme edge of the field or picture and will pass through the extreme edge of the same "picture" inside your telescope. The elector lens must be large enough to receive these rays.

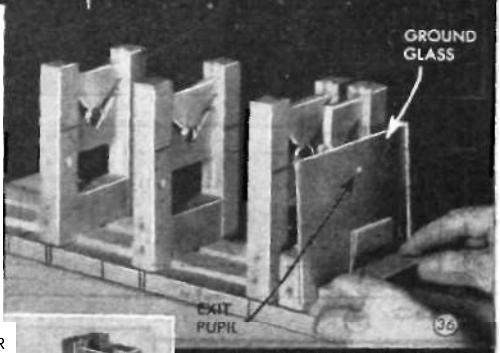
Close or spaced erectors: Here you have to decide whether you want the erectors close together or spaced well apart. Either way is suitable. Close spacing has an advantage in compactness, but it also requires longer eye relief. Therefore, it is best to space the erectors farther apart in order to shorten eye relief.

Lens image: In wide spacing, there will be an image of the objective Wx botwoon the erectors, and in close spacing, the image will be behind the second erector. The next step is to find this lens image. Use the ground glass and move it up behind the first erector until you get a circle of



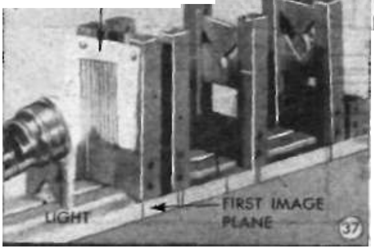
LENS SYSTEM COMPLETELY SET UP

VISUAL CHECK OF MAGNIFICATION



LOCATING EXIT-PUPIL POINT

LINES RULED"%" APART ON THIN PAPER



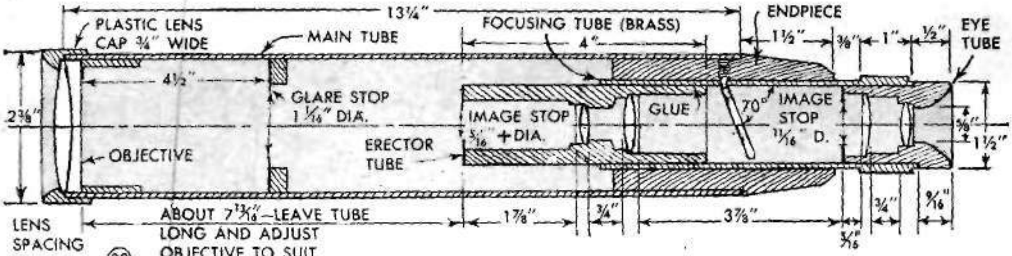
CHECKING APPARENT FIELD

light in sharp focus as in Fig. 28. This is the lens image. Mark its size and position on the layout. Continue the light rays. The marginal rays are parallel with the centerline. Note that since they originally passed through the edge of the objective, they now will pass through the .edge of the objective image. Similarly, the ray from the edge of the field, which originally passed through the center of the objective, now passes through the center of the objective image. These rays continue until they strike the second erector. To favor the small second erector, it is placed about *IVi* in. behind the lens image.

The second image: Put the ground glass behind the second erector and pull it back until ydu get a sharp image of the copy. This is the second image plane, and will be upright. Indicate its position on the layout and make a ring of cardboard with a central hole the same size as the first image, which is %s in. Mount this disk at the first image plane as in Fig. 29. Since you are using 2X magnification through the erectors, the image on the ground glass at the second image plane should be about % in. in diameter. Mark the diameter on the layout. Set up the eyepiece and focus. Mark the position of field and eye lenses on the layout. Continue the light rays from the second erector, through the second image, to the fieid lens. Fig. 34 shows the complete setup *on* an optical bench. On the layout, you now work from the eye end to complete the ray tracing. Find the exit-pupil point, Fig. 36. Mark this point on the layout and draw a line from it to the eye-lens line at an angle of 20 deg. to the centerline. Connect this point on the eye lens with the end of the edge-of-field ray at the field lens. Measure the diameter of the exit pupil and draw lines parallel with the centerline, connecting them with the ends of marginal rays at the field lens.

Mechanical construction: This is shown in Figs. 31 and 33. Two tubes are used; one houses the objective and the other carries the erecting eyepiece. The hole in the eye cap is determined by the 20-deg. line on the layout. The depth of the eye cap should be such as to set the proper eye relief. The one shown is shallow for use with eye glasses. The scope as set up is focused at 20 ft., which represents the longest extension required.

Visual check of magnification: Make a visual test by looking through the telescope with one eye and directly at the copy with tho other eye, Fig. 35. You will see the two views one over the other. Note sizes; that is, so many fines of copy as seen by scope covers the full sheet of copy as seen by eye. Now measure the two distances. In this particular case, 1% in. of copy seen through the scope covers the full height of



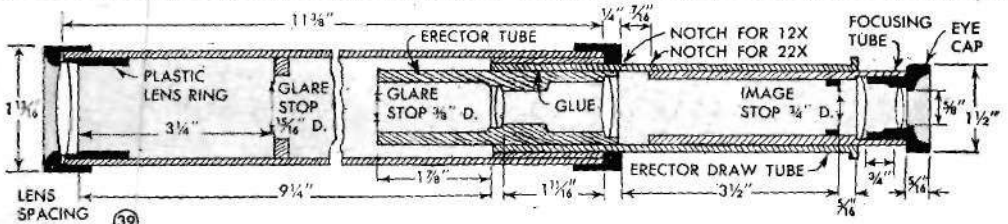
38

14x Spiral focusing

LENSES	Millimeters		Inches	
	Dia.	Focus	Dia.	Focus
Objective	52	193	2.04	7.60
Erector 1	18	49	.71	1.93
Erector 2	25	95	.98	3.74
Field	26	45	1.02	1.77
Eye	17	38	.67	1.49

Combined focus of eyepiece $\frac{45 \times 38}{45 + 38 - 19} = 27$ mm.
Erector magnification = 95 ÷ 49 = 1.9X
Equiv. focus of objective = 193 X 1.9 = 367 mm.
Magnification = 367 ÷ 27 = 13½X
Luminosity = 59%
Field (actual) = 40 yds. at 1,000 yds.

TUBES	Dia.	Length
Main	2 1/16" I.D.	13¼"
Erector	1⅜" O.D.	4"
Endpiece	2¼" O.D.	3⅝"
Focusing	1⅜" I.D.	5⅜"
Eyepiece	1½" O.D.	1 13/16"



39

12x to 22x variable

LENSES	Millimeters		Inches	
	Dia.	Focus	Dia.	Focus
Objective	36	181	1.42	7.13

Other lenses same as scope at top of page. Various styles or powers of eyepieces can be substituted without affecting the general construction

Eyepiece: 27 mm. focus
Erector magnification: 1.9X
Equiv. focus of objective = 181 X 1.9 = 344 mm.
Magnification = 344 ÷ 27 = 13X normal
Luminosity at 12X = 35%
Luminosity at 22X = 10%
Field (12X): 42 yds. at 1,000 yds.
Field (22X): 23 yds. at 1,000 yds.

TUBES	Dia.	Length
Main	1 11/16" O.D.	11⅜"
Erector	1⅜" O.D.	3⅞"
*Erector draw	1⅜" I.D.	6"
Focusing	1⅜" O.D.	4¼"
Eye cap	1½" O.D.	1¼"

*Plastic drain tube for lavatory (plumbing)

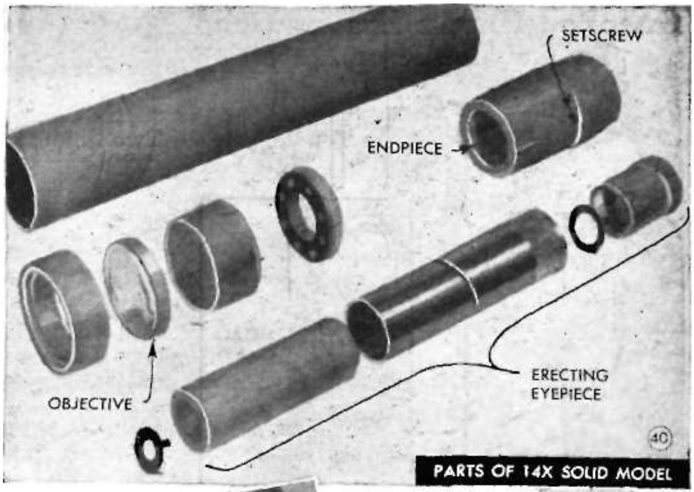
copy, 20 in. Then, 20 divided by 1.75 equals about 12X magnification.

Visual check of field: The field is checked by measuring the width of copy you can see through the scope at 20 ft. Multiply this distance in inches by 4 to get the approximate field in yards at 1000 yards. In this case, the. field at 20 ft. measures 14 in., so the field at 1000 yards will be 56 yds. This is a little less than the paper value as determined from calculation No. 8, Fig. 25. No. 8 calculation is based on maintaining a full 40-deg. apparent field, which is not always the case.

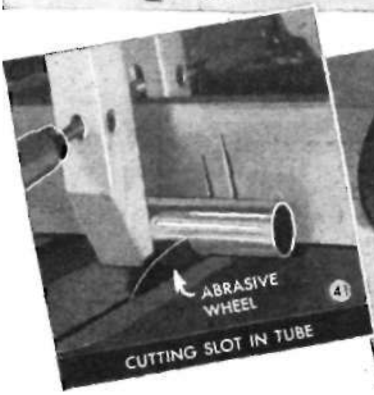
Visual check of apparent field: The apparent held angle is ths extreme angle which light rays make on reaching the eye; the true field angle is the apparent field angle divided by the magnification. Values given in Fig. 24 take a 40-deg". apparent field for granted. You can make a visual check by ruling lines *Vie*, in. apart on a sheet of tracing or other thin paper. Mount this at the first image plane and illuminate it from the objective side, Fig. 37. Count the number of lines you can see through the eyepiece. If the eyepiece is maintaining a 40-deg. field, you should see five lines. Less than this means you are not getting a 40-deg. field, the reason being that erector magnification at the second image plane makes the image too large to he viewed by a normal-size eyepiece. This merely means that the field of view will be somewhat reduced in size and calculation No. 8 cannot then be used.

Luminosity: In daylight, the pupil of your eye is about 5 mm. in diameter. Calculation No. 7, Fis. 35, gives light percent-. age and is based on 100 percent for a 5-rn.m. pupil. At night, the pupil of your eye dilates to about 7 mm. To find luminosity of any scope as a night glass, substitute 7 for 5 in the calculation.

Conjugate magnification: As described, erector magnification is obtained when the second erector is of longer focal length than the first. Another way of getting erector magnification is by setting up the lenses at distances! other than their focal lengths. This works exactly like a camera. Consilder the first image to be p, solid object, such as a person's head. To get a large picture of this object, the camera lens is pushed close to it, at the samej time extending the bellows. You do the same thing in a telescope by pushing the first erector closer to the first image plane. This gives a large second image at a distance farther back than the focal length of the second erector. A small amount of conjugate magnification usually is introduced when any lens system is set up by eye; you can deliberately introduce a great amount of magnification in this way. The 11X scope can be pushed up to 30X if desired. However, note that the second image is much too large to be viewed by the eyepiece, with the result that you lose field area, and'the increase in magnification means less illumination. Conjugate magnification cannot be calculated by the simple rules given, but it is easily determined visually.



PARTS OF 14X SOLID MODEL



CUTTING SLOT IN TUBE

EYE-END VIEW OF SCOPE

Specific designs: Dimensioned designs are impractical as there is no assurance that you can get tubes and lenses specified. However, such designs are useful as a general guide, and two are shown and briefly described. The first is- a 14X spiral-focusing scope, as diagrammed in Fig. 38 and further illustrated by Figs. 23, 40, 41 and 42. It is a solid model and does not telescope. Using the short objectives described in this article, the whole range of focusing from 20 ft. to infinity is very short, averag-

fa*M ^ i11- or" lcaa o£ -trcx-vol. Hence, it is practical to make a solid scope and confine the focusing to a threaded or spiral-focusing device. This one uses a spiral. It is cut about halfway across the focusing tube, which should be metal or plastic to have the required stiffness. The job is easily done on a circular saw, using an abrasive wheel, as shown in Fig. 41. A setscrew through the endpiece engages in this slot, permitting a travel of about % in. as the focusing tube is turned. The wooden tube in which erectors are mounted is a drive or glued fit inside the focusing tube. Lens spacing is about normal, so that the true magnification is equivalent to DO divided by FE, or 14X. The eyepiece is a modified Kellner, with field lens of slightly longer focus than eye lens.

The second specific design, Figs. 23 and 39, features conjugate magnification. As previously described, high magnification is obtained by pushing the erectors close to the first image; at the same time it is necessary to extend the eyepiece a considerable distance to bring the object into focus. In this scope, the erector draw tube slides inside the main tube and the focusing" tube slides inside the erector draw tutoe. Marks or notches on the erector tube indicate the setting for high or low magnification and the setting can be anywhere between these marks.