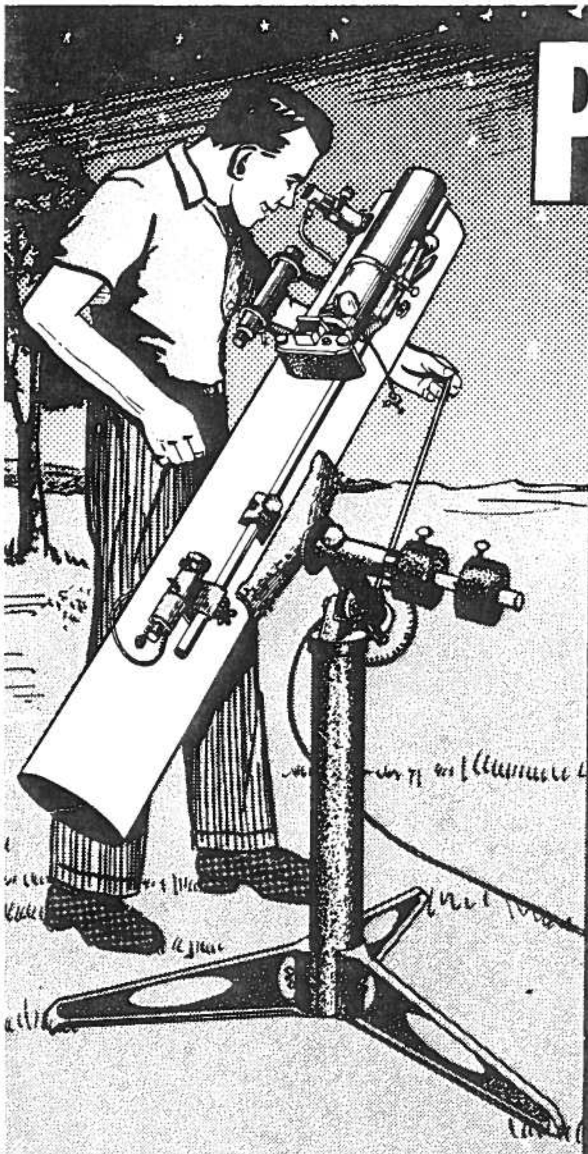
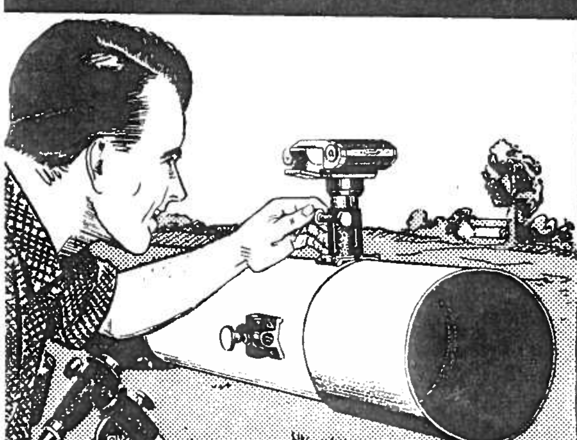
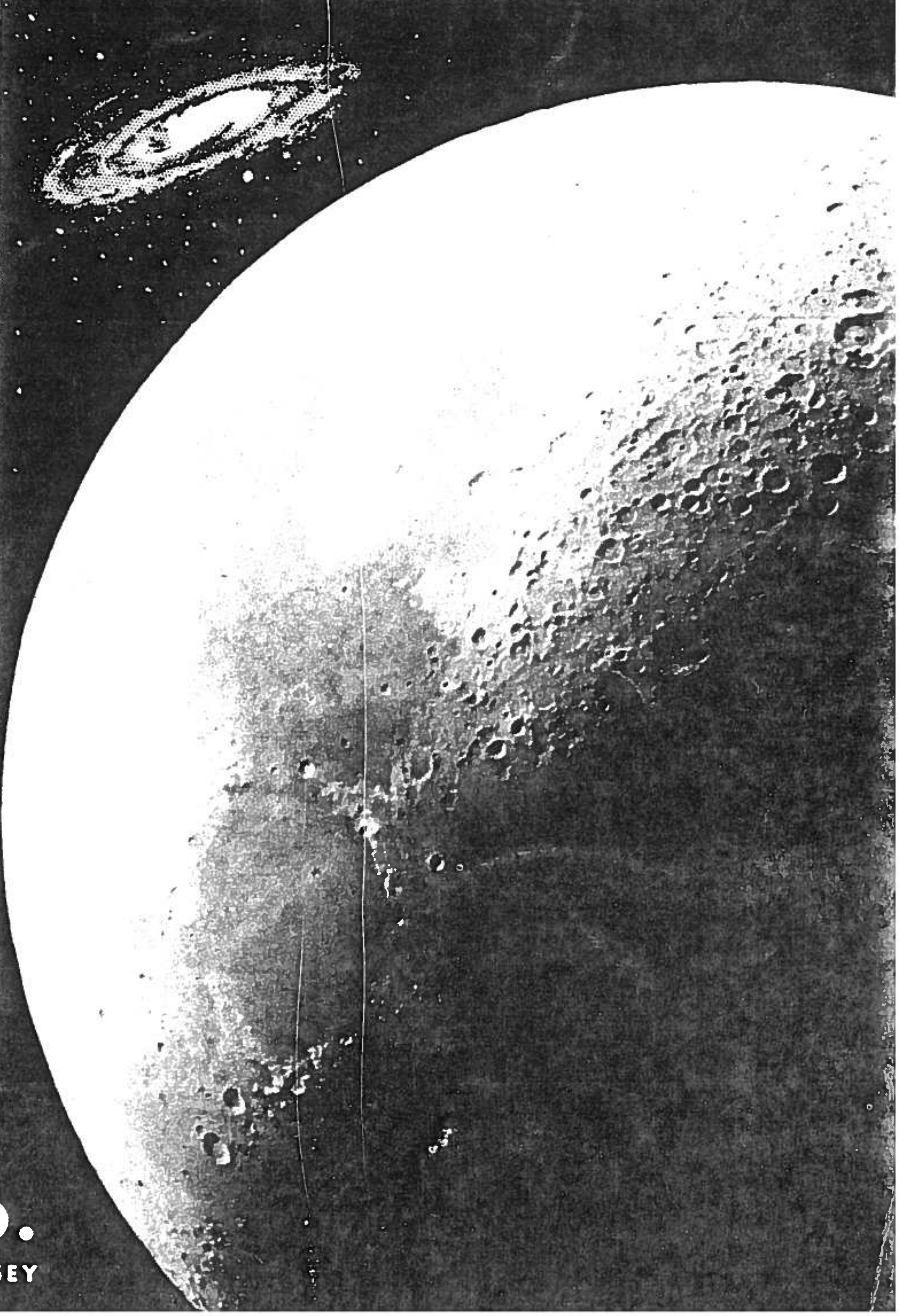
PHOTOGRAPHY with your TELESCOPE







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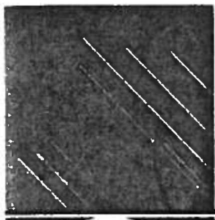
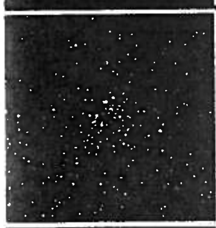
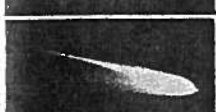
QUICK GUIDE to sky shooting

	What to Shoot	EQUIPMENT	OPTICAL SYSTEM	METHOD – REMARKS
	STAR TRAILS	ANY CAMERA FROM 35MM SIZE UP TO 8 x 10 INCH. CAMERA MUST BE ON TRIPOD OR OTHER SUPPORT	ANY LENS, 2" TO ABOUT 12" F.L. CLEAR APERTURE SHOULD BE AT LEAST 5/8" AND PREFERABLY LARGER	SET CAMERA LENS AT INFINITY AND POINT AT TARGET. MAKE A TIME EXPOSURE OF 10 MIN. OR MORE. SKY MUST BE DARK – DO NOT SHOOT WITH MOON IN SKY
	MOON	REFLECTING OR REFRACTING TELESCOPE WITH ADAPTER FOR CAMERA BODY. CLOCK DRIVE USEFUL BUT NOT ESSENTIAL	45" TO 80" E.F.L. APERTURE 1" OR MORE, f/8 TO f/80 MOON IMAGE DIA. = .009 x E.F.L.	WITH FIXED MOUNT, USE FAST FILM TO PERMIT SHORT EXPOSURE OF 1/100 SEC. OR LESS. WITH CLOCK DRIVE USE SLOWER, FINE-GRAIN FILM AND LONGER EXPOSURES
	SUN	TELESCOPE AND CAMERA. BY FILTER OR OTHER MEANS, THE LIGHT MUST BE REDUCED TO FULL MOON INTENSITY	SAME AS FOR MOON. USUALLY NOT LESS THAN 2" APERTURE, f/8 TO f/80. USUALLY A PROJECTION SYSTEM	WITH IMAGE AT FULL MOON BRIGHTNESS, FAST EXPOSURES OF 1/100 TO 1/500 SECOND CAN BE MADE ON SLOW FILM, SUCH AS HIGH CONTRAST COPY
	STAR FIELDS	ANY CAMERA. THE TELESCOPE IS USED FOR GUIDING ONLY. A CLOCK DRIVE WITH SLOW-MOTION CONTROL IS ESSENTIAL	PREFERABLY NOT LESS THAN 1" CLEAR APERTURE. 3" TO 12" F.L., DIRECT OBJECTIVE. FIELD SHOULD BE FLAT, COMA-FREE	USE FAST FILM. GUIDING CONSTANTLY WITH TELESCOPE, MAKE TIME EXPOSURE OF 10 MINUTES OR MORE. GOOD STARTER... EASIEST TARGET FOR GUIDED TELESCOPE
	OPEN STAR CLUSTERS	CAMERA, 20" OR MORE F.L. TELESCOPE USED FOR GUIDING BUT MAY BE THE CAMERA, IN WHICH CASE A LONG F.L. GUIDESCOPE IS NEEDED	NOT LESS THAN 2" APERTURE -- THE LARGER THE APERTURE THE MORE STARS YOU CAN PHOTOGRAPH. F.L. TO SUIT TARGET SIZE	GUIDED TELESCOPE, 15 MIN. OR MORE TIME EXPOSURE. THE LONG F.L. OF CAMERA MAKES GUIDING MORE DIFFICULT – A SLOW-MOTION MAY BE NEEDED ON DECLINATION SHAFT
	NEBULAE and GALAXIES	CAMERA IS OFTEN THE TELESCOPE ITSELF. BIG APERTURE, LONG F.L. NEEDED. CLOCK DRIVE WITH SLOW-MOTION	NOT LESS THAN 3" APERTURE. 20" TO 100" F.L. USUALLY DIRECT OBJECTIVE FOR LOW f/NUMBER BUT PROJECTION SYSTEM IS USEFUL	USE FAST FILM. SOME NEBS ARE BRIGHT AND CAN BE CAPTURED ON TRI-X FILM IN AS LITTLE AS 10 MINUTES. MOST TARGETS ARE DIM -- BIG APERTURE AND FAST FILM NEEDED
	PLANETS	TELESCOPE WITH AMPLIFYING SYSTEM TO GET E.F.L. OF 100" TO 1000". TELESCOPE ON EQUATORIAL MOUNT WITH CLOCK DRIVE	LONG E.F.L. IS MAIN NEED. f/16 TO f/100. POSITIVE OR NEGATIVE PROJECTION OF 3X TO 8X IS USUAL SETUP	USE FINE-GRAIN FILM TO PERMIT ENLARGEMENT. PLANETS ARE BRIGHT BUT HIGH f/NUMBER CALLS FOR LONG EXPOSURE OF 1 TO 10 SEC. THIS IS DIFFICULT PHOTOGRAPHY
	COMETS	LENS 8" TO 18" F.L. MANUAL SLOW-MOTION ON BOTH AXES	APERTURE NOT LESS THAN 2", f/3 TO f/8, USED WIDE OPEN	TIME EXPOSURE, 10 SEC. TO 10 MIN. YOU MUST GUIDE ON COMET HEAD DURING EXPOSURE
	METEORS	ANY CAMERA. WIDE FIELD IS NEEDED -- NOT LESS THAN 40°	WITH 35MM CAMERA, 2" F.L. IS PREFERRED FOR WIDEST FIELD	KNOWING TIME AND GENERAL AREA OF A METEOR SHOWER, MAKE A STARTRAIL – AND HOPE!

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Photography with your TELESCOPE

MOST of the pictures taken with a telescope are of an astronomical nature, being pictures of the sun and moon, stars and planets. However, you can also use your "long glass" to advantage for certain types of daytime photography, particularly those views which are too distant to be captured by the short focal length objectives normally used on small cameras.

Whatever the subject, a camera using small-size film is preferable, with the popular 35mm film size being first choice for most work. Photography on 35mm film is inexpensive. There is also the plain fact that the average telescope set-up will not cover larger film sizes. Reflex focusing is highly desirable because you can see to focus and see to position your target object the way you want it. In brief, the 35mm single lens reflex is the camera you can use to best advantage. You can purchase a camera of this kind for as little as $60 or as much as $600; secondhand much less. Much of the cost of a single lens reflex is in the original objective. It is not necessary that the camera have a top-quality fast lens because you will rarely use the lens anyhow for the type of photography we are considering, the general situation being that the telescope itself is the objective, while the camera is mainly a film transport and viewer. Some useful camera equipment can be homemade, and with this in view the original purchase must permit the use of interchangeable objectives, preferably with a screw-in thread.

Four optical systems are generally recognized in photography with the telescope, as shown in drawing below. Actually these boil down to just two basic types: (1) the direct objective, (2) projection system. With the direct objective, light goes direct from the lens or mirror objective to the film; the picture is taken at the primary or first focus. In all other systems, the primary image is projected to form a second image, and the picture is taken at this second image plane. It will be obvious that if the primary objective forms a perfect image at the first image plane, any additional following lens or mirror cannot possibly improve the image quality. In other words, the best you can expect from any projection system is simply that it will retain most of the original sharpness. This is possible. The big advantage of the projection system is, of course, the fact you can get equivalent long focal length in a short instrument.

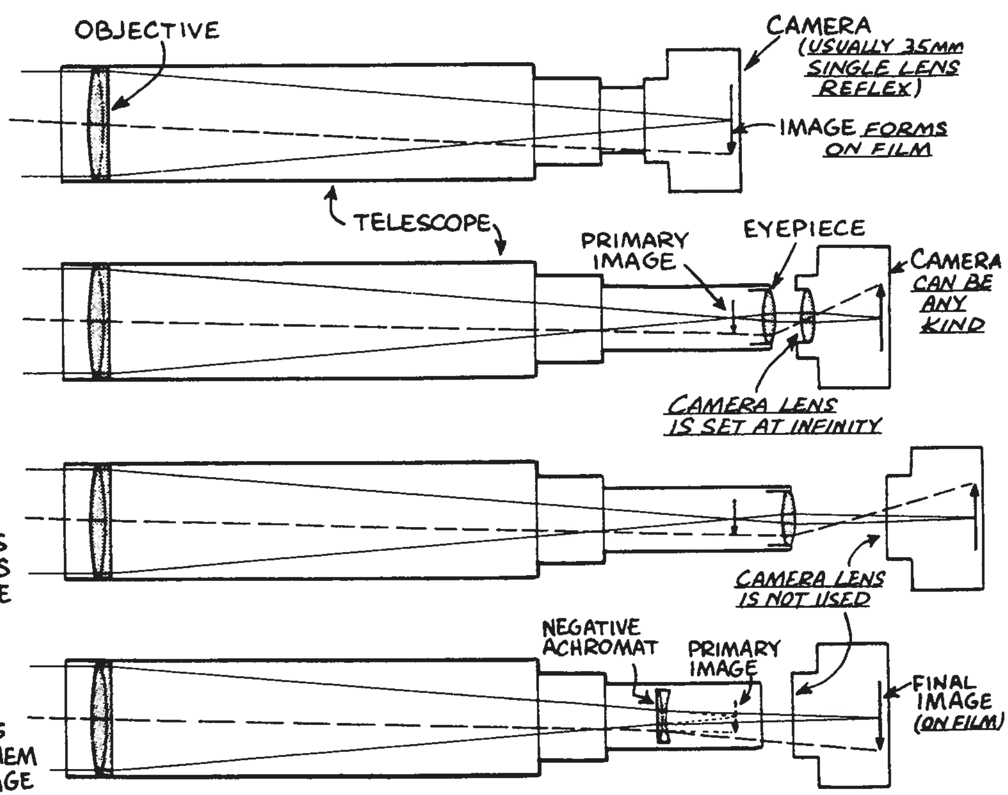
4 Systems

[1] DIRECT OBJECTIVE
LIGHT GOES DIRECT FROM OBJECTIVE (*LENS OR MIRROR*) TO FILM

[2] AFOCAL CONSISTS OF A TELESCOPE IN FOCUS AS FOR EYE USE, COMBINED WITH ANY CAMERA WITH LENS SET AT INFINITY

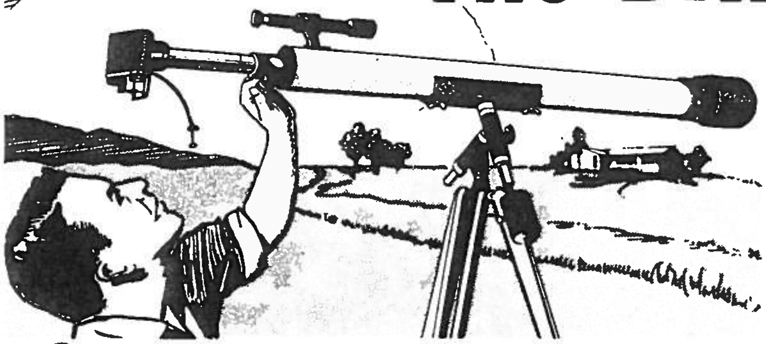
[3] PROJECTION WITH A **POSITIVE LENS**
EYEPIECE OF TELESCOPE IS USED AS A PROJECTION LENS TO FORM AN ENLARGED IMAGE

[4] PROJECTION WITH A **NEGATIVE LENS**
A NEGATIVE LENS INTERCEPTS THE LIGHT RAYS AND EXTENDS THEM TO FORM AN ENLARGED IMAGE



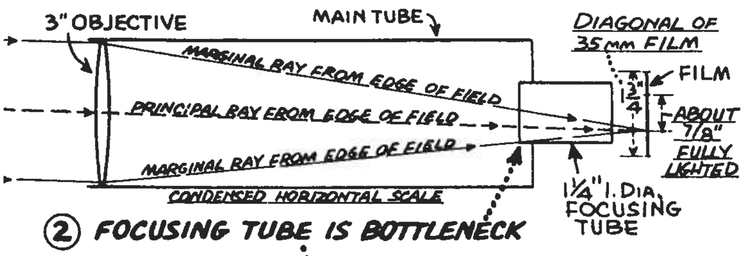
the simplest system...

The DIRECT OBJECTIVE

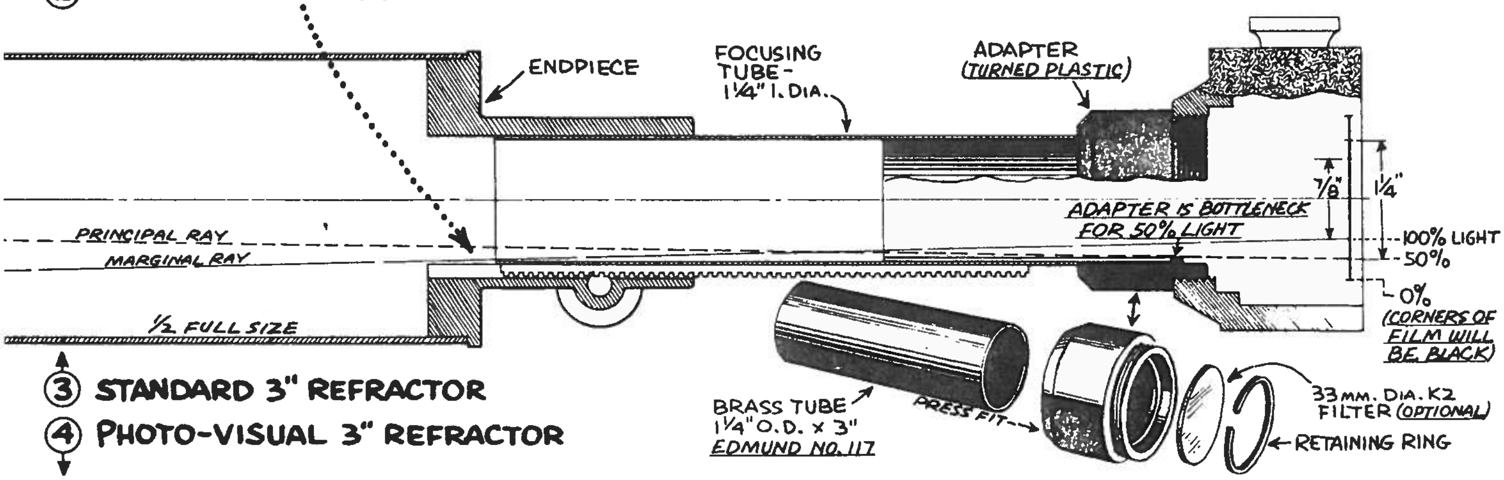


① 3-INCH REFRACTOR AS A DIRECT OBJECTIVE

CONTAINING the least possible number of optical elements, the direct objective is the simplest and most-used picture-taking system--99% of all cameras use a direct objective. Normally it is also the simplest system mechanically, although this can't be said of a telescope conversion where the switch may require more work than afocal and projection systems. Advantages of the direct objective are highest light transmission and best definition. In other words, this is the fastest and sharpest optical system for shooting pictures--only once in a blue moon will you run into a compensating optical system where the performance of the primary is improved by the addition of other optical elements. The only

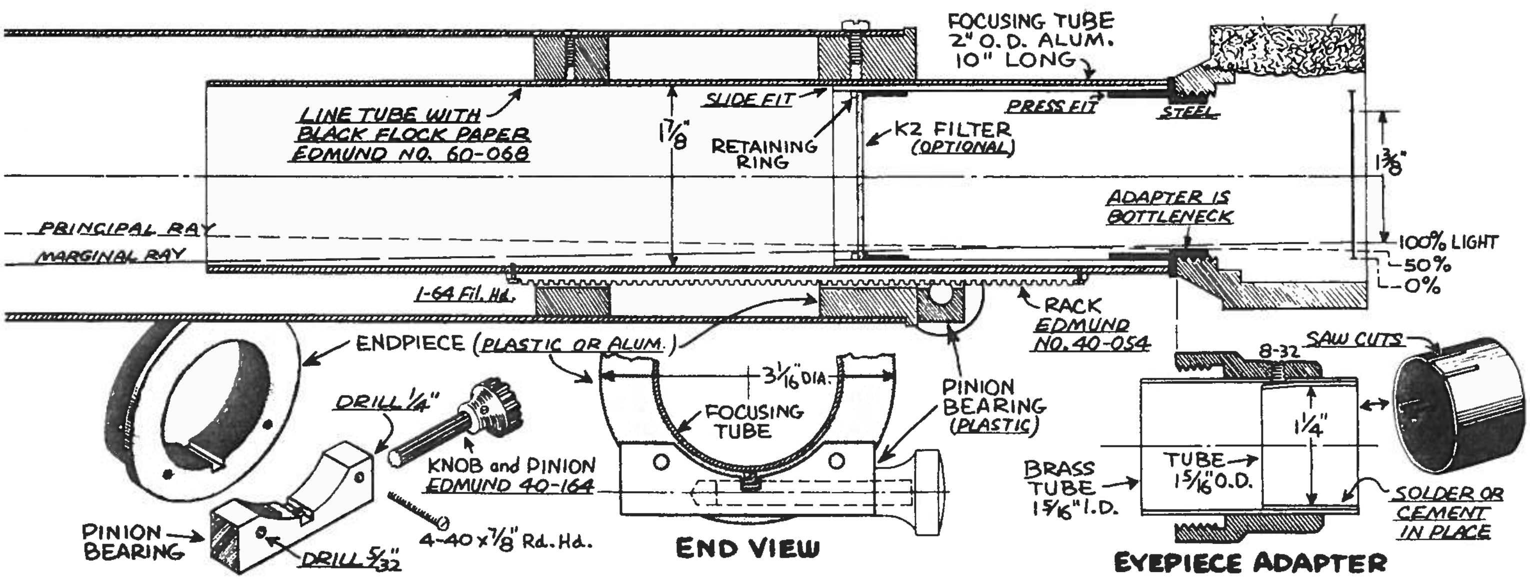


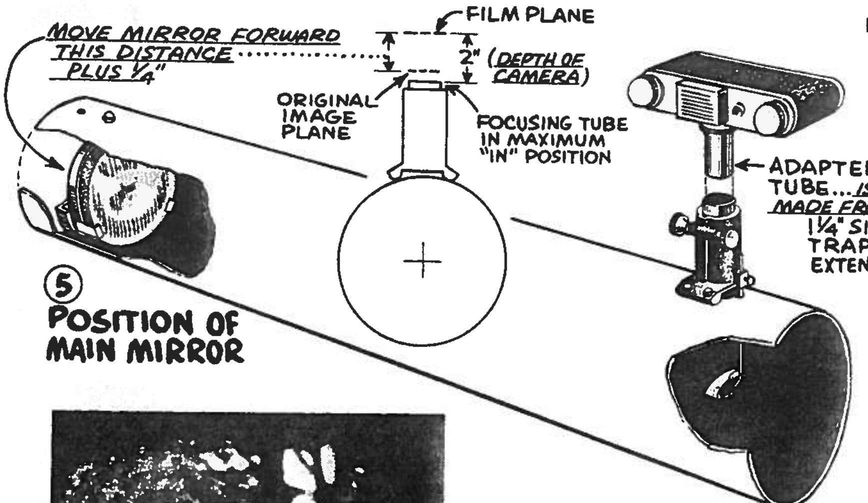
② FOCUSING TUBE IS BOTTLENECK



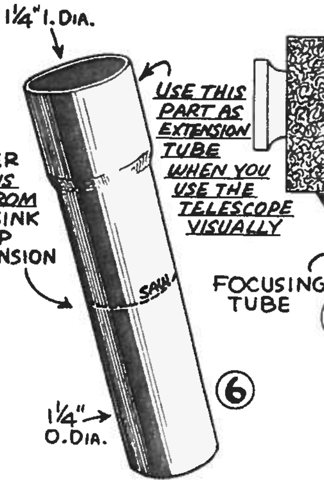
③ STANDARD 3" REFRACTOR

④ PHOTO-VISUAL 3" REFRACTOR

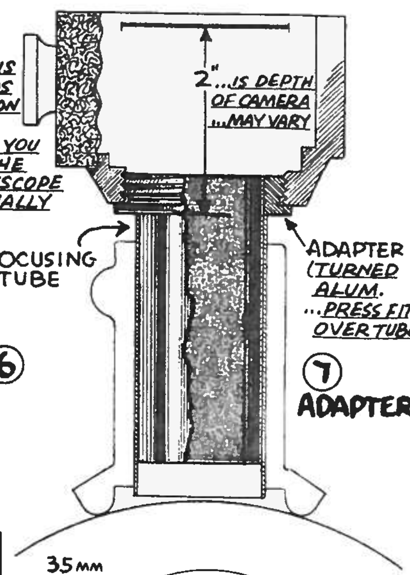




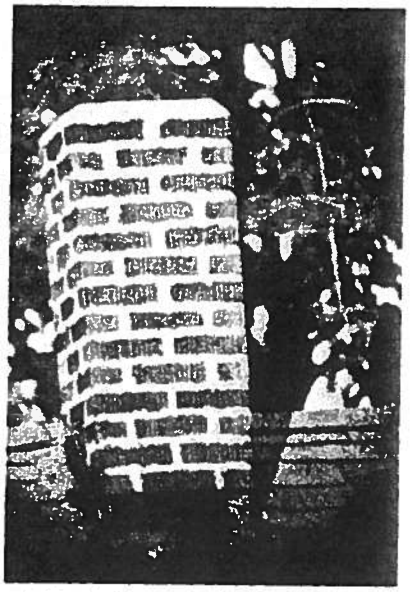
5 POSITION OF MAIN MIRROR



6



7 ADAPTER

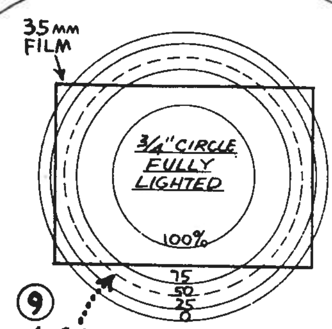


VIGNETTING CAUSED BY SMALL DIAMETER OF FOCUSING TUBE
TEST PIC WITH 4¼" REFLECTOR FROM INDOORS POINTING THRU OPEN WINDOW TO OBJECT AT 100 YDS. TRI-X FILM, 1/200 SEC.
THE LIGHT STREAK ACROSS PICTURE IS POWER CABLE IN FOREGROUND

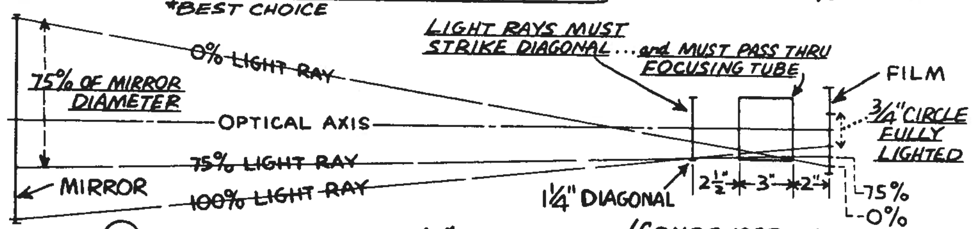
8 DIAMETER OF ILLUMINATED FIELD

6" REFLECTOR	100%	75%	50%	25%	0%
WITH 1¼" DIAGONAL	5/16" D	7/8" D	1¼" T	1⅜" T	1½" T
WITH 1½" DIAGONAL*	5/8 D	1⅛ D	1¼ T	1⅜ T	1½ T
WITH 1⅝" DIAGONAL	3/4 T	1⅛ T	1¼ T	1⅜ T	1½ T
4¼" REFLECTOR	T - FOCUSING TUBE IS BOTTLENECK; D - DIAGONAL IS BOTTLENECK				
WITH 1 1/16" DIAGONAL	½" D	7/8" D	1¼" T-D	1⅜" T	1½" T
WITH 1¼" DIAGONAL*	3/4 D	1⅛ T-D	1¼ T	1⅜ T	1½ T
WITH 1½" DIAGONAL	7/8 T	1⅛ T	1¼ T	1⅜ T	1½ T

*BEST CHOICE



9 LIGHTING IS GOOD TO EDGE OF 50% ZONE

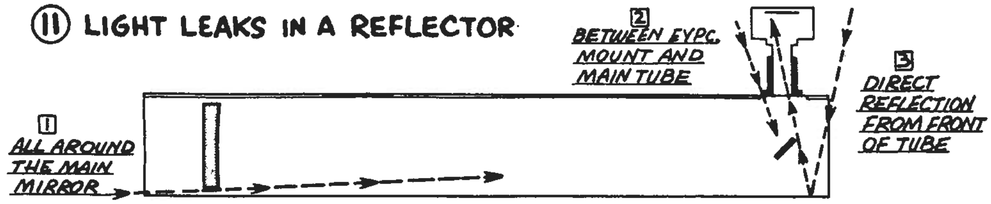


10 LIGHT DIAGRAM - 4¼" REFLECTOR (CONDENSED HORIZONTAL SCALE)

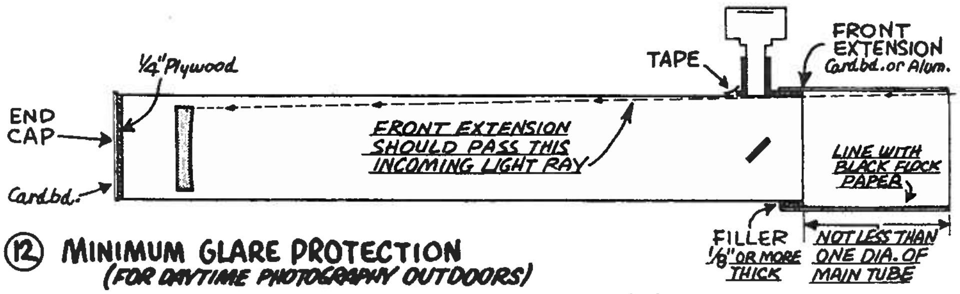
poor feature of the direct objective is lack of compactness, which becomes an item of considerable importance as the focal length is increased.

THE REFRACTOR AS A CAMERA. You can make a good telecamera from a refractor by simply mounting a 35mm single lens reflex camera by means of an adapter tube, as shown in Figs. 1 and 3. You can get nice pictures--land or sky--with such an outfit, but they will show a black vignette about as shown in photo above. This comes from the small diameter of the telescope focusing tube, which restricts the fully-lighted image field to less than an inch diameter. To increase the illuminated field, it is obvious you must enlarge the focusing tube, and this means practically building a new instrument. A simple type of construction is shown in Fig. 4; a new set of glare stops inside the main tube will also be needed. Such a conversion will show only a touch of black at the extreme corners of 35mm film. A visual adapter as shown in Fig. 4 detail makes the conversion back to telescope for use with standard eyepieces.

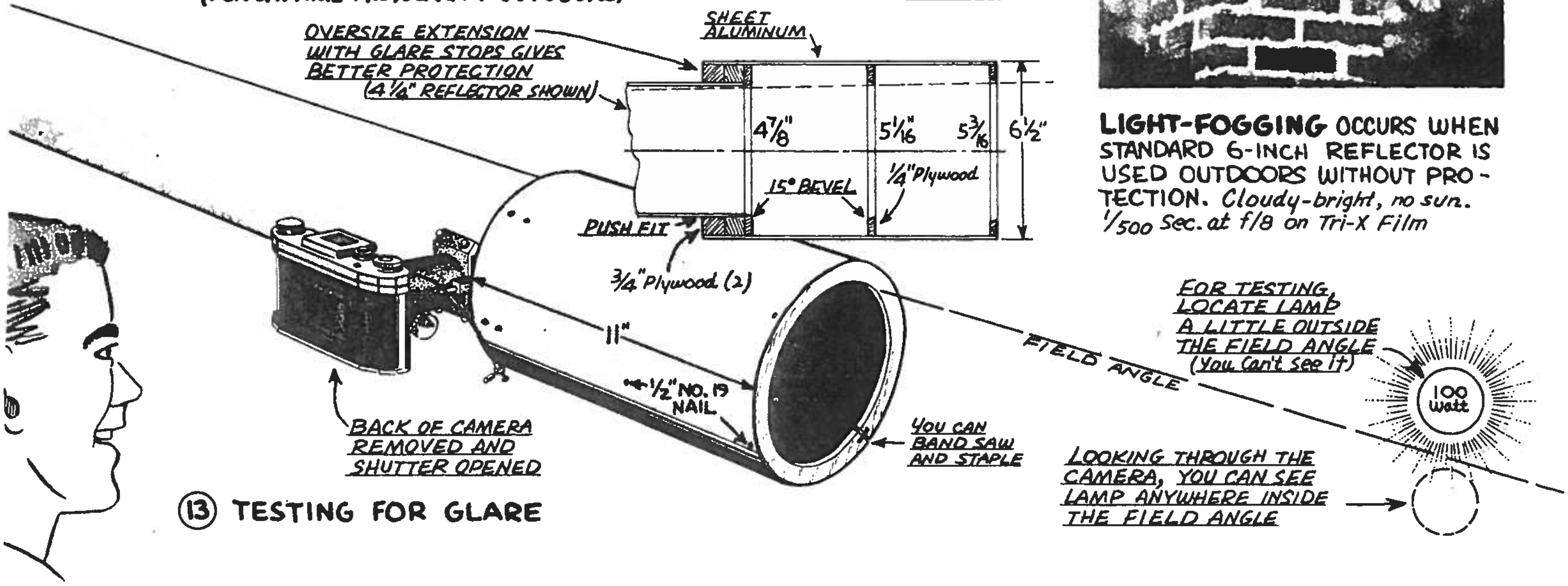
THE REFLECTOR AS A CAMERA. The reflecting telescope poses the same problem of small-diameter focusing tube. Another snag is that the image plane is not even accessible. What you have to do first of all is move the main mirror forward a short distance, as shown in Fig. 5. This will advance the image plane to a position where it can be made to coincide with the film plane of the camera. Even so, space is at a premium and the adapter, Fig. 7, should be made as shallow as practical. The extended position of the image plane will not interfere with the use



(11) LIGHT LEAKS IN A REFLECTOR



(12) MINIMUM GLARE PROTECTION (FOR DAYTIME PHOTOGRAPHY OUTDOORS)



(13) TESTING FOR GLARE

LIGHT-FOGGING OCCURS WHEN STANDARD 6-INCH REFLECTOR IS USED OUTDOORS WITHOUT PROTECTION. *Cloudy-bright, no sun. 1/500 Sec. at f/8 on Tri-X Film*

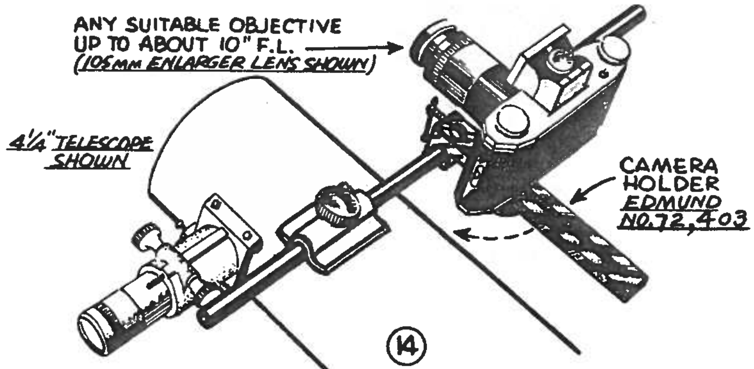
of the telescope visually, but you will have to use a short extension tube, easily made from a chrome sink trap extension, Fig. 6.

One more obstacle now appears: the standard-size diagonal is too small. Mainly, this results because the linear size of 35mm film is quite a bit larger than what you ordinarily look at with an eyepiece. Contributing is the fact the image plane is at a greater distance from the diagonal. You can correct by using the next larger standard size diagonal, but you still have the considerable vignette caused by the small-diameter focusing tube. Fig. 8 table shows that some vignetting will occur regardless of how big you make the diagonal; the focusing tube is the bottleneck. However, enough light gets through to make useful pictures. A 4-1/4-inch reflector will vignette a little more than a 6-inch, the villain in this case being the main tube itself, which is too small to admit the full incoming light cone. A few things about vignetting in general are worth noting: (1) Practically all camera lenses vignette 25% or more at corners of film when used wide open, (2) a 50% vignette is hardly detectable on the ground glass, and often does not show at all on prints unless negatives are very thin, (3) if you plan only moon shots and similar astro targets, the vignette will have little or no effect because the area outside the moon is black anyhow.

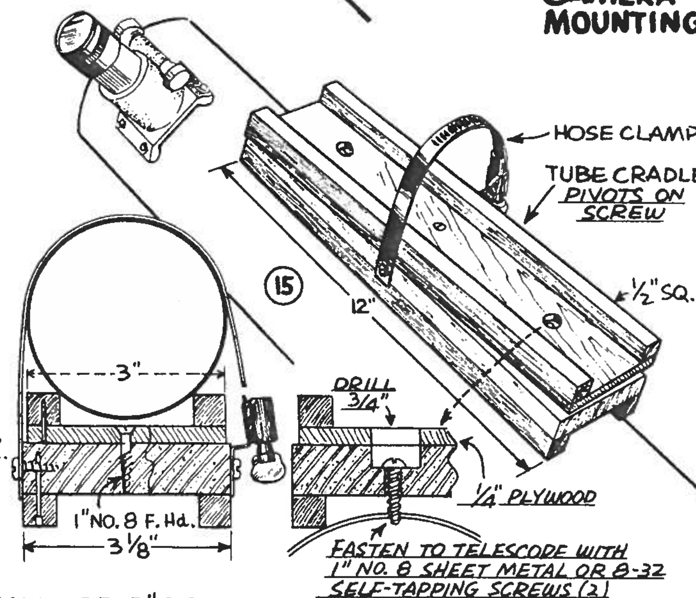
GLARE PROTECTION. The refractor is well-protected against unwanted glare light, and you can shoot pics outdoors in the sun just like any camera. The reflector is another story. Even though no direct glare light can reach the film, you will pick up enough one and two-bounce reflections to fog the picture, Fig. 11. The worst offender is the one-bounce reflection from the front end of the main tube. A simple cure is a sun shade, Fig. 12; a long, over-size extension fitted with glare stops is even more effective, Fig. 13.

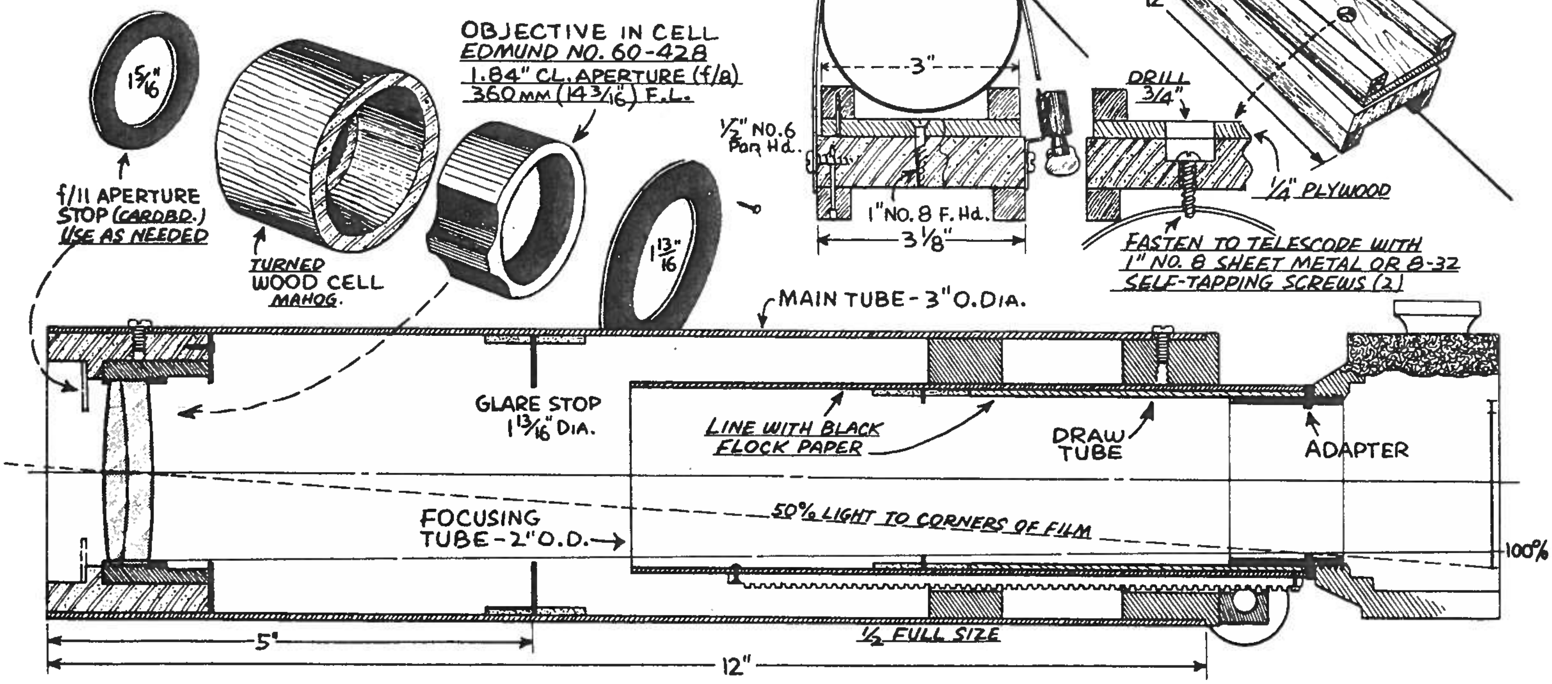
Check your setup for glare light outdoors, or, do the job indoors with a lamp in the manner shown in Fig. 13. This little bit of look-and-see should be a routine test for all telecamera systems. You will be able to see immediately any areas which are unduly bright. By sighting from the corners of the film opening, you can also check the extent of illumination. The setup is also a good check for collimation--all of the various apertures should appear concentric with the film opening of camera.

AUXILIARY LENSES. You can shoot a lot of pictures with a telescope, but more than half of all pictures taken with a telescope are not taken with a telescope. The situation in astrophotography is that while you need the equatorial movement and clock drive of a telescope, the actual picture-taking is often done with an ordinary camera mounted on the telescope tube. For short focal length camera objectives up to about 10 in. f.l., some kind of a camera bracket,



CAMERA MOUNTING





16 14-INCH F.L. DIRECT OBJECTIVE
(SAME CONSTRUCTION AS FIG. 4)

Test Pics: ALL TRI-X PAN FILM, NO FILTER, BRIGHT SUN. DISTANCE ABOUT 100 Yds.

105MM ENLARGING LENS DIRECT OBJECTIVE. 1/500 SEC., f/11. HAND-HELD

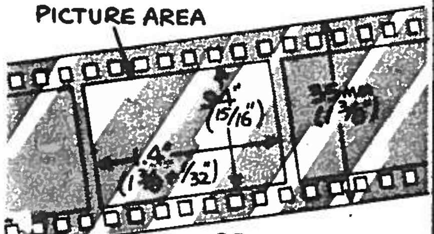
14-INCH ACHROMAT AS SHOWN ABOVE. 1/500 SEC. AT f/8. CAMERA HELD BY HAND

3x BARLOW AND 14" ACHROMAT. COMBO IS 42" F.L., f/24. 1/200 SEC. ON TRIPOD

TABLE 1

Angular and Linear Field Covered by 35mm Film

PICTURE AREA



35MM FILM

USE THIS TABLE TO DETERMINE IF F.L. YOU ARE USING WILL COVER THE OBJECT YOU PLAN TO SHOOT

1.69" diagonal

Example 1 PLEIADES

THE ANGULAR SIZE CAN BE OBTAINED FROM STAR MAPS OR LISTS OF SKY OBJECTS. IT IS ABOUT 1½° (90')

ANGULAR FIELD COLUMN IN TABLE SAYS A 35IN. F.L. LENS WILL COVER 92MIN. HENCE, IT WILL COVER THE PLEIADES (90')

Example 2 PEOPLE

ALLOW 8-FT. FIELD FOR FULL-LENGTH, 4 FT. FOR HALF-LENGTH AND 2FT. FOR HEAD-AND-SHOULDERS

SUPPOSE YOU WANT HALF-LENGTH PORTRAIT AT 300 FT. *RUN YOUR EYE DOWN THE 300 FT. COLUMN TO LOCATE NEEDED FIELD OF 4 FT. (48"). IN LEFT-HAND COLUMN READ 70" FOCAL LENGTH*

DIRECT CALCULATION FOR APPROX. IMAGE SIZE OF ANY SKY OBJECT WHEN F.L. AND ANGULAR SIZE ARE KNOWN

Example: M13 CLUSTER IN HERCULES, 10MIN. DIA. F.L. - 300 IN. (10 × 60 = 600 SEC.)

WRITE DOWN ANGULAR SIZE IN SECONDS 600
DIVIDE BY 2 300
MULTIPLY BY F.L. 300
POINT OFF 5 PLACES .... ‸90000

IMAGE SIZE = .9IN.

F.L. OR E.F.L. OF LENS	ANGULAR FIELD	LINEAR FIELD (SHORT SIDE OF FILM ONLY) [1]							
		AT 100 FT.	AT 200 FT.	AT 300 FT.	AT 500 FT.	AT ¼ M.	AT ½ M.	AT 1 M.	AT 5 M.
2"	26.5° x 39.7°	47 FT.	94 FT.	141 FT.	235 FT.	621 FT.	414 YD.	828 YD.	4140 YD.
3"	17.8° x 26.7°	31 FT.	63 FT.	94 FT.	157 FT.	413 FT.	827 FT.	551 YD.	2756 YD.
4"	13.4° x 20.1°	24 FT.	47 FT.	70 FT.	117 FT.	310 FT.	620 FT.	413 YD.	2066 YD.
5"	11.0° x 16.5°	19 FT.	39 FT.	58 FT.	97 FT.	255 FT.	509 FT.	339 YD.	1696 YD.
6"	9.0° x 13.5°	16 FT.	31 FT.	47 FT.	79 FT.	208 FT.	415 FT.	830 FT.	1383 YD.
7"	7.7° x 11.5°	13 FT.	27 FT.	40 FT.	67 FT.	177 FT.	354 FT.	708 FT.	1180 YD.
8"	6.7° x 10.1°	12 FT.	24 FT.	35 FT.	59 FT.	156 FT.	313 FT.	626 FT.	1043 YD.
9"	6.0° x 9°	10 FT.	21 FT.	31 FT.	52 FT	138 FT.	275 FT.	550 FT.	917 YD.
10"	5.4° x 8.1°	9 FT.	19 FT.	28 FT.	47 FT.	125 FT.	249 FT.	498 FT.	830 YD.
12"	4.5° x 6.8°	8 FT.	16 FT.	23 FT.	39 FT.	103 FT.	206 FT.	412 FT.	687 YD.
14"	231' x 347'	7 FT.	13 FT.	20 FT.	33 FT.	88 FT.	177 FT.	353 FT.	589 YD.
16"	202' x 303'	6 FT.	12 FT.	18 FT.	29 FT.	77 FT.	155 FT.	309 FT.	516 YD.
18"	180' x 270'	5 FT.	10 FT.	16 FT.	26 FT.	69 FT.	137 FT.	275 FT.	458 YD.
20"	162' x 243'	4½ FT.	9 FT.	14 FT.	23 FT.	62 FT.	124 FT.	247 FT.	412 YD.
25"	129' x 194'	45 IN.	90 IN.	11 FT.	19 FT.	50 FT.	100 FT.	198 FT.	993 FT.
30"	108' x 162'	38 IN.	75 IN.	9 FT.	15 FT.	41 FT.	83 FT.	165 FT.	827 FT.
35"	92' x 138'	32 IN.	64 IN.	97 IN.	13 FT.	35 FT.	70 FT.	142 FT.	708 FT.
40"	81' x 122'	28 IN.	56 IN.	84 IN.	12 FT.	31 FT.	62 FT.	124 FT.	620 FT.
45"	72' x 108'	25 IN.	50 IN.	75 IN.	10 FT	28 FT.	55 FT.	110 FT.	550 FT.
50"	65' x 98'	23 IN.	45 IN.	68 IN.	9 FT.	25 FT.	50 FT.	99 FT	496 FT.
60"	53' x 80'	19 IN.	38 IN.	56 IN.	94 IN.	21 FT.	41 FT.	83 FT.	414 FT.
70"	46' x 69'	16 IN.	32 IN.	48 IN.	81 IN.	18 FT.	35 FT.	71 FT.	354 FT.
80"	40' x 60'	14 IN.	28 IN.	42 IN.	71 IN.	16 FT.	31 FT.	62 FT.	310 FT.
90"	36' x 54'	12.5 IN.	25 IN.	38 IN.	63 IN.	14 FT.	28 FT.	55 FT.	276 FT.
100"	32' x 48'	11 IN.	23 IN.	34 IN.	56 IN.	12 FT.	25 FT.	50 FT.	248 FT.
125"	26' x 39'	9 IN.	18 IN.	27 IN.	45 IN.	10 FT.	20 FT.	40 FT.	199 FT.
150"	22' x 33'	7.5 IN.	15 IN.	23 IN.	38 IN.	99 IN.	17 FT.	33 FT.	165 FT.
175"	18' x 27'	6.4 IN.	13 IN.	19 IN.	32 IN.	85 IN.	14 FT.	28 FT.	142 FT.
200"	16' x 24'	5.6 IN.	11 IN.	17 IN.	28 IN.	74 IN.	12 FT.	25 FT.	124 FT.
250"	13' x 20'	4.5 IN.	9 IN.	14 IN.	23 IN.	60 IN.	10 FT.	20 FT.	99 FT.
300"	11' x 16'	3.8 IN.	8 IN.	11 IN.	19 IN.	50 IN.	99 IN.	17 FT.	83 FT.
400"	8' x 12'	2.8 IN.	5.6 IN.	8 IN.	14 IN.	37 IN.	74 IN.	12 FT.	62 FT.
500"	6.4' x 9.6'	2.3 IN.	4.5 IN.	6.8 IN.	11 IN.	30 IN.	60 IN.	10 FT.	50 FT.
600"	5.4' x 8'	1.9 IN.	3.8 IN.	5.6 IN.	9 IN.	25 IN.	50 IN.	99 IN.	41 FT
700"	4.6' x 7'	1.6 IN.	3.2 IN.	4.8 IN.	8 IN.	21 IN.	43 IN.	85 IN.	35 FT
800"	4.0' x 6'	1.4 IN.	2.8 IN.	4.2 IN.	7 IN.	19 IN.	37 IN.	74 IN.	31 FT
900"	3.6' x 5.4'	1.25 IN.	2.5 IN.	3.8 IN.	6 IN.	17 IN.	33 IN.	66 IN.	28 FT.
1000"	3.2' x 4.8'	1.13 IN.	2.3 IN.	3.4 IN.	5.6 IN.	15 IN.	30 IN.	60 IN.	25 FT.

[1] *THE LINEAR FIELD OF LONG SIDE OF 35MM FILM CAN BE CALCULATED BY MULTIPLYING FIELD OF SHORT SIDE (FROM TABLE) BY 1.5*

APPROX. FIELD OF OTHER FILM SIZES: *USE ANGULAR OR LINEAR FIELD GIVEN FOR SHORT SIDE OF 35MM FILM AND MULTIPLY BY THE SIZE OF YOUR FILM IN INCHES*

Fig. 14, is the common mounting method. It can be seen that the camera is bolted in place, and the camera in turn supports the objective lens. With focal lengths over 10 inches, it is more practical to mount the lens tube, and the tube then supports the camera. Fig. 15 is a typical mount of this kind; the adjustable-position feature is not for alignment since the camera can point in any direction, but simply to give you some choice of guide stars. All of this is explained in the chapter, "Shooting the Stars."

In the way of auxiliary lenses, the usual choice is standard anastigmats up to about 6 or 7 inches focal length. Over 8 inches f.l., achromats begin to function very well because of the comparatively narrow field angle involved. A 14 in. f.l. objective on a 35mm camera looks at a 7-degree field, and for this narrow angle an achromat is nearly as good as the most expensive anastigmat. Of course you don't get speed, the usual rating being about f/8. However, with the fast films now available, f/8 is more than enough aperture for most objects. Fig. 16 details the construction of a 14-inch f.l. telecamera. This is a very practical size for many land and sky objects; it can be hand-held for land objects if you are shooting at 1/500 second or faster. Its 7-degree field is just about the right size for many popular star groups. Fitted with adapter and 1-inch eyepiece, its 14x power is about all you can hold for rich field star-gazing. Coupled with a Barlow working at 3x, it zooms up to 42 inches equivalent focal length.

FIELD AND SCALE. With land objects, the photographer can get wide field or narrow field, big scale or small scale--all by the simple process of changing his position in relation to the target object. Not so in the sky. Every object in outer space has a fixed angular field, and your only control is by changing objectives. If you want to shoot wide-angle star fields, you need objectives of short focal length; if you want big images of small objects, you need a long f.l. glass or its equivalent in a compound optical system. You can get the angular size of any popular sky object from almost any list or catalog of stars. The rest is a matter of selecting the proper focal length. Sometimes you will be able to shoot direct with the telescope lens or mirror; other objects may require an auxiliary lens of shorter focal length. All of the needed data can be obtained from Tables 1 and 2. Image size is proportional to focal length; if you want data for, say, 14 inch f.l., simply read the values for 140 inch f.l. and point off one decimal place to the left.

TABLE 2 **IMAGE SIZE**

F.L. or E.F.L.	ANGULAR SIZE (SECONDS OR MINUTES OF ARC)								
	20"	40"	1'	5'	10'	30'	31'	40'	60'
10"	.001	.002	.003	.015	.029	.087	.090	.12	.18
20"	.002	.004	.006	.029	.058	.17	.18	.23	.35
30"	.003	.006	.009	.044	.087	.26	.27	.35	.52
40"	.004	.008	.012	.058	.12	.35	.36	.47	.70
50"	.005	.010	.015	.073	.15	.44	.45	.58	.87
60"	.006	.012	.017	.088	.18	.52	.54	.70	1.05
70"	.007	.014	.020	.10	.20	.61	.63	.81	1.22
80"	.008	.016	.023	.12	.23	.70	.72	.93	1.40
90"	.009	.018	.026	.13	.26	.79	.81	1.05	1.57
100"	.010	.020	.029	.15	.29	.87	.90	1.16	1.75
120"	.012	.024	.034	.17	.35	1.05	1.08	1.40	2.10
140"	.014	.028	.041	.20	.41	1.22	1.26	1.63	2.44
160"	.016	.032	.047	.23	.47	1.39	1.44	1.86	2.79
180"	.018	.036	.052	.26	.52	1.57	1.62	2.10	3.14
200"	.019	.039	.058	.29	.58	1.74	1.80	2.33	3.49
225"	.022	.044	.066	.33	.66	1.94	2.03	2.62	3.93
250"	.024	.048	.073	.37	.73	2.18	2.26	2.91	4.36
275"	.027	.053	.080	.40	.80	2.40	2.48	3.20	4.80
300"	.029	.058	.087	.44	.87	2.62	2.71	3.49	5.24
400"	.039	.078	.12	.58	1.16	3.49	3.61	4.66	6.98
500"	.049	.097	.15	.73	1.45	4.36	4.51	5.82	8.73
600"	.058	.12	.18	.88	1.75	5.24	5.41	6.98	10.48
700"	.068	.14	.20	1.02	2.04	6.11	6.31	8.15	12.22
800"	.078	.16	.23	1.16	2.33	6.98	7.22	9.31	13.97
900"	.087	.18	.26	1.31	2.62	7.85	8.12	10.48	15.71
1000"	.097	.19	.29	1.46	2.91	8.73	9.02	11.64	17.46

ALL DIMENSIONS IN INCHES

E.F.L. - EQUIVALENT FOCAL LENGTH

▲ USE THIS COL. FOR SUN OR MOON (31' column)

ANGULAR SIZE OF SOME **ASTRO OBJECTS**

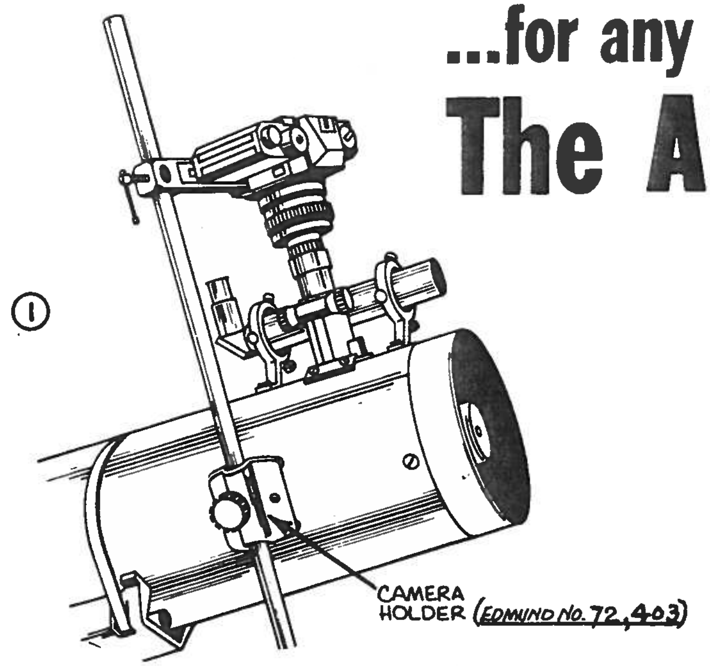
SUN	32'*	M8 - LAGOON	60'
MOON	31'*	M13 - HERC. CLUSTER	10'
MOON OBJECTS	APPROX 1 SEC. PER MILE	M27 - DUMBBELL	8'
JUPITER	40"*	M31 - ANDR. NEB.	160'
SATURN BALL / RING	18" / 42"*	M42 - ORION NEB.	60'
VENUS	20"*	M44 - BEEHIVE	90'
MARS	8"*	M45 - PLEIADES	120'
M1 - CRAB NEB.	6'	M57 - RING NEB.	1½'

*AVERAGE

Image size (in) = [illegible] FL(in) · Angular size (deg) · 0.01746

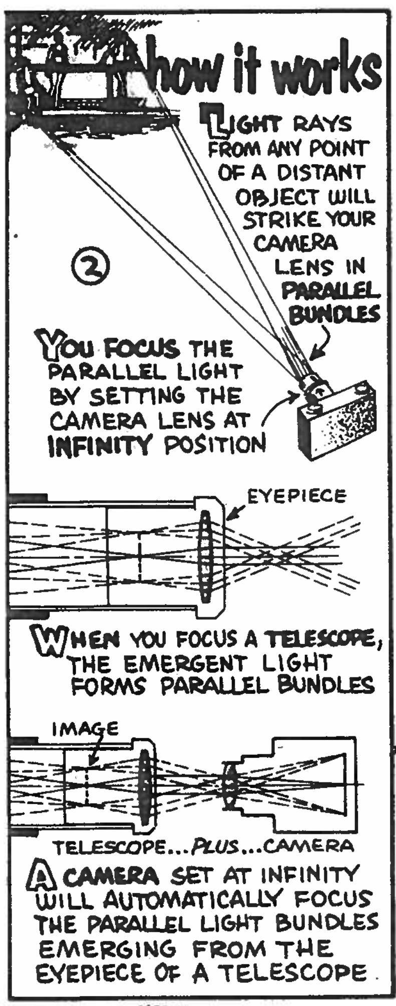
...for any camera

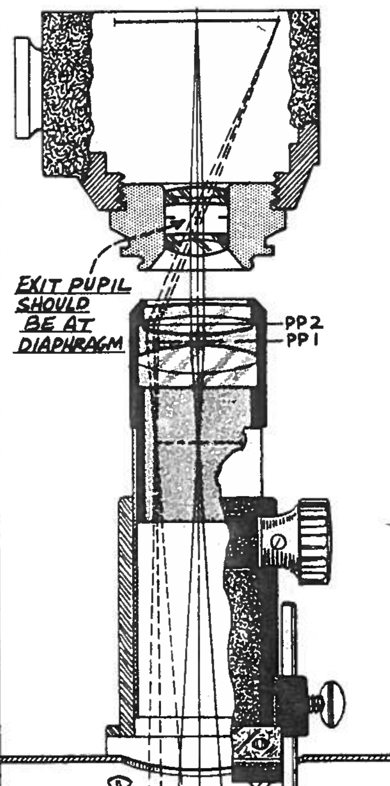
The AFOCAL SYSTEM

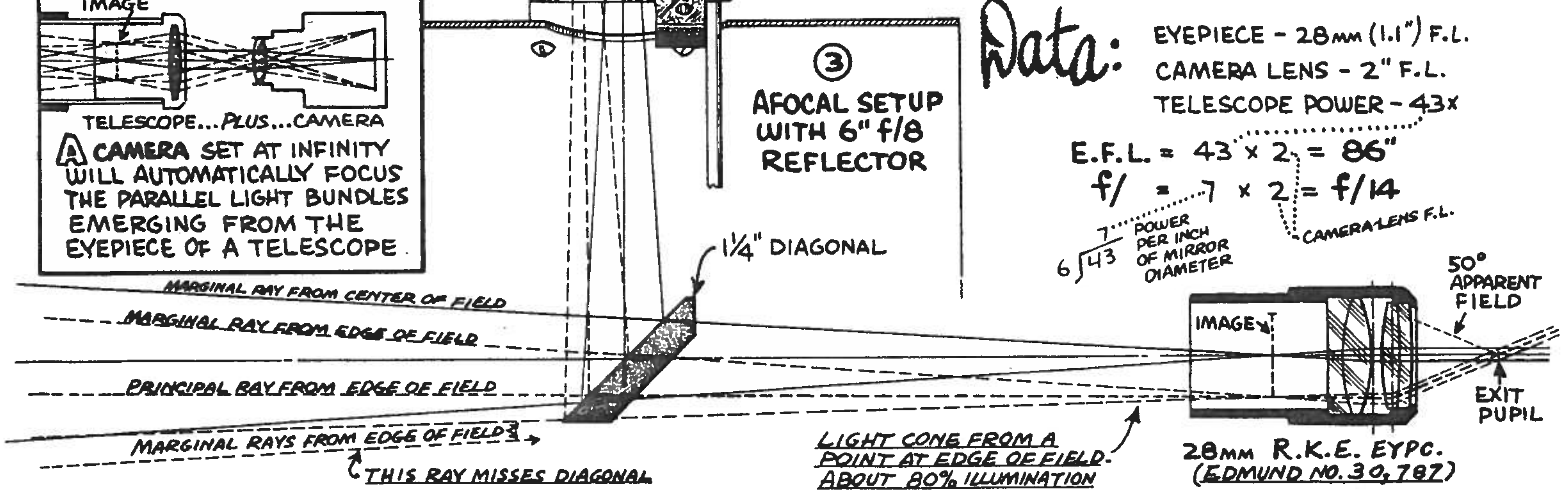


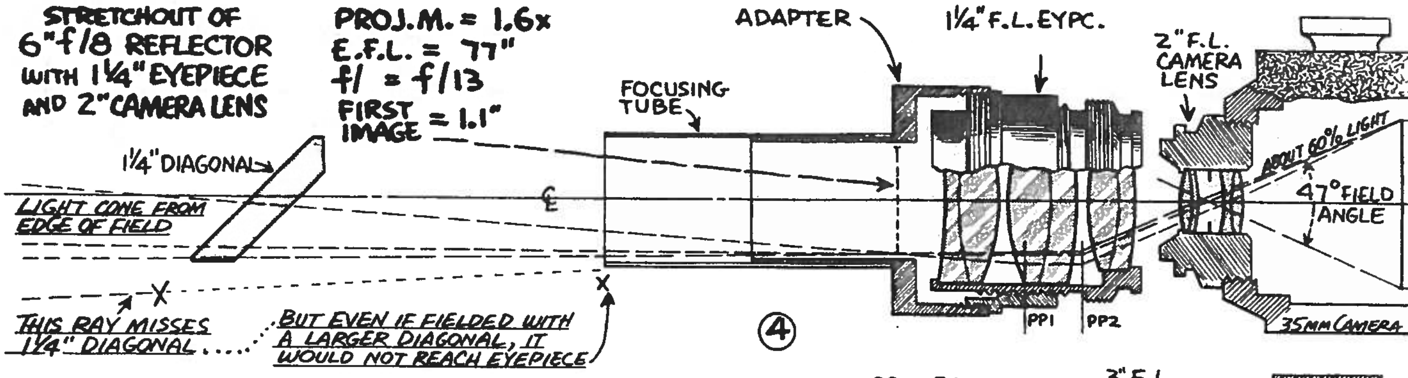
THE AFOCAL system consists of a telescope in front of a camera. It gets its name from the fact that the telescope eyepiece is located exactly its own focal length from the first image, while the camera lens is exactly its own focal length from the second image. Technically, the system is one of projection, the only distinction being that it is an afocal projection system as differing from other projection systems where object and image distances do not match the focal lengths of the lenses used. A telescope in focus for eye use is in afocal adjustment. This fact makes it possible to shoot pictures with a small telescope or binoculars in combination with a "blind" camera by simply focusing the telescope by eye and then putting it in front of the blind camera which is set at infinity. However, the precise focusing needed for long focal length telescopes is much too critical to permit this kind of guesswork.

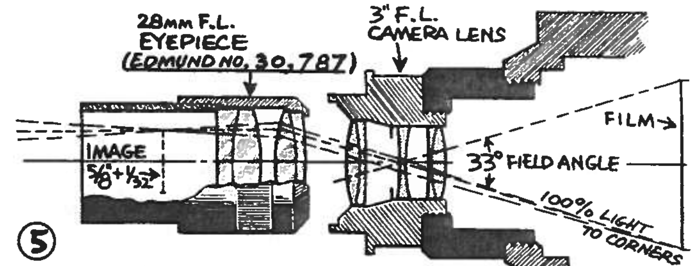
Figs. 1 and 3 show a typical system. The telescope eyepiece and the camera lens must be in fair alignment, but they are not coupled. The small intervening space need not even be enclosed unless you are shooting outdoors in sunlight. The camera must be supported externally and gadgets for this purpose can be purchased or made as desired. The equivalent focal length of the whole system is the power of the telescope multiplied by the focal length of the camera lens. While the example shown in Fig. 3 is quite modest, it will be apparent that terrific magnification











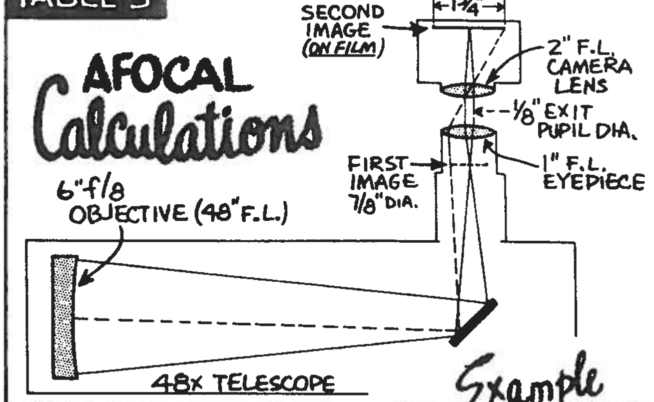
A 3" CAMERA LENS REDUCES FIELD ANGLE
E.F.L. = 129"
f/ = f/22 (WITH 6" f/8 REFLECTOR)

can be obtained by using an eyepiece of short focal length in combination with a long f.l. lens on the camera.

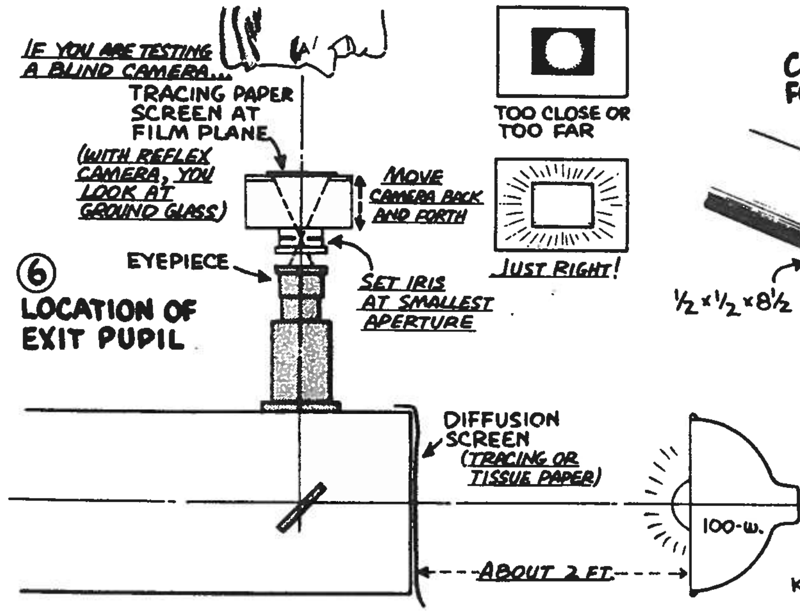
AFOCAL CALCULATIONS. Afocal systems are easy to calculate by using the formulas given in Table 3. Usually the power of the telescope with a certain eyepiece will be known, and in such case the calculations are based on this specification. However, it is often easier to calculate the system from the amount of Projection Magnification, and equations for doing this are given in the lower half of the table. In an afocal system, magnification is obtained by having the rear lens (the camera lens) of longer focal length than the front lens (the eyepiece). If your camera lens is 2 in. focal length and you use a 1 in. eyepiece, the Projection M. is 2x. When the eyepiece is the same focal length as the camera lens, the magnification is unity or 1x, that is, same size, no magnification.

FIELD ANGLE. In all afocal systems, the apparent field angle of the eyepiece should equal or exceed the field angle of the camera. If you are using a standard 35mm camera with 2-inch focal length objective, the field angle will be a maximum of 47 degrees, Fig. 4. Now, since what goes into the camera must come out of the eyepiece, you can see that light rays emerging from the eyepiece must embrace an angle of at least 47 degrees. If the eyepiece has a smaller apparent field than 47 degrees, it will not cover the 47 degree angle required by the film. This situation occurs frequently since most Huygens and Ramsden eyepieces, many Symmetricals and some Kellners will have no more than 40 degrees apparent field. The result will be slight vignetting at the corners of the film. Even when the eyepiece has the required wide field, vignetting will occur at 1.6x or less projection magnification because the small-diameter focusing tube will not field the big primary image which

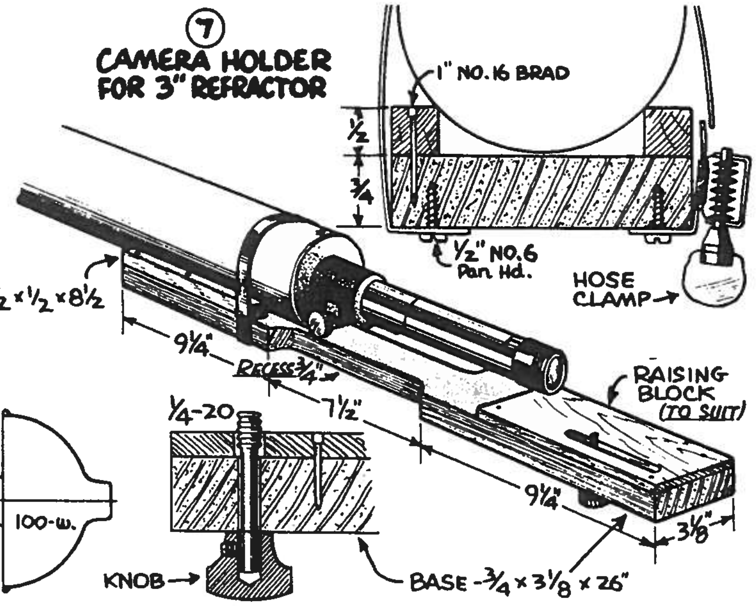
TABLE 3



	Example
E.F.L. = POWER OF TELESCOPE X CAMERA F.L.	48 x 2 = 96"
f/ = EQUIVALENT F.L. / APERTURE OF TELESCOPE	96 ÷ 6 = 16 (f/16)
f/ (ALTERNATE) = CAMERA F.L. / EXIT PUPIL	$2 \div \frac{1}{8} = 2 \times \frac{8}{1} = 16$
f/ (ALTERNATE) = TELESCOPE POWER-PER-INCH X F.L. OF CAMERA	48 ÷ 6 = 8X PER INCH; 8 x 2 = 16
ALTERNATE Calculations BASED ON PROJECTION MAGNIFICATION	
PROJECTION MAGNIFICATION = CAMERA F.L. / EYEPIECE F.L.	2 ÷ 1 = 2 (2X)
E.F.L. = F.L. OF TELESCOPE X PROJ. M.	48 x 2 = 96"
f/ = f/VALUE OF TELESCOPE X PROJ. M.	8 x 2 = f/16
DIA. OF FIRST IMAGE = FILM DIAGONAL / PROJECTION M.	1.75 (35MM FILM) ÷ 2 = .87 (7/8")



(6) LOCATION OF EXIT PUPIL



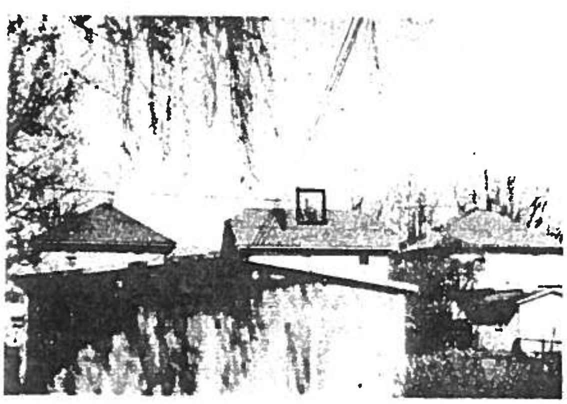
(7) CAMERA HOLDER FOR 3" REFRACTOR

goes with low power. Fig. 4 is an example. On the other hand, high-power means that the first image will be small and the focusing tube is no longer a bottleneck.

If your camera permits changing lenses, it is sometimes advantageous to use a slightly longer focal length, Fig. 5. As can be seen, this reduces the field angle of the camera, which in turn means that the eyepiece has an easy job. Such a system works with no vignetting whatever, and also is non-critical as regards the location of the exit pupil of the telescope.

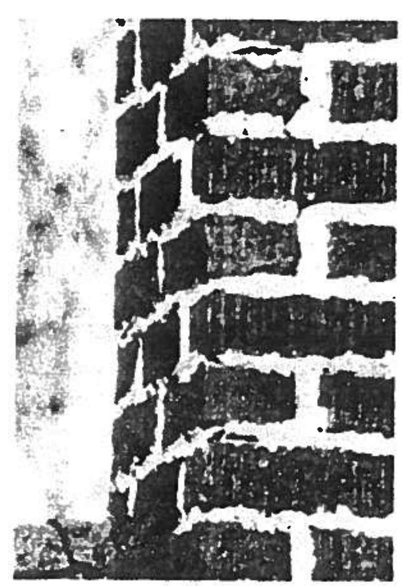
LOCATION OF EXIT PUPIL. The space between eyepiece and camera is optically free space, meaning that a little more or less space will have no effect on the power of the system or the location of the final image. But the camera lens must pass all of the required cone of light, and the best insurance to meet this requirement is to locate the exit pupil of the telescope at or near the iris of the camera lens. The proper position is obtained automatically with a simple visual test, Fig. 6. If you push the camera back and forth, you will note that the corners of the ground glass (or tracing paper screen) will show black when the camera is too close or too far from the eyepiece. Determine by this test some position where the lighting is uniform over the whole film area; make a note of the spacing for future use in mounting the camera.

Most shooters will use the afocal system with

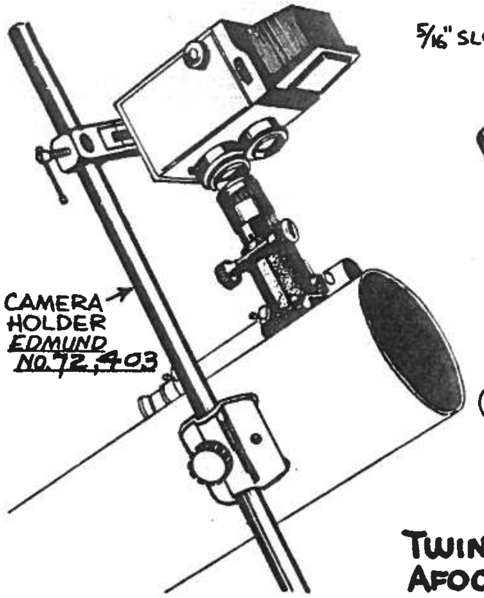


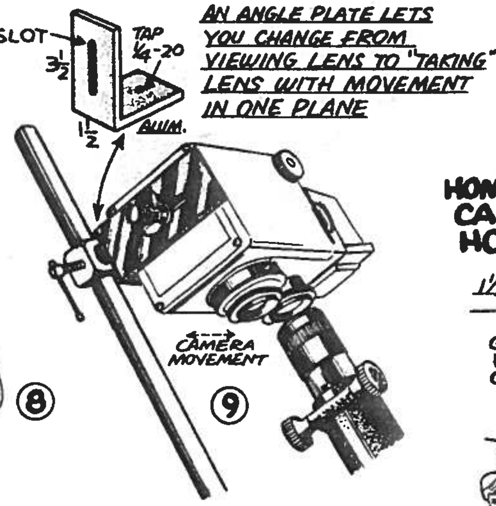
BIG PLATE SCALE... IS GRAPHICALLY PORTRAYED WHEN REGULAR 2-INCH F.L. OF 35MM CAMERA LENS IS COMPARED WITH SAME VIEW SEEN WITH A 6-INCH REFLECTOR TELESCOPE OF 48" F.L. ALL PICS TAKEN FROM INDOORS THRU OPEN WINDOW. THE SCENE, ABOVE, 1/200 SECOND AT f/11 ON PLUS-X FILM

6" REFLECTOR AT FOCUS. PANATOMIC-X, 1/100 SEC. AT f/8

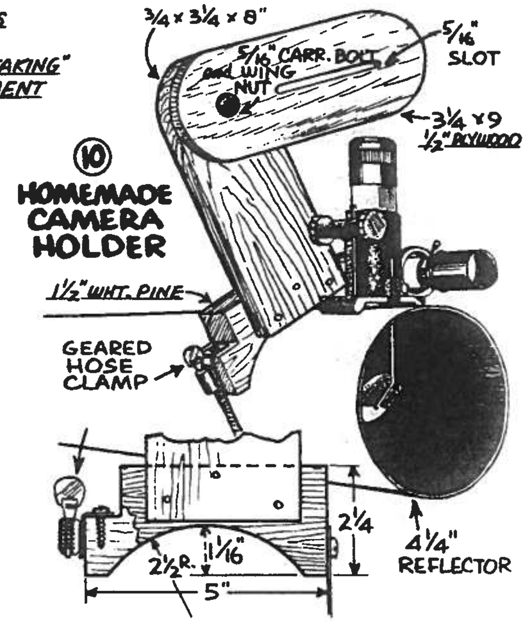


2.7x BARLOW (GOODWIN) ON 6-INCH REFLECTOR. 1/10 SEC. AT f/22





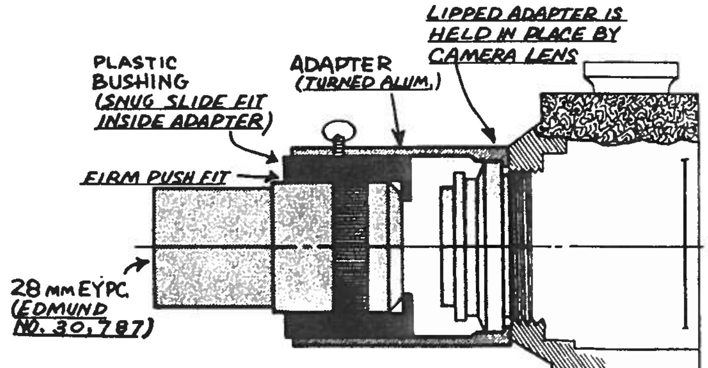
TWIN LENS REFLEX CAMERA AFOCAL WITH 4¼" REFLECTOR



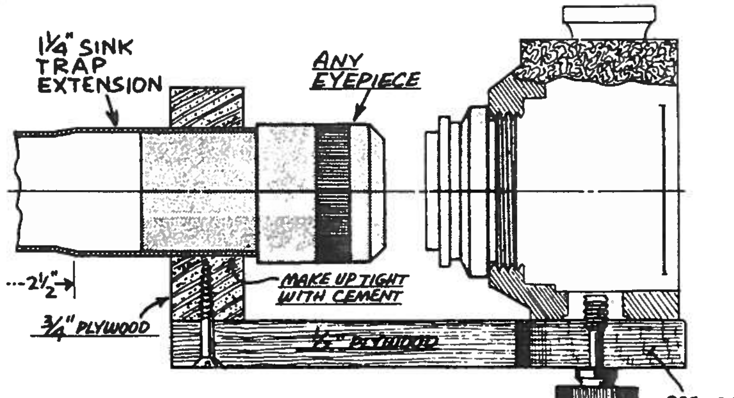
the iris wide open, just as insurance that all the light gets through. However, if you have the exit pupil exactly at the iris, you can stop down as desired. If you can stop down below the rated f/value of the telecamera, the new f/value can be read directly from the f/scale. As noted, however, you must have the exit pupil exactly at the iris and concentric with it to make use of this feature. Probably the best standard practice is to stop down to about f/8. The idea, of course, is simply that the stopped-down iris makes a good glare stop.

MOUNTING THE CAMERA. If you are using a refractor, a simple camera mount is a board clamped to the main tube, Fig. 7. A twin lens job is more of a problem, since with ordinary mounting bracket, Fig. 8, it is clumsy and time-consuming to set the camera for the viewing and taking positions. One partial solution is to use an angle plate, Fig. 9, which confines the needed movement to a single plane. The single lens reflex is easy to mount and almost any kind of wood or metal bracket can be used; Fig. 10 design is pivoted at the center in order to get around the finder which is usually in the way of a straight support made of wood.

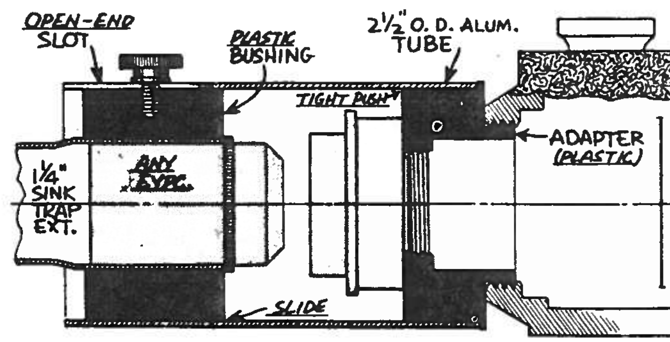
If you like the afocal system, coupled mounting is worth consideration. The idea here is that the combined eyepiece and camera is free-standing, supported only by the focusing tube in much the same manner as a long and bulky eyepiece. A nice feature of this setup is that you can rotate the camera as needed to square the picture with the side of the film; with a fixed bracket, the only way you can do this is by rotating the telescope. Most coupled afocal



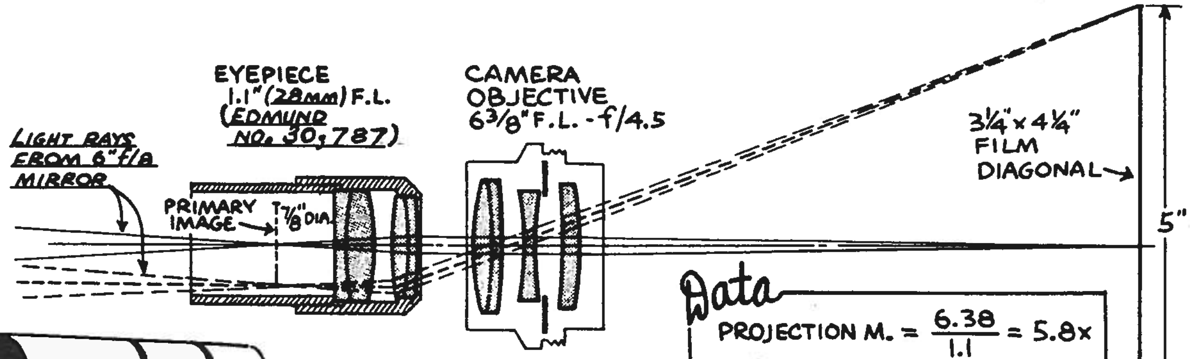
(11) 1.8× COUPLED AFOCAL ATTACHMENT



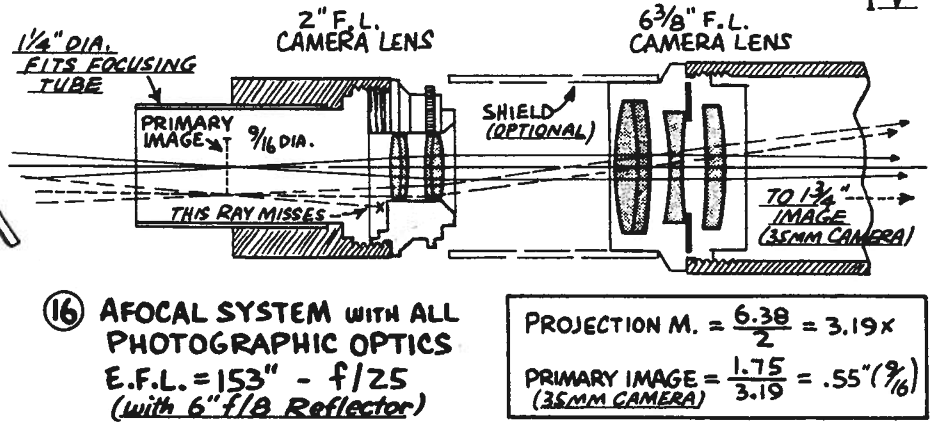
(12) COUPLED AFOCAL ON OPEN BASE



(13) COUPLED AFOCAL WITH 3" F.L. CAMERA LENS



(15) AFOCAL SYSTEM
279" E.F.L. - f/46



(16) AFOCAL SYSTEM WITH ALL PHOTOGRAPHIC OPTICS
E.F.L. = 153" - f/25
(with 6" f/8 Reflector)

(14) CAMERA CAN BE ON SEPARATE TRIPOD

systems can be arranged to take interchangeable eyepieces and so make available a wide range of magnifications.

If a bulky, heavy camera is used, it can be mounted on its own tripod, independent of the telescope. Such an arrangement using a Graflex camera and 6-inch reflector is shown in Fig. 14. The telescope tube should be rotatable in order to position the eyepiece in approximate level position. This kind of setup is impractical for astro objects, such as the moon, but is okay looking at a stationary terrestrial target. The setup is best made indoors with the telescope pointing out an open door or window. Under such circumstances, the reflector will work satisfactorily without the need of sun shades or other light baffles.

The large camera poses an additional problem of field coverage. At least 5x projection magnification is usually needed to cover the film diagonal. Fig. 15 example is nearly 6x, resulting in an effective focal length of 279 inches. From the fact that a "super" telephoto lens is a mere 1000mm (40 inches), you can realize this afocal combo is big, big equipment in terms of equivalent focal length. Sturdy mounting is required for both telescope and camera to prevent vibration. Uusally in an outfit of this size it is impractical to use the focal plane shutter because of the vibration from the falling mirror. In the afocal system there is usually some space between eyepiece and camera lens, and it is at this point that you make the exposure by the well-known method of flicking a dark card across the light beam. Alternately, a piece of dark cardboard or a dark felt hat can be used in front of the telescope itself.

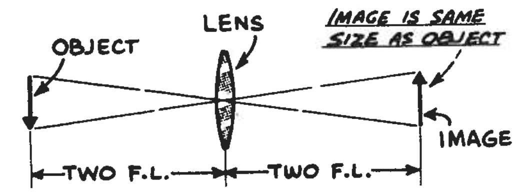
ALL PHOTOGRAPHIC OPTICS. If you have a battery of short focal length direct objectives, they can be made to do double duty in afocal combinations. Fig. 16 example shows a 2-inch combined with a 6-inch, the longer f.l. lens as usual being to the rear. This setup is for a 35mm camera. Even for this small area, the first lens is invariably the bottleneck, and at least 3x projection magnification is needed to get a primary image small enough for the first lens to cover. In all cases, you must field the principal ray to get satisfactory lighting at the corners of the film. Another way of saying this is that the corners of the film should get at least 50 percent lighting; if you can field the principal ray, 50 percent lighting is assured. The example shown gets about 60 percent of the light beam to the extreme corners of the film. With this kind of lighting, the slight vignette will not show at all on a normally exposed film.

positive and negative PROJECTION Systems

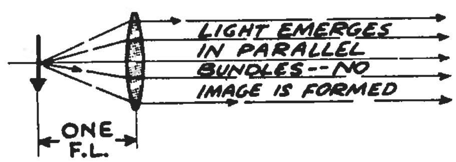
ALMOST any telescope can be used as a projection system by merely extending the eyepiece a little from the normal afocal position. Even the Galilean telescope may be used in this manner, although the negative lens projection is more generally recognized as a Barlow or telephoto system. The usual positive projecting eyepiece is simply a telescope eyepiece--it gets tagged as a "projection" eyepiece only from the manner in which it is used. Regular slide projector lenses are sometimes used as well as short focal length camera lenses. The most practical focal lengths are the same as for visual use--in the neighborhood of 1 inch--and eyepieces can be used interchangeably for looking and shooting. The comfortable magnifying range runs from 2x to 6x projection magnification. This builds up the equivalent focal length rather quickly since the telescope itself is a long focus lens. With a 6-inch f/8 reflector of 48 in. focal length, a 3x projection system makes the e.f.l. 144 inches.

PROJECTION WITH A POSITIVE LENS

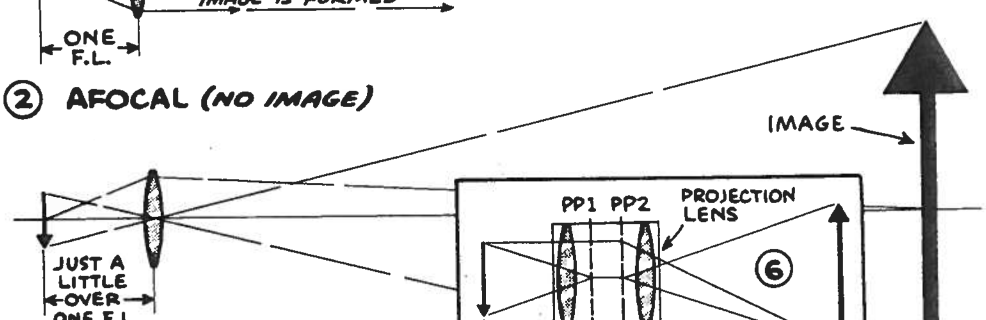
In all projection systems, magnification is obtained by making the image distance greater than the object distance. In the telescope setup, the "object" to be projected is the real image formed by the telescope objective, while the "image" is the real second image formed on the film. Fig. 1 shows a basic type of lens spacing which results in an image the same size as the object. When the lens or eyepiece is one focal length from the object, no real image is formed, Fig. 2. This is the afocal position, the way an eyepiece is adjusted for visual use. Between



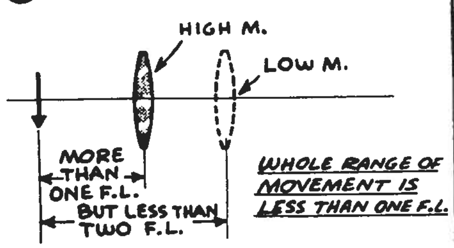
① UNITY (1x) MAGNIFICATION



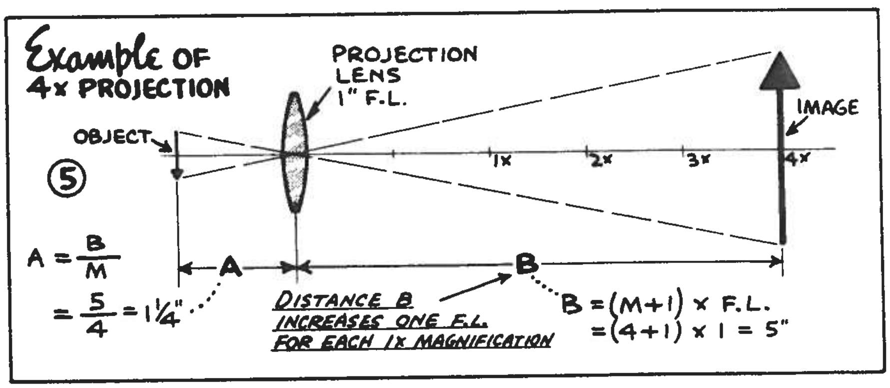
② AFOCAL (NO IMAGE)

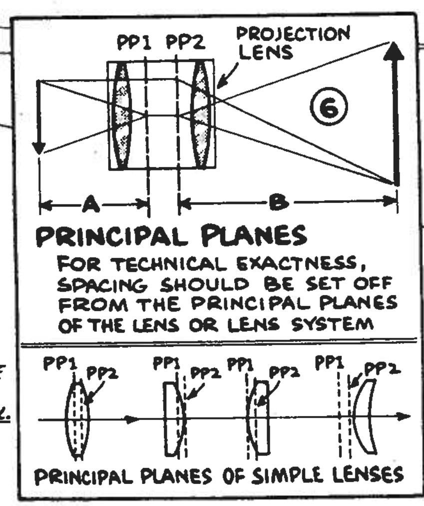


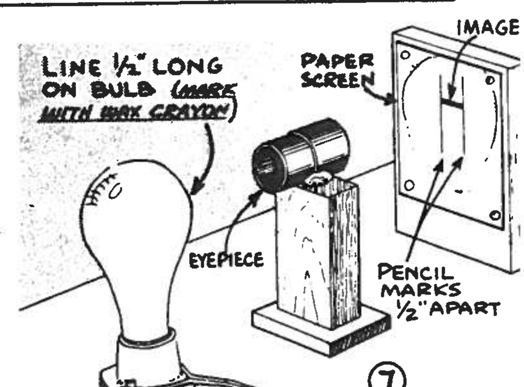
③ GREATEST MAGNIFICATION



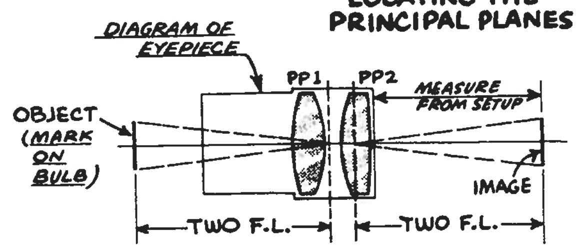
④ WHOLE RANGE







LOCATING THE PRINCIPAL PLANES



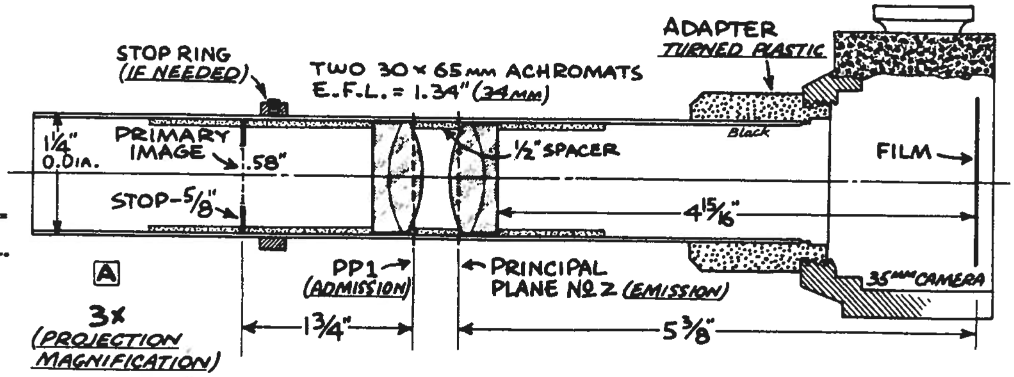
(8)

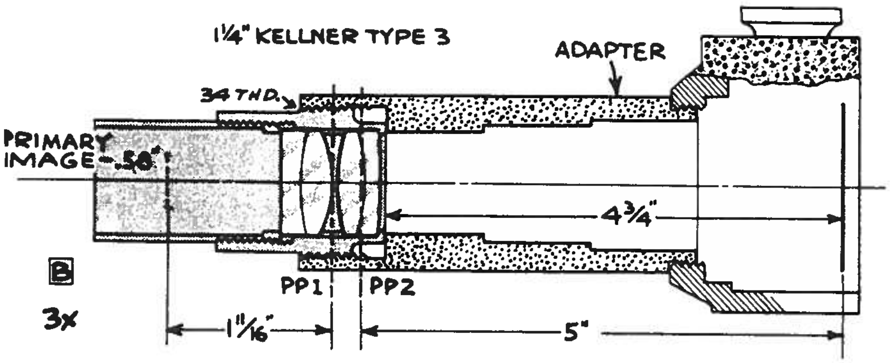
PROJECTING EYEPIECES

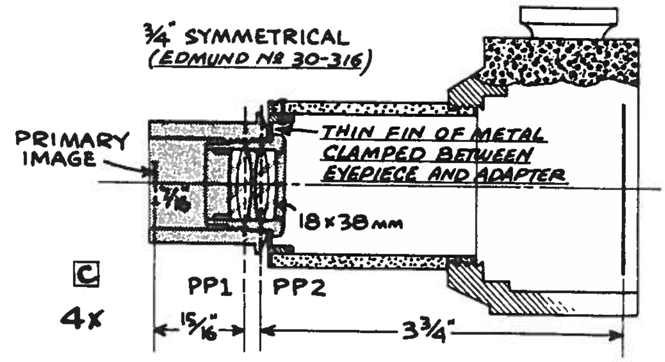
USE WITH ANY OBJECTIVE
OR WITH ANY TELESCOPE
USING 1¼" DIA. EYEPIECES

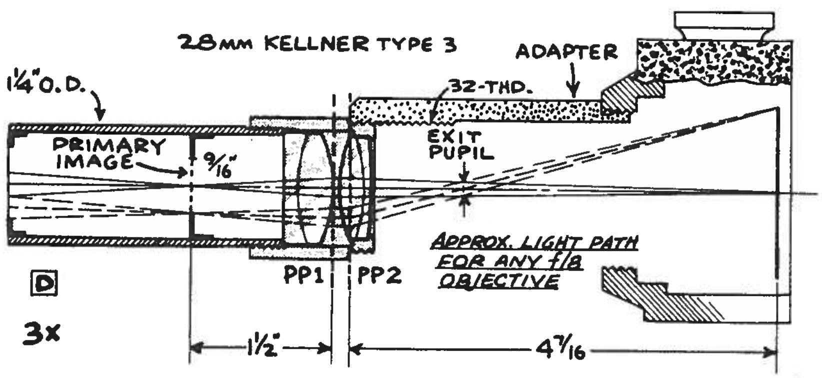
E.F.L. = PROJECTION M. × OBJECTIVE F.L.

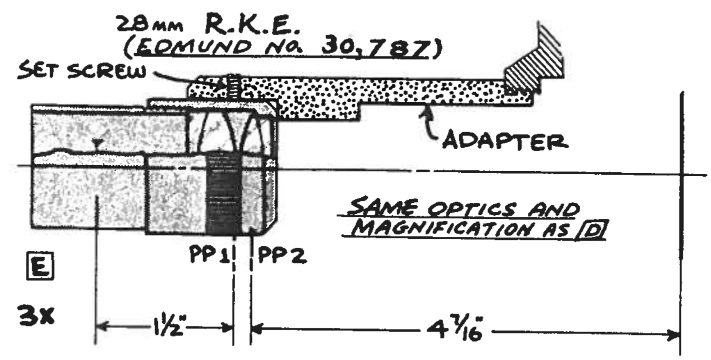
f/ = PROJECTION M. × f/OBJECTIVE

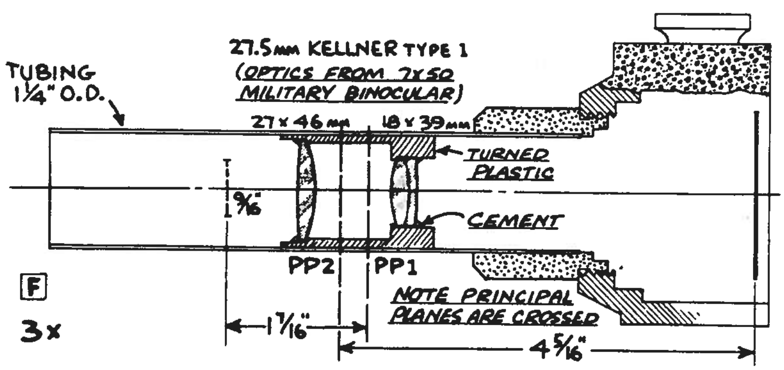


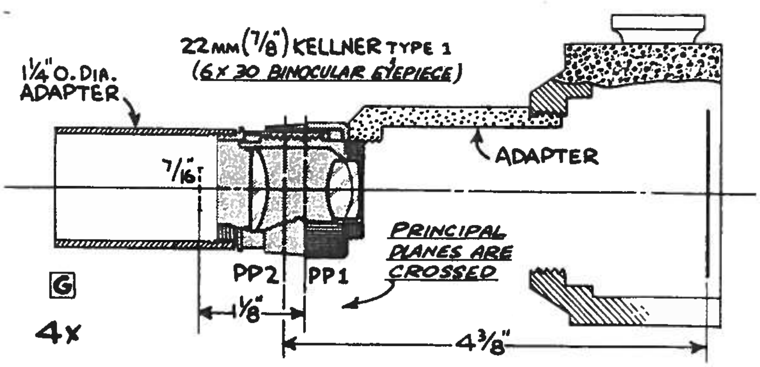


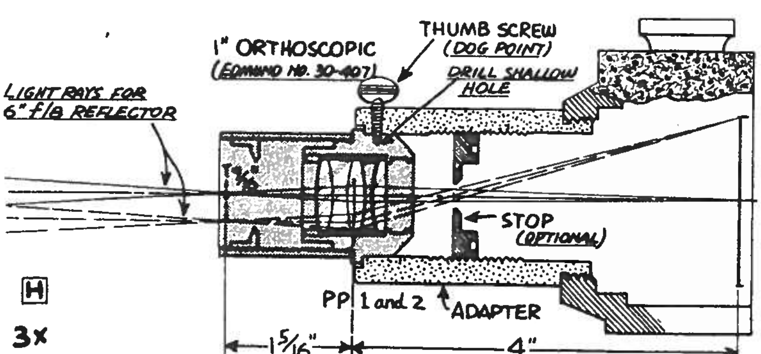


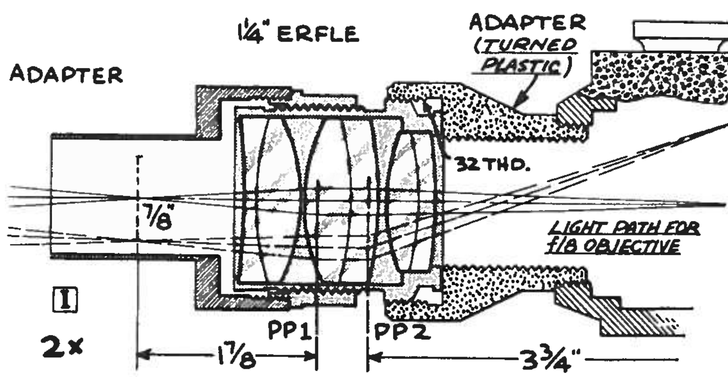


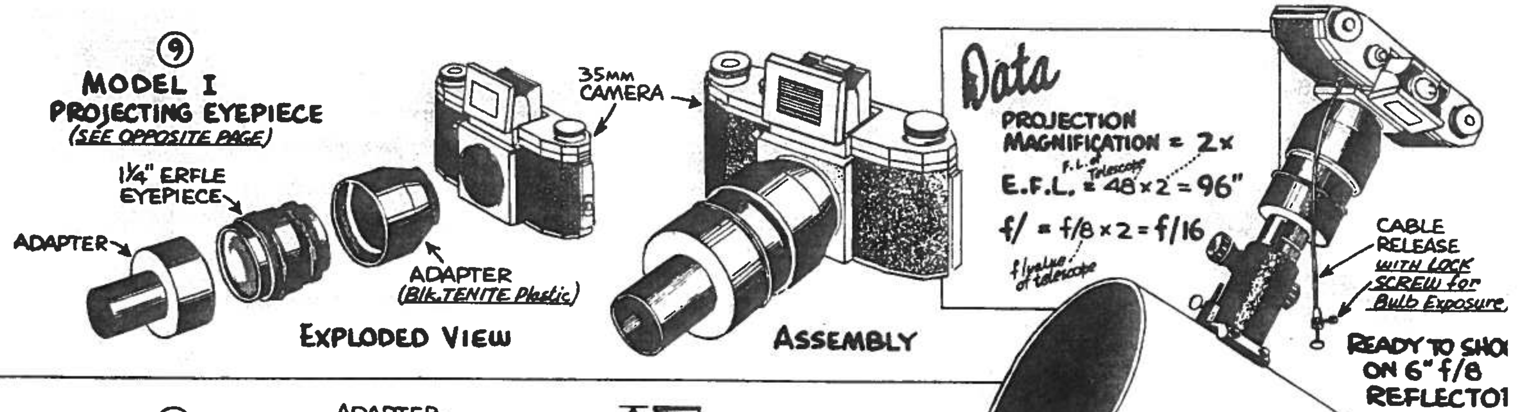


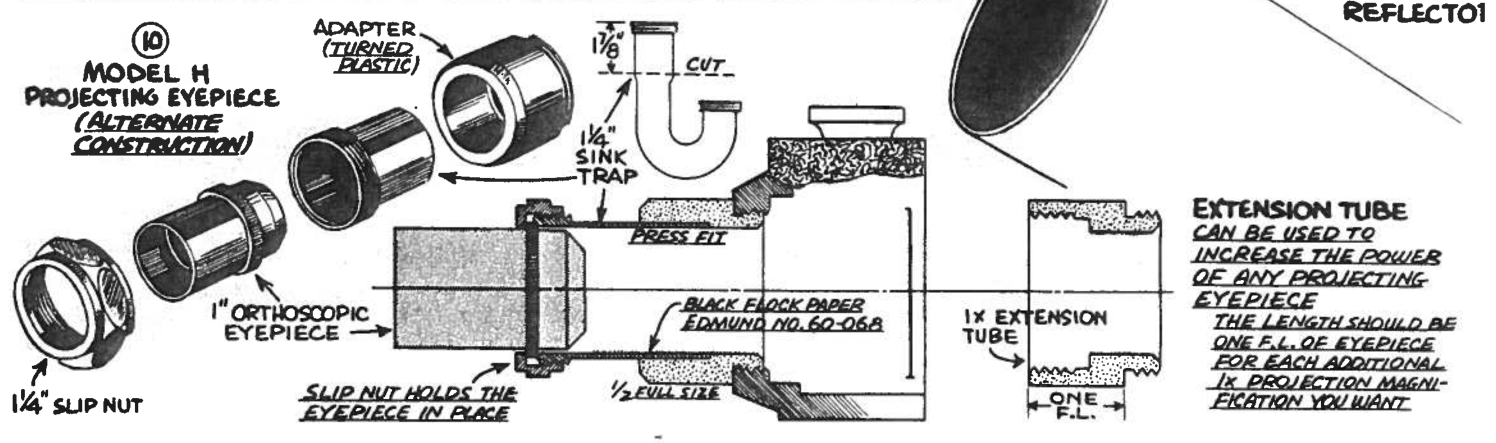










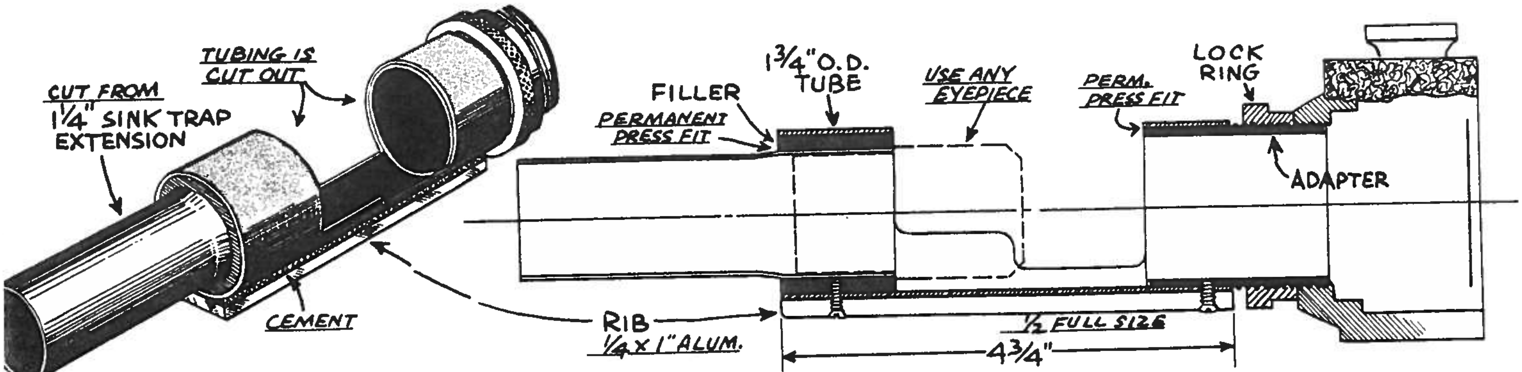


the 1x position and the afocal position it is possible to obtain a complete range of magnifications, from no magnification to infinite magnification--all with a lens adjustment of less than one focal length, Fig. 4.

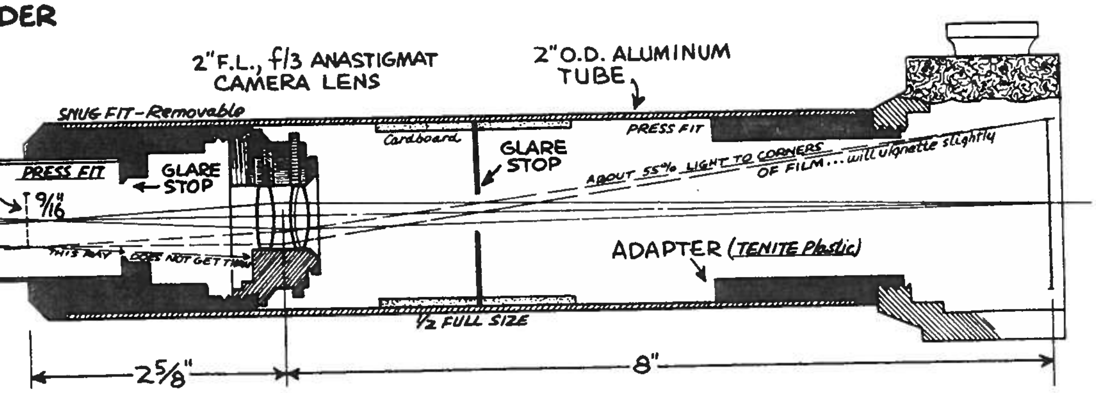
The required spacing for any degree of projection magnification can be calculated from the simple formulas given in Fig. 5. Dimension B is the controlling dimension--it is the same as the "throw" distance of a slide projector. Being a comparatively long dimension, it is not unduly affected by slight errors. In the usual practice, spacing distances are set off from the center of the lens or lens system, but if you want to be technically correct, the spacing should be measured from the principal planes, Fig. 6. If you know the focal length of any lens or eyepiece, you can locate the principal planes with the simple setup shown in Fig. 7. The general idea is to juggle the eyepiece and screen back and forth until the image formed on the screen is exactly in focus and exactly 1/2 inch long, the same as the object. Then, if you measure two focal lengths from the object, you will locate PP1, the plane of admission. Since the setup is 1x, the plane of emission, PP2, is also two focal lengths distance from the image. Once known, the principal planes of any eyepiece can be used as measuring points for any application of the eyepiece. If you make light ray diagrams, draw the rays to PP1, then parallel with the axis to PP2, and then to the image. Such rays do not show the actual path through the glass, but are accurate as regards entering and exit surfaces, which is all you need to know.

PROJECTING EYEPIECES. Typical projecting eyepieces are shown in Fig. 8. These are standard telescope eyepieces, the adaptation being mainly a matter of an extension tube which sets the eyepiece a fixed distance from the film plane. You can change the magnification of any design by simply changing the spacing. Low power is the most difficult to obtain since this demands a big field lens. Of the designs shown, only Model I can work at less than 2x.

Fig. 9 shows the construction and mounting of Model I projecting eyepiece. Like most projecting systems, this is a compact unit requiring no additional support other than the normal mounting in the focusing tube of the telescope. Fig. 10 shows an alternate construction for Model H projecting eyepiece which you may prefer to drilling a hole in the eyepiece. If you want more power from any system, all you need is an extension tube of suitable length; for the 1 inch f.l. orthoscopic eyepiece, a 1x extension is 1 inch long from end to shoulder, as shown in Fig. 10 detail. A glare stop at the exit pupil is optional in any projection eyepiece. This is an ideal location for a stop since it is here that the light funnels down to its smallest diameter. However, most



(11) OPEN EYEPIECE HOLDER



(12) CAMERA LENS USED FOR PROJECTION

systems are sufficiently glare-proof with black flock paper cemented to the inside of extension tube or adapter.

If used exclusively in the dark for astro objects, a projection system can be used with open tube, or even no tube at all. As can be seen in Fig. 11, the open tube allows changing eyepieces as desired to obtain different magnifications. Another advantage is that you can use a piece of black cardboard as a "shutter," thereby eliminating the annoying mirror bounce which in 35mm cameras sometimes causes enough movement to spoil your pictures. To make the exposure by card, the card is placed in the tube cutout where it cuts off the light to the camera. The shutter on "bulb" is opened and held open by the clamp on the cable release. The card is then lifted quickly and replaced, giving an exposure of about 1/8 second.

Note that Fig. 11 setup positions the eyepiece farther out then when the eyepiece is placed directly in the focusing tube of the telescope - - you may need "in" focusing travel for some eyepieces. This setup is especially good for the situation where the main mirror of a reflector is set forward to allow shooting at the focus. In such position, there is of course plenty of "in" focusing travel available.

USING PHOTOGRAPHIC OPTICS. Systems of this kind will usually show sharp imagery, but they have faults in excessive length and low edge-of-field illumination. Fig. 12 shows a typical system. The assembly is quite long - - it may require external support. The lighting of 55% at corners of film is satisfactory; full lighting would be obtained with 4x or more projection magnification. The camera lens is usually reversed from its normal position, following the general rule that a lens will usually work best if its normal front side faces the longer of the two conjugate distances. Many lenses will work equally well either way. Microscope objectives and small projector lenses will invariably pose the same problem of small aperture.

PROJECTION CALCULATIONS. Much of the arithmetic connected with projection systems can be eliminated by using Table 4 which gives spacing distances for most of the lenses you are likely to use. If you use some focal length not listed, find, from table, the spacing for a 1-inch f.l. lens at the desired magnification. Then, multiply these values by the f.l. of the lens you plan to use. Alternately, use Table 5, which covers all of the various equations and transpositions needed to calculate any system.

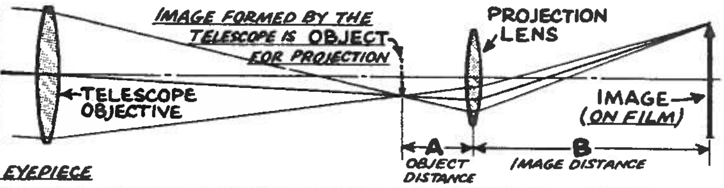
NEGATIVE LENS PROJECTION

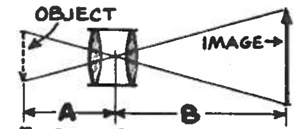
Whether you prefer a negative lens or a positive lens for a photographic system is largely dependent on the quality of the optics. Assuming good optics, the negative lens is preferable, most practical. The outstanding feature of projection by using a negative lens is

TABLE 4

OBJECT-IMAGE SPACING for Projection Systems

PROJECTION WITH A POSITIVE LENS



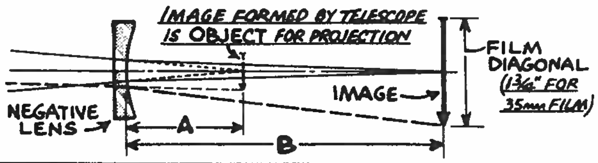


FOR DOUBLE LENSES OR ANY KIND OF EYEPIECE, MEASURE FROM CENTER (SEE TEXT)

FOCAL LENGTH OF PROJECTION LENS OR EYEPIECE

F.L.		1¼x	1½x	2x	3x	4x	5x	6x	7x	8x	9x	10x	12x	15x	20x
3/8″ (9.5mm)	A →	.67″	.62″	.56″	.50″	.47″	.45″	.44″	.43″	.42″	.42″	.41″	.40″	.40″	.39″
	B →	.84	.93	1.12	1.50	1.87	2.25	2.62	3.00	3.37	3.75	4.12	4.87	6.00	7.87
1/2″ (12.7mm)	A →	.90	.83	.75	.67	.62	.60	.58	.57	.56	.55	.55	.54	.53	.52
	B →	1.12	1.25	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.50	8.00	10.50
5/8″ (15.9mm)	A →	1.12	1.04	.93	.83	.78	.75	.73	.71	.70	.69	.68	.67	.66	.65
	B →	1.40	1.56	1.87	2.50	3.12	3.75	4.37	5.00	5.62	6.25	6.87	8.12	10.00	13.12
3/4″ (19.1mm)	A →	1.34	1.25	1.12	1.00	.94	.90	.88	.86	.84	.83	.82	.81	.80	.79
	B →	1.68	1.87	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50	8.25	9.75	12.00	15.75
7/8″ (22.2mm)	A →	1.58	1.46	1.31	1.16	1.09	1.05	1.02	1.00	.98	.97	.96	.95	.93	.92
	B →	1.97	2.19	2.63	3.50	4.38	5.25	6.13	7.00	7.87	8.75	9.62	11.37	14.00	18.37
1″ (25.4mm)	A →	1.80	1.66	1.50	1.33	1.25	1.20	1.17	1.14	1.13	1.11	1.10	1.08	1.07	1.05
	B →	2.25	2.50	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	13.00	16.00	21.00
1⅛″ (28.6mm)	A →	2.02	1.87	1.68	1.50	1.40	1.35	1.31	1.28	1.27	1.25	1.24	1.22	1.20	1.18
	B →	2.53	2.81	3.37	4.50	5.62	6.75	7.87	9.00	10.13	11.25	12.37	14.62	18.00	23.62
1¼″ (31.8mm)	A →	2.25	2.08	1.87	1.67	1.56	1.50	1.46	1.43	1.41	1.39	1.37	1.35	1.33	1.31
	B →	2.81	3.12	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50	13.75	16.25	20.00	26.25
1⅜″ (34.9mm)	A →	2.47	2.29	2.06	1.83	1.72	1.65	1.60	1.57	1.55	1.53	1.51	1.49	1.47	1.44
	B →	3.09	3.43	4.13	5.50	6.87	8.25	9.62	11.00	12.37	13.75	15.12	17.87	22.00	28.87
1½″ (38.1mm)	A →	2.69	2.50	2.24	2.00	1.88	1.80	1.76	1.71	1.68	1.66	1.64	1.62	1.60	1.58
	B →	3.37	3.74	4.50	6.00	7.50	9.00	10.50	12.00	13.50	15.00	16.50	19.50	24.00	31.50

PROJECTION WITH A NEGATIVE (BARLOW) LENS



WHOLE TeleCamera: POSITIVE OR NEGATIVE SYSTEM

E.F.L. = F.L. OBJECTIVE X PROJECTION M.

f/ = f/OBJECTIVE X PROJECTION M.

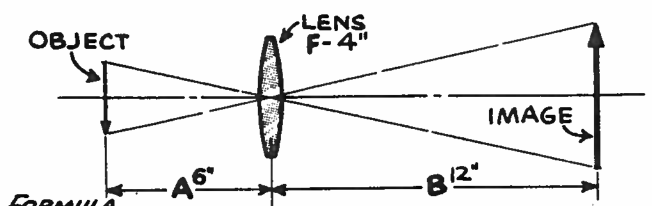
DIAMETER OF FIRST IMAGE = FILM DIAGONAL / PROJECTION M.

F.L.		1¼x	1½x	2x	2½x	3x	3½x	4x	4½x	5x	6x	7x	8x	9x	10x
-1″ (25.4mm)	A →	.20″	.33″	.50	.60″	.67″	.71″	.75″	.78″	.80″	.83″	.86″	.87″	.89″	.90″
	B →	.25	.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	5.00	6.00	7.00	8.00	9.00
-2″ (50.8mm)	A →	.40	.67	1.00	1.20	1.33	1.43	1.50	1.55	1.60	1.67	1.71	1.75	1.78	1.80
	B →	.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	10.00	12.00	14.00	16.00	18.00
-3″ (76.2mm)	A →	.60	1.00	1.50	1.80	2.00	2.14	2.25	2.33	2.40	2.50	2.57	2.62	2.67	2.70
	B →	.75	1.50	3.00	4.50	6.00	7.50	9.00	10.50	12.00	15.00	18.00	21.00	24.00	27.00
-4″ (102mm)	A →	.80	1.33	2.00	2.40	2.67	2.86	3.00	3.11	3.20	3.33	3.43	3.50	3.55	3.60
	B →	1.00	2.00	4.00	6.00	8.00	10.00	12.00	14.00	16.00	20.00	24.00	28.00	32.00	36.00
-5″ (127mm)	A →	1.00	1.66	2.50	3.00	3.33	3.57	3.75	3.88	4.00	4.17	4.28	4.37	4.44	4.50
	B →	1.25	2.50	5.00	7.50	10.00	12.50	15.00	17.50	20.00	25.00	30.00	35.00	40.00	45.00
-6″ (152mm)	A →	1.20	2.00	3.00	3.60	4.00	4.29	4.50	4.67	4.80	5.00	5.14	5.25	5.33	5.40
	B →	1.50	3.00	6.00	9.00	12.00	15.00	18.00	21.00	24.00	30.00	36.00	42.00	48.00	54.00
-7″ (178mm)	A →	1.40	2.33	3.50	4.20	4.67	5.00	5.25	5.44	5.60	5.83	6.00	6.12	6.22	6.30
	B →	1.75	3.50	7.00	10.50	14.00	17.50	21.00	24.50	28.00	35.00	42.00	49.00	56.00	63.00
-8″ (203mm)	A →	1.60	2.66	4.00	4.80	5.33	5.71	6.00	6.22	6.40	6.67	6.85	7.00	7.11	7.20
	B →	2.00	4.00	8.00	12.00	16.00	20.00	24.00	28.00	32.00	40.00	48.00	56.00	64.00	72.00
-9″ (229mm)	A →	1.80	3.00	4.50	5.40	6.00	6.43	6.75	7.00	7.20	7.50	7.71	7.87	8.00	8.10
	B →	2.25	4.50	9.00	13.50	18.00	22.50	27.00	31.50	36.00	45.00	54.00	63.00	72.00	81.00
-10″ (254mm)	A →	2.00	3.33	5.00	6.00	6.67	7.14	7.50	7.78	8.00	8.33	8.57	8.75	8.88	9.00
	B →	2.50	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00	50.00	60.00	70.00	80.00	90.00

TABLE 5

The Arithmetic of PROJECTION SYSTEMS

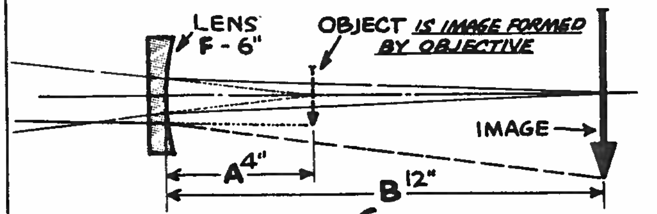
POSITIVE LENS PROJECTION



Example - 2x

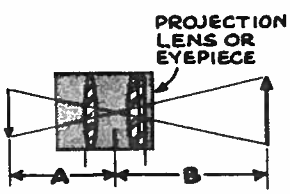
Formula No.		Example - 2x
1	$B = (M+1) \times F$	$B = (2+1) \times 4 = 3 \times 4 = 12''$
2	$B = \frac{F \times A}{A - F}$	$B = \frac{4 \times 6}{6 - 4} = \frac{24}{2} = 12''$
3	$B = A \times M$	$B = 6 \times 2 = 12''$
4	$A = \frac{B}{M}$	$A = \frac{12}{2} = 6''$
5	$A = \frac{F}{M} + F$	$A = \frac{4}{2} + 4 = 2 + 4 = 6''$
6	$A = \frac{F \times B}{B - F}$	$A = \frac{4 \times 12}{12 - 4} = \frac{48}{8} = 6''$
7	$M = \frac{B}{A}$	$M = \frac{12}{6} = 2x$
8	$M = \frac{F}{A - F}$	$M = \frac{4}{6 - 4} = \frac{4}{2} = 2x$
9	$M = \frac{B - F}{F}$	$M = \frac{12 - 4}{4} = \frac{8}{4} = 2x$
10	$F = \frac{A \times M}{M + 1}$	$F = \frac{6 \times 2}{2 + 1} = \frac{12}{3} = 4''$
11	$F = \frac{B}{M + 1}$	$F = \frac{12}{2 + 1} = \frac{12}{3} = 4''$
12	$F = \frac{A \times B}{A + B}$	$F = \frac{6 \times 12}{6 + 12} = \frac{72}{18} = 4''$

NEGATIVE LENS PROJECTION



Example - 3x

		Example - 3x
1	$B = (M-1) \times F$	$B = (3-1) \times 6 = 2 \times 6 = 12''$
2	$B = \frac{F \times A}{F - A}$	$B = \frac{6 \times 4}{6 - 4} = \frac{24}{2} = 12''$
3	$B = A \times M$	$B = 4 \times 3 = 12''$
4	$A = \frac{B}{M}$	$A = \frac{12}{3} = 4''$
5	$A = F - \frac{F}{M}$	$A = 6 - \frac{6}{3} = 6 - 2 = 4''$
6	$A = \frac{F \times B}{F + B}$	$A = \frac{6 \times 12}{6 + 12} = \frac{72}{18} = 4''$
7	$M = \frac{B}{A}$	$M = \frac{12}{4} = 3x$
8	$M = \frac{F}{F - A}$	$M = \frac{6}{6 - 4} = \frac{6}{2} = 3x$
9	$M = \frac{B + F}{F}$	$M = \frac{12 + 6}{6} = \frac{18}{6} = 3x$
10	$F = \frac{A \times M}{M - 1}$	$F = \frac{4 \times 3}{3 - 1} = \frac{12}{2} = 6''$
11	$F = \frac{B}{M - 1}$	$F = \frac{12}{3 - 1} = \frac{12}{2} = 6''$
12	$F = \frac{A \times B}{B - A}$	$F = \frac{4 \times 12}{12 - 4} = \frac{48}{8} = 6''$



FOR DOUBLE LENSES OR ANY TYPE OF EYE-PIECE, MEASURE FROM CENTER.
THIS IS NOT EXACT BUT CAUSES NO GREAT ERROR, ESPECIALLY AS APPLIED TO DIMENSION "B"

THE PROPER MEASURING POINTS FOR SPACING ARE THE PRINCIPAL PLANES OF THE LENS OR EYEPIECE

SYMBOLS:

M - *MAGNIFICATION OBTAINED BY PROJECTION*

F - *FOCAL LENGTH OF THE PROJECTION LENS OR EYEPIECE*

A - *DISTANCE FROM PROJECTION LENS TO OBJECT, THE "OBJECT" BEING THE PRIME IMAGE FORMED BY TELESCOPE OBJECTIVE*

B - *DISTANCE FROM THE PROJECTION LENS TO IMAGE, THE "IMAGE" BEING THE FINAL IMAGE, COINCIDENT WITH FILM PLANE*

Formula INDEX

IF YOU KNOW	YOU CAN FIND
F AND A	M.....8 B..... 2
F AND B	M.....9 A.....6
F AND M	A.....5 B..... 1
M AND A	F.....10 B.....3
M AND B	F.....11 A.... 4
A AND B	M....7 F.... 12

WHOLE TELE-Camera SYSTEM

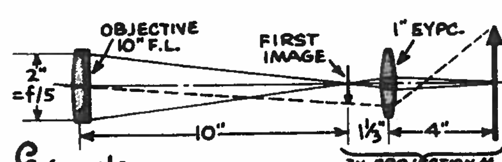
AFTER FINDING PROJECTION M, THE WHOLE SYSTEM CAN BE CALCULATED:

E.F.L. = F.L. OF OBJECTIVE × PROJECTION M

f/ = OBJECTIVE f/VALUE × PROJECTION M

f/ (ALTERNATE) = E.F.L. ÷ CLEAR DIA. OF OBJECTIVE

DIA. OF FIRST IMAGE = FILM DIAGONAL ÷ PROJECTION M

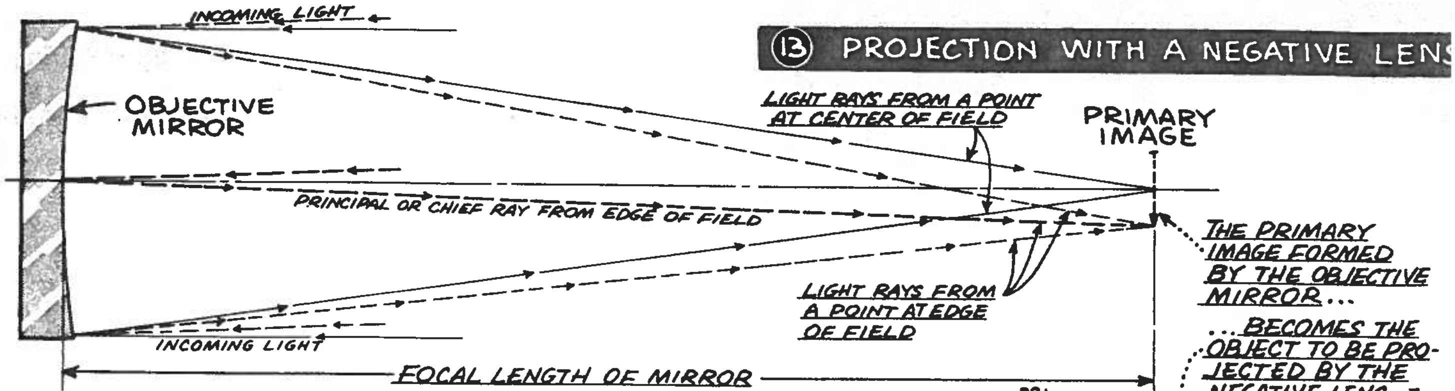


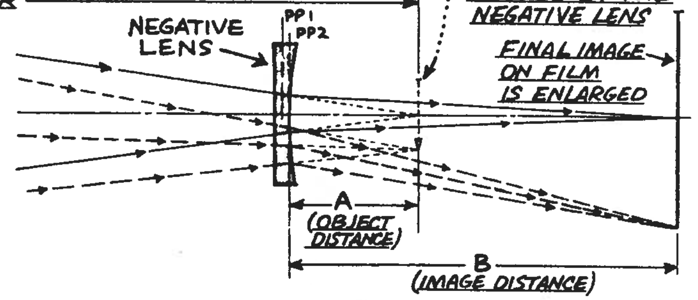
Example:

E.F.L. = 10 × 3 = 30" f/ (ALTERNATE) = 30 ÷ 2 = f/15

f/ = f/5 × 3 = f/15 FIRST IMAGE = $\frac{1.75}{3}$ = .58" FOR 35mm FILM

(13) PROJECTION WITH A NEGATIVE LENS





BASIC Calculations	Example: ASSUME YOU WANT 4x PROJECTION M. ASSUME F.L. OF NEG. LENS IS 2"
$B = (M-1) \times F$	$B = (4-1) \times 2 = 6"$
$A = \frac{B}{M}$	$A = \frac{6}{4} = 1.5"$

compactness, the lens being located inside the primary focus instead of outside as is the case for projection with a positive lens. Practically all of the big satellite tracking cameras and super telephoto lenses use some form of this optical system. As can be seen in Fig. 13, the primary image formed by the telescope objective becomes the object to be projected. It is, therefore, a virtual object, that is, it does not exist at all in reality but it is quite valid for diagrams and calculations. The whole range of lens movement from 1x magnification to infinite magnification is contained in one focal length, Fig. 14, as compared to two focal lengths for the positive lens projection system. It can be seen that the negative lens is located in a converging cone of light terminating at the primary image. To field this light cone, the lens must be a little larger than the primary image.

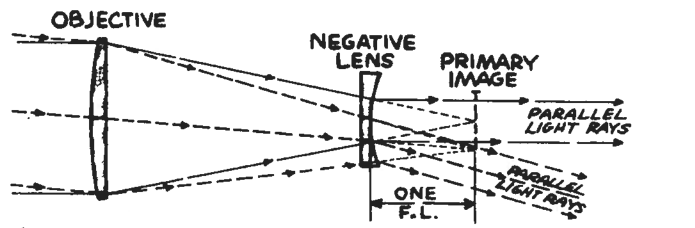
Good negative achromats--especially big ones--are hard to find because they have limited uses in optical instruments, and also because they can be fully corrected only for one specific application. Available lenses are usually designed for visual use in a telescope, working in an f/8 light cone at 2x magnification. All of which is to say that the linear field is limited to about 1/2 inch diameter; further, the lens will work best at 2x, although it will perform fairly well over a wide range of higher magnifications. The lenses

TABLE 4-A — OBJECT-IMAGE SPACING for EDMUND BARLOW LENSES

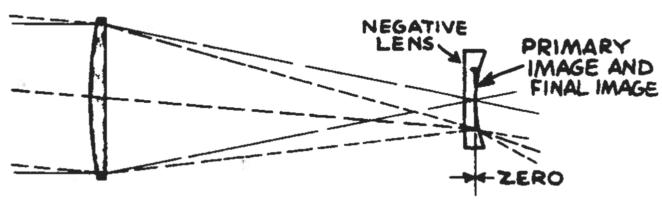
F.L.		Projection Magnification							
		1½x	2x	2½x	3x	3½x	4x	5x	6x
1.31" [A]	A→	.43"	.66"	.79"	.88"	.93"	.98"	1.05"	1.09"
	B→	.66	1.31	1.96	2.62	3.28	3.93	5.24	6.55
1.73" [B]	A→	.58	.86	1.04	1.15	1.23	1.30	1.38	1.44
	B→	.87	1.73	2.60	3.46	4.32	5.19	6.92	8.65
1.83" [C]	A→	.61	.92	1.10	1.23	1.30	1.37	1.46	1.52
	B→	.92	1.83	2.74	3.66	4.58	5.49	7.32	9.15
PRIMARY IMAGE DIA.*	→	1.17"	.87"	.70"	.58"	.50"	.44"	.35"	.29"

[A] SINGLE CROWN [B] GOODWIN ACHROMAT [C] EDMUND ACHROMAT

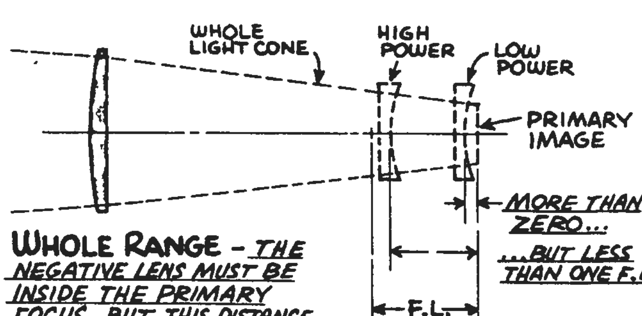
*for 35mm FILM



AFOCAL - EMERGENT RAYS DO NOT COME TO A FOCUS - NO IMAGE IS FORMED. THIS SPACING IS A GALILEAN TELESCOPE

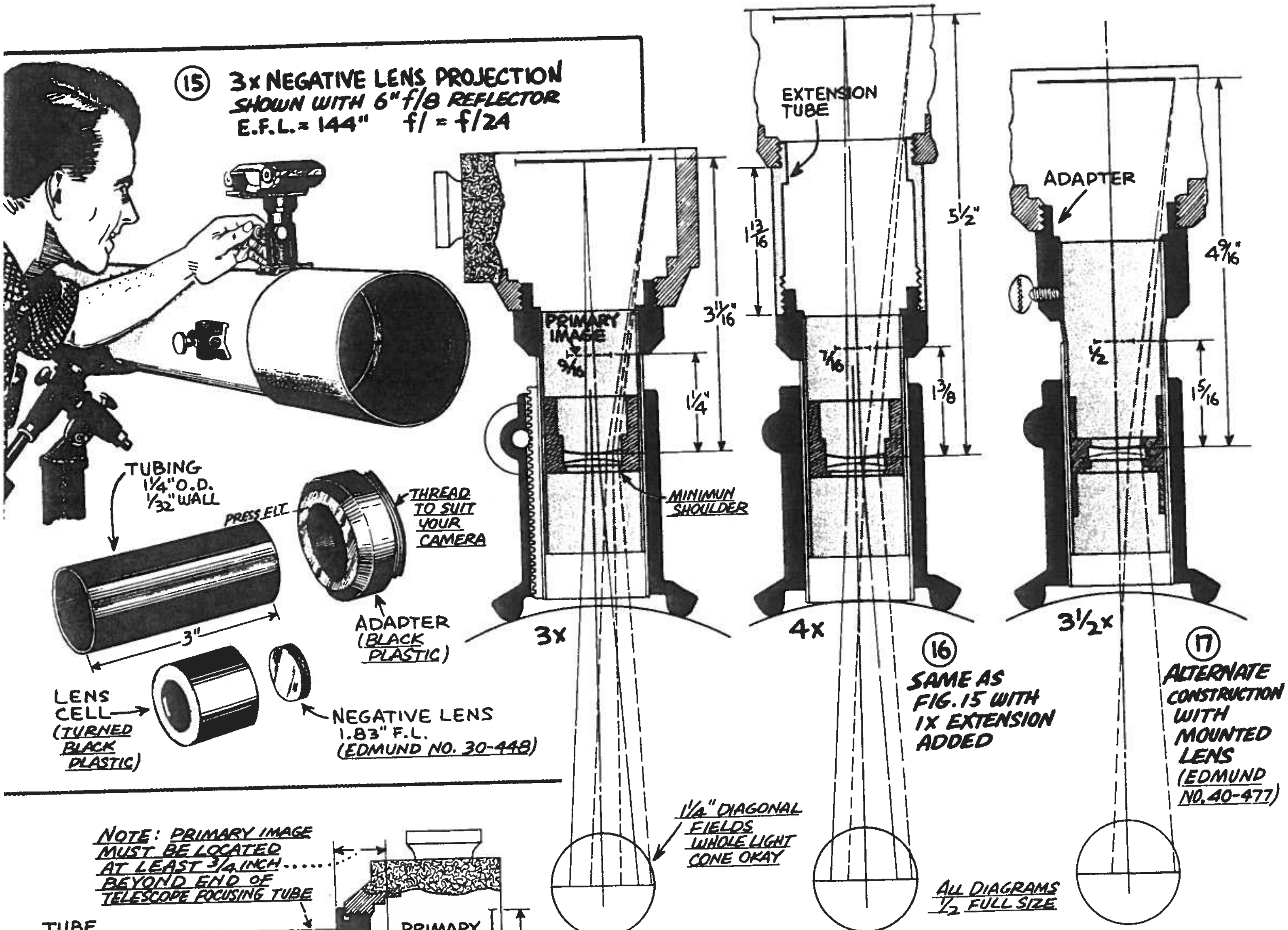


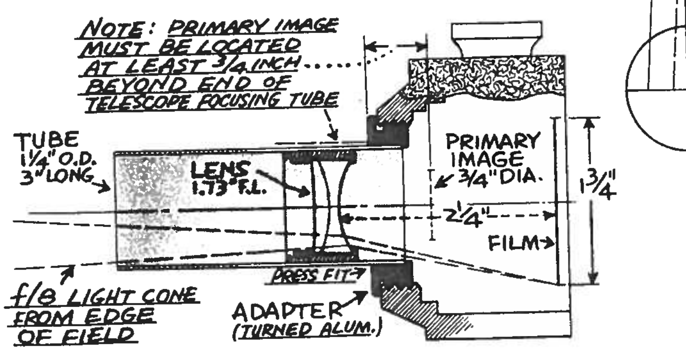
UNITY MAGNIFICATION (1x) - THE FINAL IMAGE COINCIDES WITH THE PRIMARY IMAGE - MAGNIFICATION IS UNITY OR SAME SIZE (1X)



WHOLE RANGE - THE NEGATIVE LENS MUST BE INSIDE THE PRIMARY FOCUS, BUT THIS DISTANCE MUST BE LESS THAN ONE FOCAL LENGTH

(14) SPACING LIMITS





(18) 2.3x WITH GOODWIN LENS (*from EDMUND NO. 60-122*)

are usually sold as "Barlow" lenses, named after Peter Barlow, English physicist and mathematician, first to use such a lens to increase the power of a telescope. Color-wise, the visual Barlow is perfectly satisfactory for photographic use. In fact, today's films have so nearly the same color response as the human eye, it can be said in general that any optical system that works well visually will perform equally well photographically over the same size of field.

Fig. 15 shows a 3x Barlow system mounted on a 6-inch reflector--note how compact it is compared to positive system, Fig. 11, of similar focal length and power. However, like the positive lens system, 1x additional magnification calls for an extension tube of one focal length, Fig. 16. The Edmund Barlow lens can also be purchased mounted and the whole unit used photographically, Fig. 17, requiring only an adapter. Unmounted, this lens is modestly priced at $3, and it works just as good as other more expensive Barlow lenses. It is too small for low power, but if you use 3x or more projection magnification, the lighting will be uniform to the corners of 35mm film. A 3x Barlow is often added to a finderscope for use as a tracking telescope.

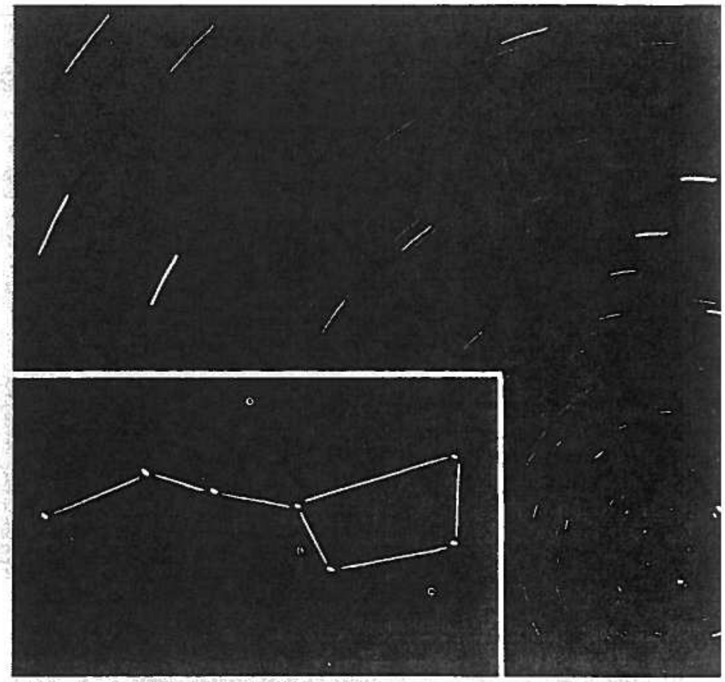
One of the larger of the visual Barlows is the Goodwin design, and this can be used down to 2.3x as shown in Fig. 18. This requires a shallow adapter, and even so you may have to shift the main mirror forward a little to put the primary image at least 3/4 inch beyond the end of the eyepiece holder. All optical systems should have dead black interiors, and this goes double for the Barlow because of the way the lens pitches the light rays outward after transmission.

STAR TRAILS

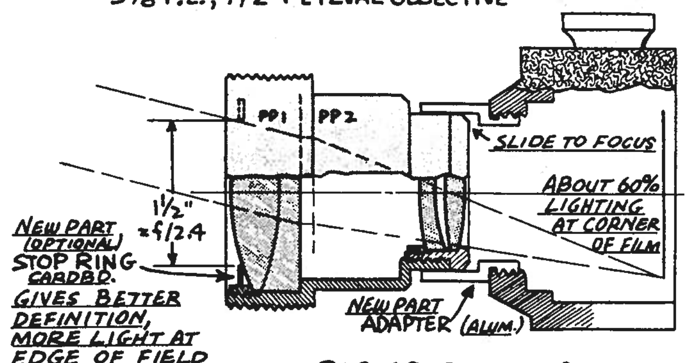
A STAR TRAIL is made by pointing any fixed camera at any part of the sky and exposing for 10 minutes or more. The stars, of course, keep moving right along, making a pattern of light streaks.

One common difficulty is field coverage. The average camera has a field of about 50 degrees. This means that if you center on Polaris, the half-field angle will reach down to about 65 N. declination, not quite reaching the Dipper. One way to capture the Dipper is by putting Polaris at one corner of the film, as shown in photo. This is a 25 min. exposure on 5x7 Tri-x film, using a 6-inch Metrogon lens at f/5.6. The bright streaks at top left are the Dipper stars.

Sky fog is another problem. Every minute you expose, the sky background becomes lighter. In 3 hrs. or so, sky fog may wash out the star trails. There is no simple solution to this except the obvious one that if you make a short exposure, the sky will stay black. The photo insert shows the Dipper stars as seen with a twin lens reflex working at f/4.5 with Tri-x film, the exposure being 2 minutes. Big star images were obtained by putting them slightly out of focus. One way to tackle sky fog is to make the trails brighter. This takes big aperture, such as the sniperscope objective shown in drawing.



3 5/8" F.L., f/2 PETZVAL OBJECTIVE



BIG APERTURE OBJECTIVE

STAR TRAIL Formulas	DECLINATION... EITHER NORTH OR SOUTH								
	0°	10°	20°	30°	40°	50°	60°	70°	80°
1 LENGTH OF STAR TRAIL (INCHES) FOR 1 MINUTE EXPOSURE TIME	F times .0044	F times .0043	F times .0041	F times .0038	F times .0033	F times .0028	F times .0022	F times .0015	F times .0008
for 1 SECOND EXPOSURE TIME	× .00007	× .00007	× .00007	× .00006	× .00006	× .00005	× .00004	× .00002	× .00001
2 LENGTH OF STAR TRAIL (INCHES) FOR ANY EXPOSURE (MINUTES)	$\frac{F \times Time}{229}$	$\frac{F \times T}{232}$	$\frac{F \times T}{244}$	$\frac{F \times T}{264}$	$\frac{F \times T}{300}$	$\frac{F \times T}{358}$	$\frac{F \times T}{458}$	$\frac{F \times T}{674}$	$\frac{F \times T}{1320}$
3 EXPOSURE TIME (MINUTES) NEEDED FOR A SPECIFIED STAR TRAIL LENGTH	$\frac{L \times 229}{F}$	$\frac{L \times 232}{F}$	$\frac{L \times 244}{F}$	$\frac{L \times 264}{F}$	$\frac{L \times 300}{F}$	$\frac{L \times 358}{F}$	$\frac{L \times 458}{F}$	$\frac{L \times 674}{F}$	$\frac{L \times 1320}{F}$
4 MAXIMUM EXPOSURE (SECONDS) WHICH WILL NOT SHOW A TRAIL BASED ON PERMISSIBLE MOVEMENT OF .004"	$\frac{55}{F}$	$\frac{56}{F}$	$\frac{59}{F}$	$\frac{63}{F}$	$\frac{72}{F}$	$\frac{86}{F}$	$\frac{110}{F}$	$\frac{162}{F}$	$\frac{316}{F}$

F... IS FOCAL LENGTH OR EQUIVALENT F.L. IF YOU PLAN TO ENLARGE, MULTIPLY F.L. BY ENLARGEMENT TO GET WHOLE PRINT E.F.L.

Example: YOUR CAMERA LENS IS 3" F.L. and YOU ARE USING 2x PROJECTION SYSTEM. YOU ALSO PLAN 3x ENLARGEMENT. SO, WHOLE PRINT E.F.L. = 3 × 2 × 3 = 18"

PROBLEM: YOU WANT 1½" (ON PRINT) STAR TRAILS FOR STARS ON EQUATOR. WHAT EXPOSURE IS NEEDED?

SOLUTION: FORMULA 3 EXPOSURE = $\frac{1.5 \times 229}{18} = \frac{343.5}{18} = 19.1$ MIN.

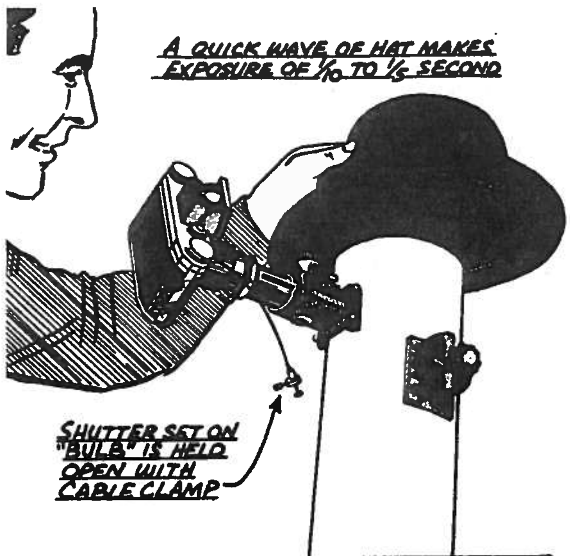
Example: YOU ARE SHOOTING STARS AT 40° N. DECLINATION WITH 6" F.L. LENS. PRINTS WILL BE ENLARGED 3X. (E.F.L. = 3×6 = 18")

PROBLEM: FIND MAX. EXPOSURE THAT WILL RETAIN ROUND STAR IMAGE

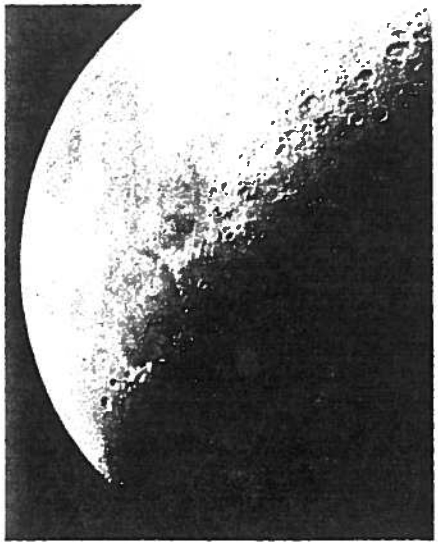
SOLUTION: FORMULA 4 $\frac{72}{18} = 4$ SECONDS

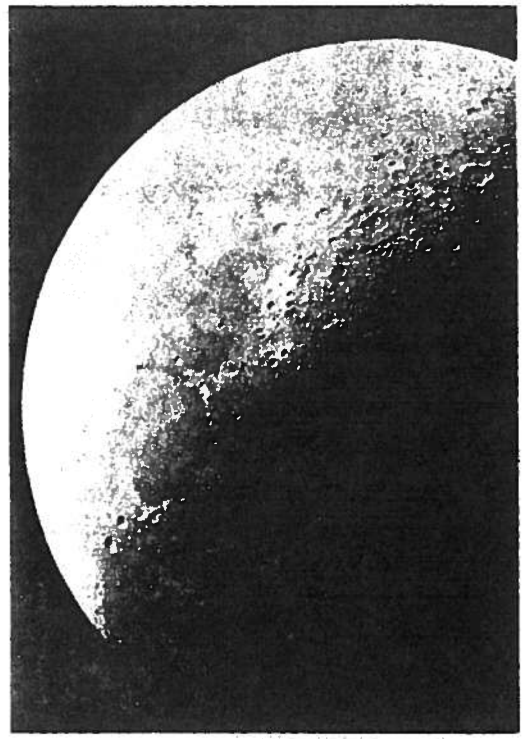
NOTE: TWO OR THREE TIMES THE SPECIFIED EXPOSURE WILL SHOW ONLY SLIGHT ELONGATION

FORMULA NO. 4 CAN BE USED FOR MOON PICS.... IF ON CLOCK DRIVE, USE FACTOR OF 1200 AND DIVIDE BY PRINT E.F.L.



AT TRICK" ELIMINATES MIRROR BOUNCE





shooting the MOON

6-DAY OLD MOON AS SEEN WITH 6-inch REFLECTOR. PANATOMIC-X FILM, FAST "HAT TRICK" EXPOSURE PICTURE AT RIGHT IS 3x BARLOW (GOODWIN) PROJECTION. PIC AT LEFT IS PROJECTION WITH 1-inch ORTHOSCOPIC EYEPIECE, ABOUT 2½x. DRUGSTORE PROCESSING OF 35MM FILM WITH 3X ENLARGEMENT. REPRODUCTION ABOUT FULL SIZE BUT CROPPED SLIGHTLY

BIGGEST, fastest, brightest object in the night sky, the moon is also the most photographed. Point your refractor or reflector her way on any clear night, and you are almost certain to get at least some kind of picture. Experts also give a look at the calendar because the moon "goes south" every month and when low in the sky may be a poor target. Follow the recommendations in table below. The sample pictures are not blue ribbon winners but are exactly the kind of pictures you will get the very first time out if you follow a few simple rules. The pics shown are all from 35mm film with drugstore processing, standard 3x enlargment; shown here full-scale but prints are cropped.

A few general rules on exposure will cover most situations. In general the full moon is simply a distant object, front-lighted by the sun. As such it takes about the same exposure as any distant land object in sunlight. The various phase pictures are no less bright at the limb (edge), but since you usually want shadow detail at the terminator, the average phase picture is exposed for the shadows, about 4 times the exposure of a full moon shot.

The full moon is most popular with beginners although it is a difficult object to photograph due to the flat lighting. The only really good cure for this is to use a high contrast film, such as High Contrast Copy or any of the various process films. High Contrast Copy was formerly known as Micro-file, and you will run across many full moon pics of bygone years taken with this film. High Contrast Copy film is a copy film intended for copying clippings, checks and other printed material; it is not intended for continu-

WHEN to shoot [1] **HOW to shoot**

PHASE	GOOD	FAIR		SUITABLE FILM	EXPOSURE [3]	REMARKS
FIRST QUARTER	JAN. thru JUNE MARCH is best	JULY thru DEC. SEPT. poorest	PHASE	PANATOMIC-X	1/10 SEC. AT f/16	USE FAST "HAT TRICK" EXPOSURE
				HI CONTRAST [2]	1 SEC. AT f/16	TELESCOPE PREFERABLY ON CLOCK DRIVE
LAST QUARTER	JULY thru DEC. OCT. is best	JAN. thru JUNE MARCH poorest		TRI-X	1/100 SEC. AT f/16	EXPOSURE BY SHUTTER OK FOR F.L. TO 100"
				PLUS-X	1/25 SEC. AT f/16	WIDE LATITUDE IN EXPOSURE TIME
FULL MOON	OCT. thru MAR. DECEMBER is best month	APRIL thru SEPT. JUNE poorest	FULL	HIGH CONTRAST COPY [2]	1/5 SEC. AT f/16	"HAT TRICK" EXPOSURE. USE CLOCK DRIVE IF YOU HAVE
				TRI-X	1/400 SEC. AT f/16	FAST EXPOSURE PERMITS USE OF SHUTTER. YEL. FILTER IMPROVES CONTRAST

[1] BASED ON ALTITUDE OF MOON ... HIGH MOON IS BEST

[2] FORMERLY MICRO-FILE. OTHER HIGH CONTRAST FILMS CAN BE USED

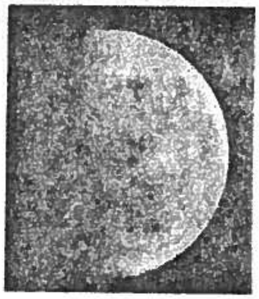
[3] SEE TABLE OF EQUIVALENT EXPOSURES FOR OTHER f/VALUES

MOON PICTURES AT FIRST FOCUS

ALL 3X ENLARGEMENTS FROM 35MM FILM, SHOWN FULL SCALE BUT CROPPED

3" REFRACTOR f/15 TRI-X K-2 FILTER

OVER-EXPOSED AT 1/25 SEC.



TOO THIN AT 1/500 SEC.

JUST RIGHT AT 1/50 SEC.

4¼" REFLECTOR TRI-X

1/200 SEC. AT f/11

6" REFLECTOR PLUS-X

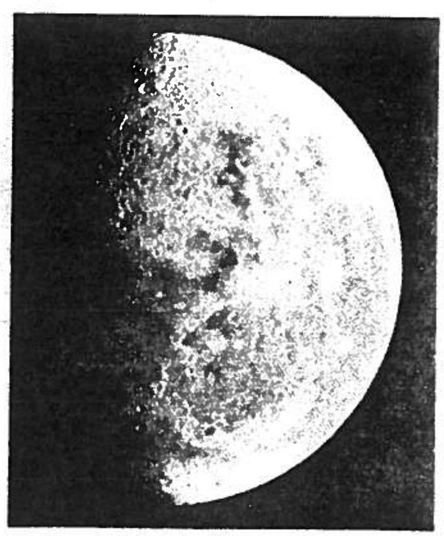
1/500 SEC. AT f/8

ous tone subjects at all, and hence has no ASA number applying to such situations. On the basis of comparative exposures, it can be rated at about ASA 5.

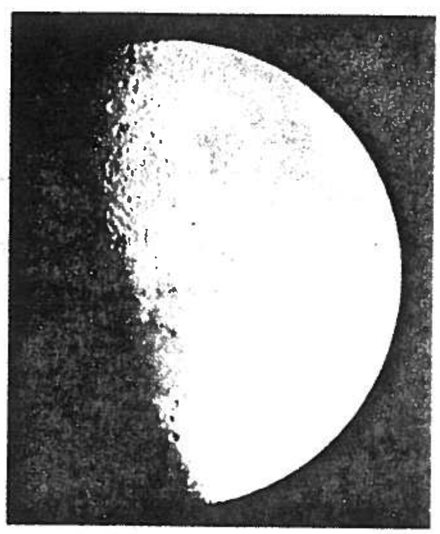
Many moon pics are not effective unless you capture the full diameter. This sets a limit to the focal length. Since the moon image is roughly 1/100 the focal length of telescope, and 35mm film is 1 inch wide, it can be seen that about 100 inches of focal length is the most you can squeeze into the 1 inch width of 35mm film. Actually since a little leeway is needed, 80 or 90 inches f.l. is about tops for a full moon picture. For a starter, the average stock refractor or reflector of about 50 inches focal length does nicely. The resulting pictures are interesting (see above) but hardly big enough to show detail. However, if you use a fine-grain film, enlargements to 20x are practical if the negative itself is sharp and clear.

For detail pictures, 2x projection is a popular starter. For such work it is often permissible to rotate the camera to put the terminator the long way of the film. With 2x projection and 3x enlargement, the print e.f.l. of a 6-inch reflector is 288 inches. You are getting up there where vibration of any kind - - even the snap of a focal plane shutter--will result in loss of definition at the image plane. A common cure for the shutter problem is the familiar "hat trick" exposure. This in turn poses the problem of the moon drifting out of the field during the interval between camera exposure and the actual "hat trick." However, with a little practice, this can be timed nicely. On clock drive, of course, this is no problem at all since the moon once centered will stay put as long as you like.

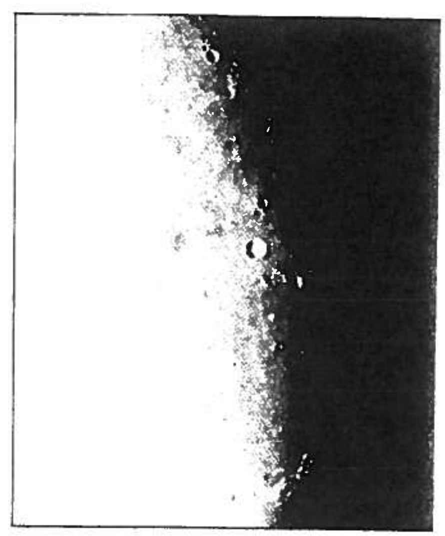
In general, without clock drive, the best technique is to use fast film in order to reduce exposure time to a minimum; if you use clock drive, longer "hat trick" exposures are practical, and you can make good use of the slower films which are usually somewhat better in graininess, resolution and contrast.



2x PROJECTION WITH 1¼" ERFLE EYEPIECE ON 3" EDMUND REFRACTOR. K-2 FILTER. TRI-X. 1/25 SEC. AT f/32

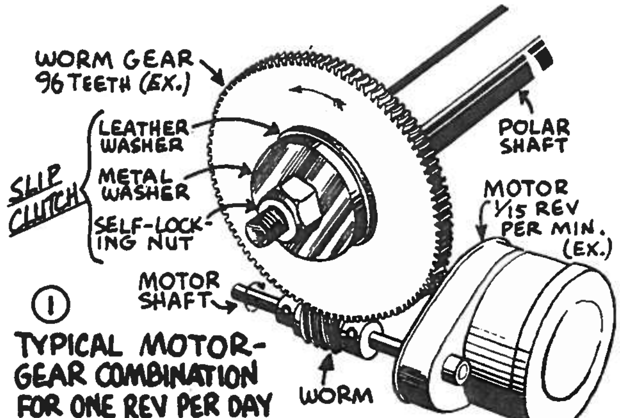


2X PROJECTION WITH 1¼" ERFLE EYEPIECE ON 4¼" REFLECTOR. PAN-ATOMIC-X. CAPPED EXPOSURE 1/5 SEC.



3x PROJECTION WITH EDMUND ACHROMATIC BARLOW ON 3" REFRACTOR. K-2, TRI-X. CAPPED EXPOSURE ABOUT 1/5 SEC.

The CLOCK DRIVE



① TYPICAL MOTOR-GEAR COMBINATION FOR ONE REV PER DAY

1/15 REV OF WORM IN 1 MIN. *TURNS* 1/15 TOOTH = 1/4°
1 REV OF WORM IN 15 MIN. *TURNS* 1 TOOTH = 3 3/4°
4 REVS OF WORM IN 1 HOUR *TURNS* 4 TEETH = 15°
96 REVS OF WORM IN 1 DAY (1440 MIN.) *TURNS* 96 TEETH = 360°
∴ IS 1 REV OF GEAR

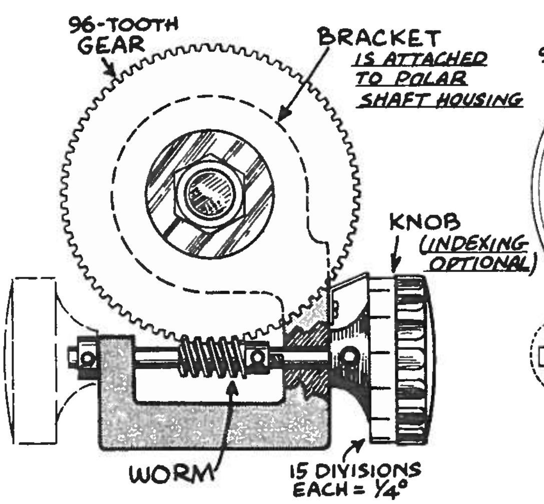
② VARIOUS MOTOR-GEAR COMBINATIONS FOR 1 REV PER DAY (ALL APPROX. 4 MINUTES SLOWER THAN SIDEREAL RATE)

MOTOR REVS PER MINUTE	TIME TO TURN WORM 1 REV	NUMBER OF TEETH TURNED IN 1440 MIN.	ANGULAR MOVEMENT PER TOOTH	NEAREST FAST DRIVE: NUMBER OF TEETH	DRIVE RATE VARIATION
1/2	2 MIN.	1440/2 = 720	1/2°	718	EXACT
1/4	4 MIN.	1440/4 = 360	1°	359	EXACT
1/5	5 MIN.	1440/5 = 288	1 1/4°	287	1 M. FAST
1/6	6 MIN.	1440/6 = 240	1 1/2°	239	2 M. FAST
2/15	7 1/2 MIN.	1440/7.5 = 192	1 7/8°	191	3 1/2 M. FAST
1/8	8 MIN.	1440/8 = 180	2°	179	4 M. FAST
1/10	10 MIN.	1440/10 = 144	2 1/2°	143	6 M. FAST
1/12	12 MIN.	1440/12 = 120	3°	119	8 M. FAST
EXAMPLE ABOVE 1/15	15 MIN.	1440/15 = 96	3 3/4°	95	11 M. FAST
1/20	20 MIN.	1440/20 = 72	5°	71	16 M. FAST
1/24	24 MIN.	1440/24 = 60	6°	59	20 M. FAST
1/30	30 MIN.	1440/30 = 48	7 1/2°	47	26 M. FAST
1/40	40 MIN.	1440/40 = 36	10°	35	36 M. FAST
1/45	45 MIN.	1440/45 = 32	11 1/4°	31	41 M. FAST
1/48	48 MIN.	1440/48 = 30	12°	29	44 M. FAST PER DAY

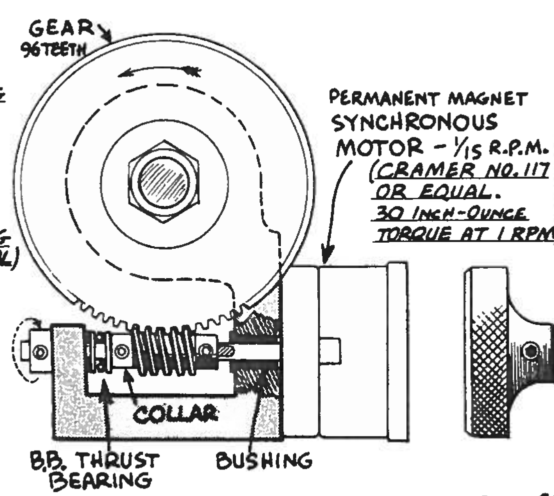
VARIOUS motor-gear combinations can be used to maintain the one-rev-per-day pace of the stars. In general, the more teeth in the worm gear, the more accurate and smoother the drive will be. At the same time, a big gear is out of place on a small telescope, making the 96-tooth worm gear of about 3 inches diameter a practical choice. This automatically fixes the motor speed, which can be none other than 1/15 r.p.m. to get the desired 1 rev per day.

Synchronous motors run on standard solar time. As you may know, the stars travel a little faster, making one revolution in 23 hours, 56 minutes of solar time. In other words, the motor runs slow--the telescope lags the stars by about 4 minutes per day. In actual practice, this is not an inconvenience. Even with an exact sidereal clock, the drive can never be truly exact if for no other reason than refraction by the earth's atmosphere which changes the apparent position of stars, and hence the driving rate. If an exact drive rate is required--as in photography--it is necessary to add hand guiding to the clock drive. Obviously, as long as you have to guide, it is just as easy to guide the little bit extra to correct the lag in the conventional drive. If you are curious about a drive faster than the sidereal rate, the right hand side of Fig. 2 table gives the nearest approach. Of course most of the odd-tooth gears are not available.

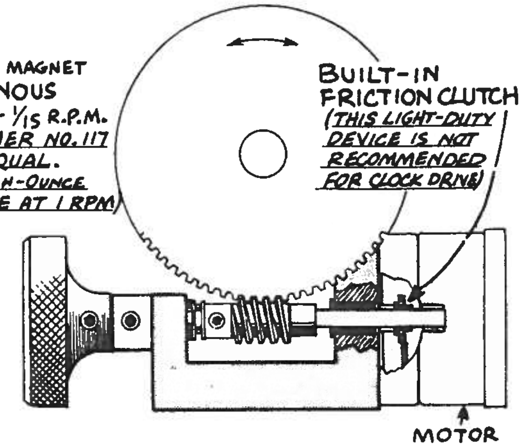
The same gearing used for a clock drive is often used for a manual drive, Fig. 3. The motorized drive is just a matter of adding the motor, Fig. 4. Many amateurs get the happy idea of a



③ MANUAL SLOW-MOTION



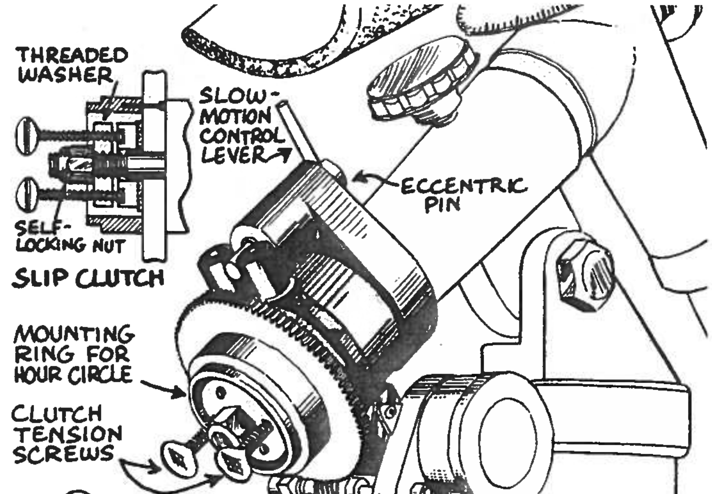
④ CLOCK DRIVE



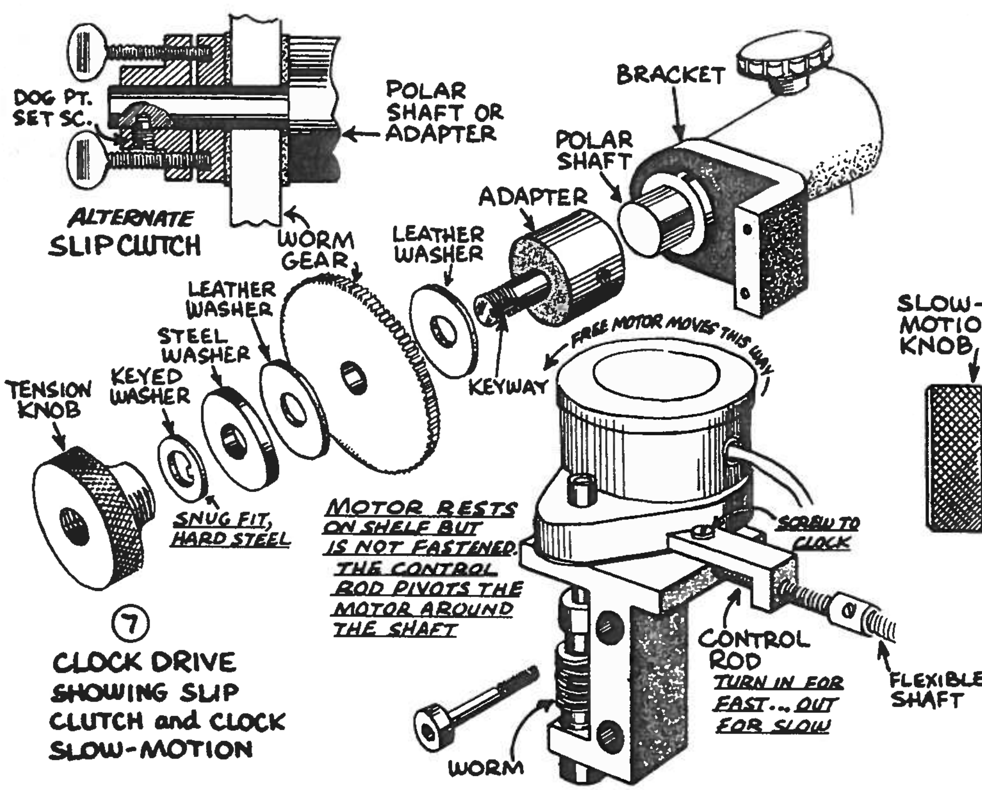
⑤ COMBINATION MANUAL SLOW-MOTION and CLOCK DRIVE manual drive and a clock drive, all on the same shaft, Fig. 5. You can see this needs a clutch between worm and motor, and an apparent solution to this is the built-in friction clutch which motor manufacturers supply for about 25¢ extra. However, your luck runs out at this point because the built-in clutch is seldom husky enough to stand the continual twisting of the manual drive. The end result is a clutch so worn the motor will not drive the telescope at all. A two-way drive of this kind is practical with an external adjustable friction clutch, preferably with a quick-action disengagement control.

CLOCK SLOW-MOTION. Among amateur builders, favorite way of getting a slow-motion on the clock itself is to remove the mounting bolts from the clock motor and let it "float," controlled by a threaded rod, Fig. 7. In another system, Fig. 8, the motor and worm are moved as a unit. 1/8 inch travel is plenty for the purpose, which is only to correct the driving rate. Fig. 6 is a refinement of this idea, with the clock and worm again as a unit, but rotating around the polar axis. The slow-motion in this example is supplied by an eccentric cam operated by a lever.

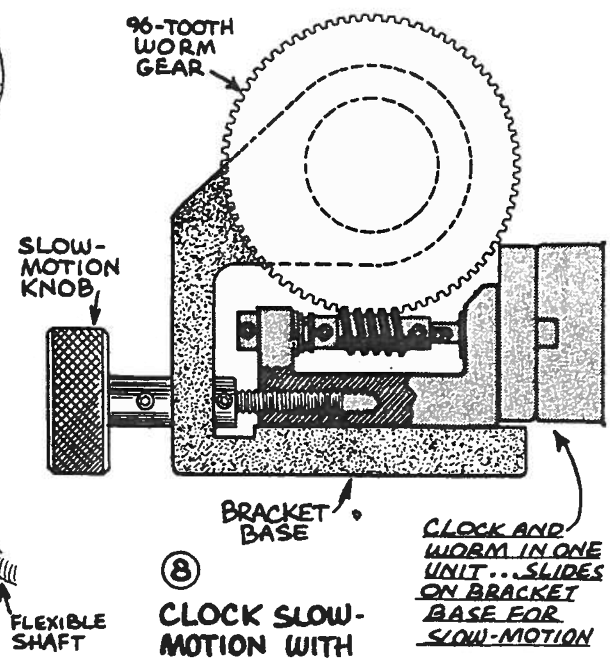
SLIP CLUTCH. A slip or friction clutch must supply enough tension to drive the telescope, and yet must be loose enough to allow easy manipulation of the scope by hand. A common solution is simply a self-locking nut, Fig. 1. Better but more expensive is the keyed washer method shown in Fig. 7. The alternate detail shows a clutch with a backstop ring fastened to the shaft with a dog point set screw. The actual friction pressure comes from two thumb screws. This is a good slip clutch, offering any desired degree of friction with quick, easy release. The same idea is shown in Fig. 6 except the fixed backstop consists of a self-locking nut screwed tightly against a threaded washer. In all cases the tension knob or nut must turn with the polar shaft to keep from "winding-up" when the telescope is moved. If the nut stands still--its natural tendency--the friction will tighten when the scope is moved to the west, and loosen when scope is moved to the east.



⑥ CLOCK DRIVE ON HEAVY-DUTY MOUNT

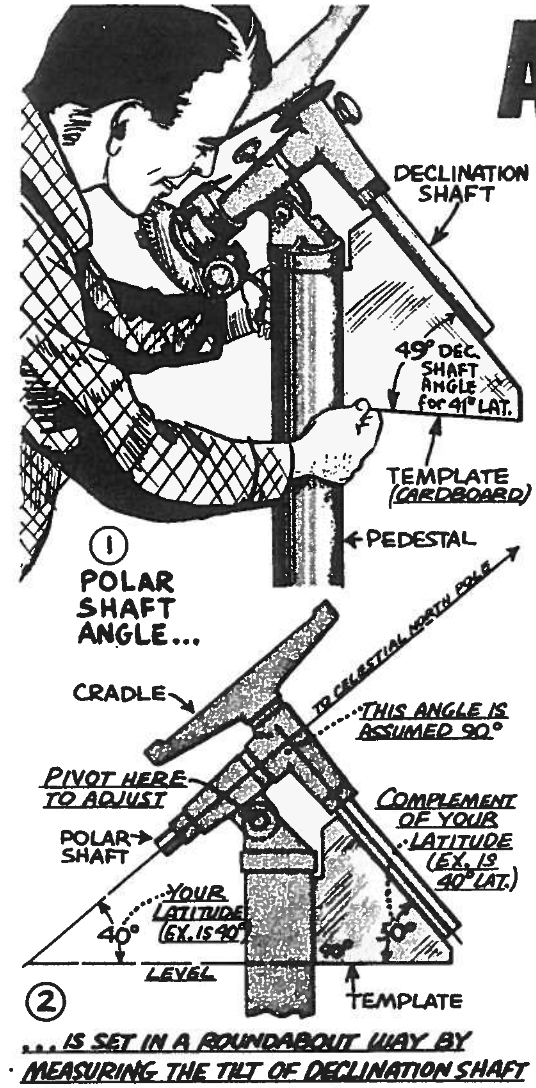


⑦ CLOCK DRIVE SHOWING SLIP CLUTCH and CLOCK SLOW-MOTION



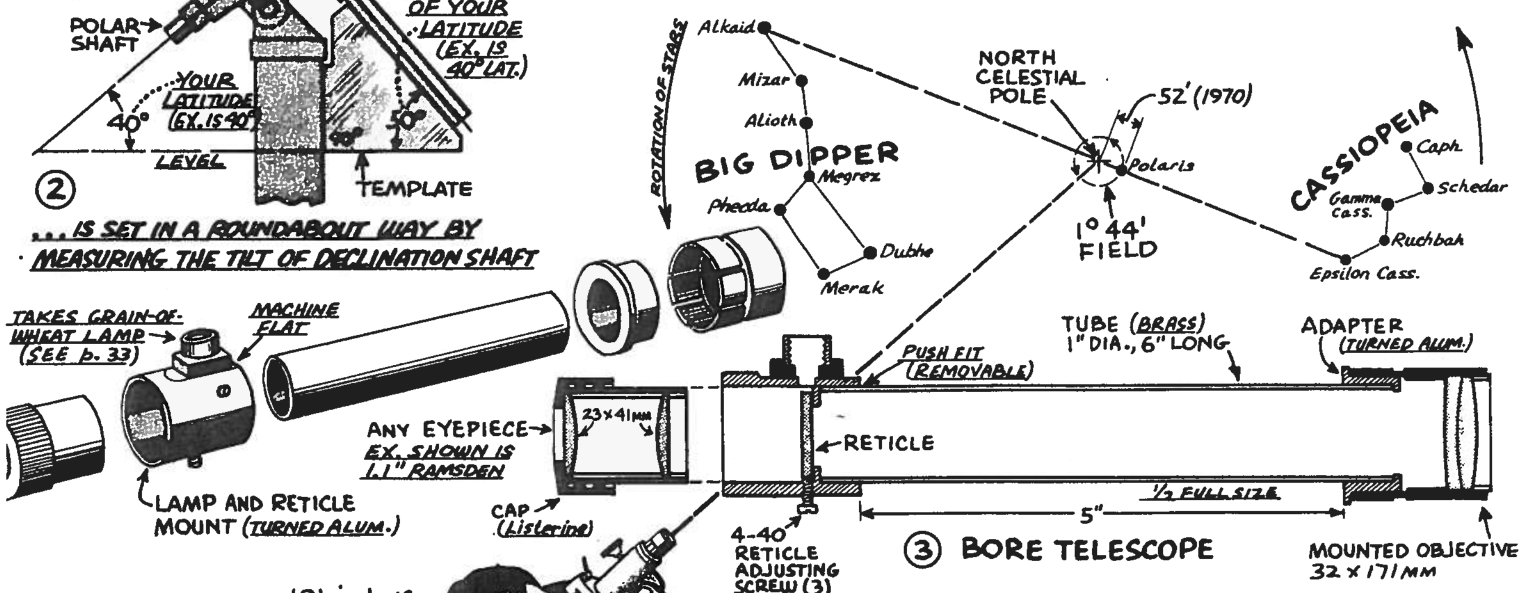
⑧ CLOCK SLOW-MOTION WITH SLIDING WORM

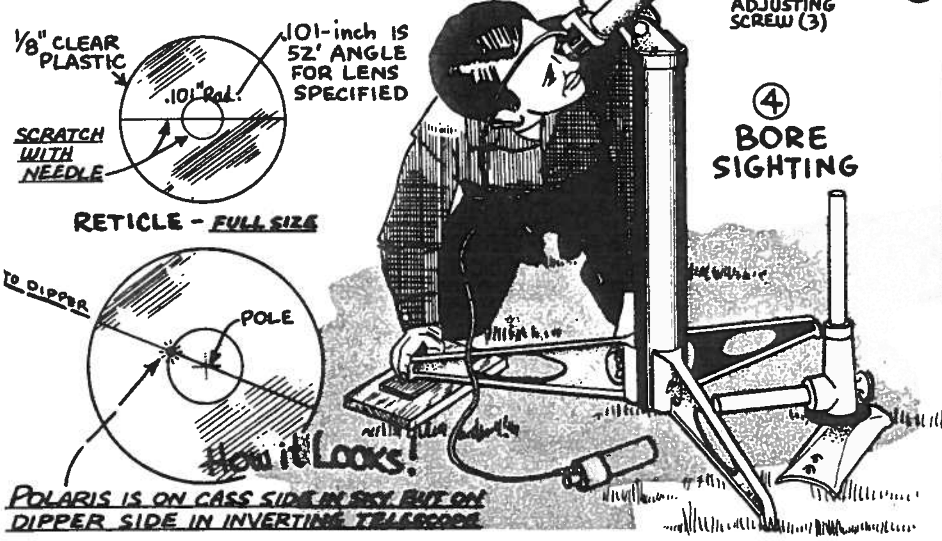
Adjustment to POLE

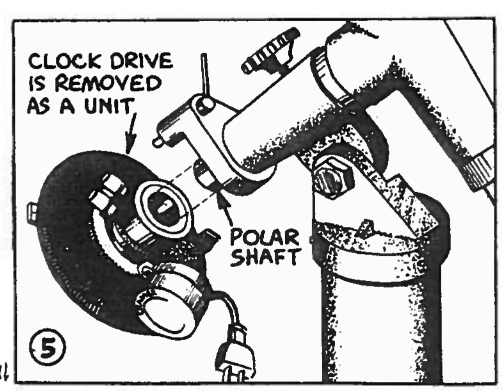


THE FIRST adjustment in setting up any equatorial mount is to set the polar shaft at the same angle as the latitude of your location. When this is done, the polar shaft will point to the same height above the horizon as the celestial north pole itself. This adjustment can be made indoors, using such levels, protractors, etc. as may be available. If you have a pedestal mount, one of the simplest methods is to measure the angle between pedestal and declination shaft, as shown in Figs. 1 and 2. Assuming you use your mount with single leg pointing south, the preferable polar shaft tilt is a half-degree or so higher than your latitude. Outdoors, you then adjust exactly to the pole with shims under the south leg.

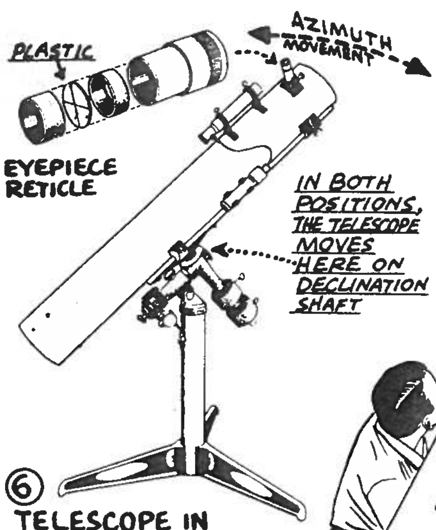
BORE SIGHTING. The simple, direct way to get the polar shaft pointing exactly to the pole is to sight right through the bore of the polar shaft housing. This is not a practical method with many mounts because of the numerous parts



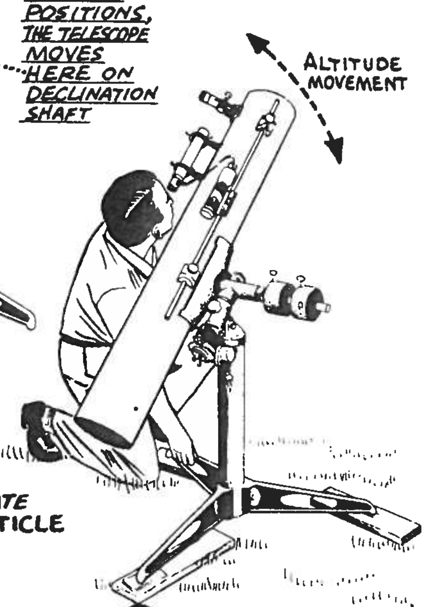




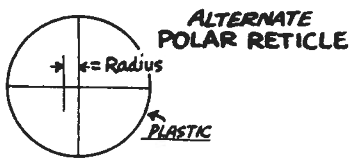
BORE SIGHTING IS PRACTICAL ONLY IF THE CLOCK DRIVE IS EASY TO REMOVE
EDMUND DRIVE SHOWN IS SELF-CONTAINED, EASY TO REMOVE BY LOOSENING SET SCREWS



⑥ TELESCOPE IN "TOP" POSITION CAN MOVE IN AZIMUTH BUT IS FIXED IN ALTITUDE



⑦ TELESCOPE IN "SIDE" POSITION CAN BE MOVED UP AND DOWN IN ALTITUDE-- IS FIXED IN AZIMUTH



MULTIPLY FOCAL LENGTH OF BORE SCOPE OR FINDER OBJECTIVE LENS BY .015 TO GET RADIUS OF RETICLE CIRCLE

that must be removed piecemeal. With some mounts, however the whole drive can be removed by loosening two set screws. Of course, to sight through the bore, you need a bore telescope, Fig. 3. The reticle is checked for alignment by rotating the assembled telescope on vee blocks while looking at a distant target or Polaris or any collimator target.

Fig. 4 shows the bore sight being made. The illuminated reticle is helpful but not essential since it is practical to work at dusk or in moonlight when an ordinary non-illuminated reticle is easily visible against the luminous sky. Get Polaris in the field and then by shifting and shimming the base of the mount, put Polaris on the reticle circle and at the same angle as your reference star, which can be either Alkaid in the Dipper or Epsilon in Cassiopeia. If desired you can turn either the bore telescope or the reticle holder to make the reticle line assume the same angle as the reference star, Fig. 4.

POLE ADJUSTMENT WITH FINDERSCOPE. A finderscope can be used in the same manner as the borescope. The catch to this operation is that the finderscope itself must first be adjusted parallel with the polar axis, immediately after which you can set to the pole. With practice, you can do this in 15 minutes--but not the first time!

An additional step is the adjustment of the main telescope parallel with the polar shaft. This extra operation is sometimes by-passed, that is, you simply assume the main telescope is parallel with the polar shaft, which it very nearly is in most cases.

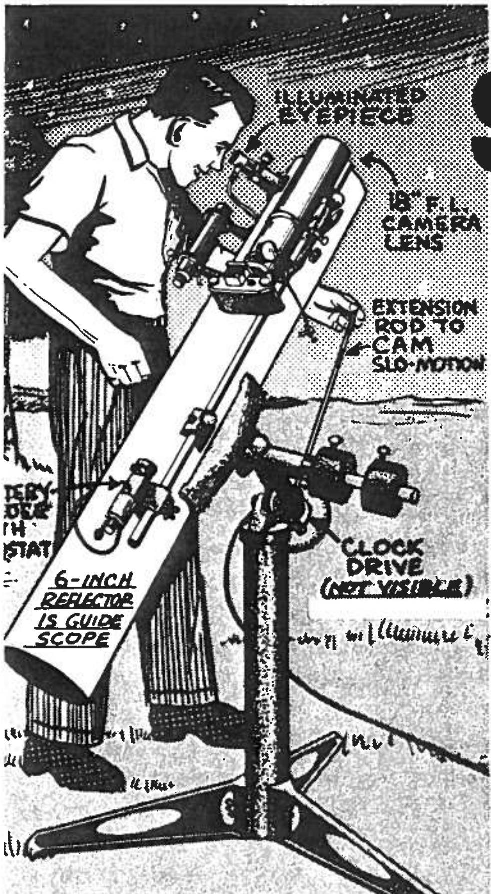
Start by pointing the telescope north. Have the tube in "top" position, Fig. 6. Get Polaris in the field of the main telescope, which should be fitted with a crossline reticle. A slight movement in azimuth around the declination shaft is permissible. Centering of Polaris in altitude must be done by shimming one or more legs of the mount.

Now, put the telescope in "side" position on west side of tripod, like Fig. 7 except the initial sighting is being done with main telescope. Again, center Polaris. Remember the altitude of the mount is already set--do not disturb. However, it is permissible to move the telescope slightly in altitude by movement around the declination shaft. Any needed movement in azimuth must be made by pushing the whole telescope base around in the needed direction.

Polaris is now exactly in the center of the field of the main telescope, splitting the crosshairs. The scope is on west side of pedestal. At this point you can check the parallelism of the telescope with the polar axis by rolling the telescope to opposite (east) side of pedestal, where it should again center on Polaris after slight adjustment, if needed, in altitude only, by movement around the dec shaft. Any appreciable error in azimuth should be corrected with a slip of thin cardboard pasted to the main tube at the point where it contacts the cradle.

Return the telescope to west side of pedestal. All that you have done up to now is to center the main telescope on Polaris. Lock both shafts. Adjust the finderscope to center on Polaris by means of the adjusting screws. This is a simple operation. You now have the finderscope parallel with the main telescope and the main telescope is parallel (or nearly so) with the polar shaft. The job of setting the finder parallel with the main telescope need not be repeated unless you change the position of the main mirror.

The situation now is that the finderscope is centered exactly on Polaris. What you want is the pole itself on center, and this will be so if you off-center Polaris on the finderscope reticle. Lock both shafts securely; the slight movement you have to make must be done by shimming one or more legs (altitude adjustment) and by shifting the mount bodily (azimuth adjustment), as shown in Fig. 7.



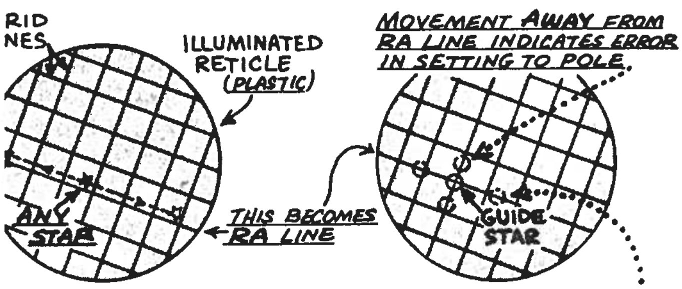
A TYPICAL SETUP FOR ASTRO-PHOTOGRAPHY

SHOOTING THE STARS

SHOOTING pictures of the stars is probably the most fascinating phase of astro photography. Objects which you see dimly or not at all are revealed clearly in time exposures. Picture-taking equipment need not be expensive; you can get nice image quality with ordinary achromats as objectives. The one "must" in equipment is a clock drive, plus a compensating slow-motion on the clock drive itself. You will hear tales of star shooters getting good pics using ordinary manual guiding of the telescope, but such feats are never enjoyable and are rarely repeated.

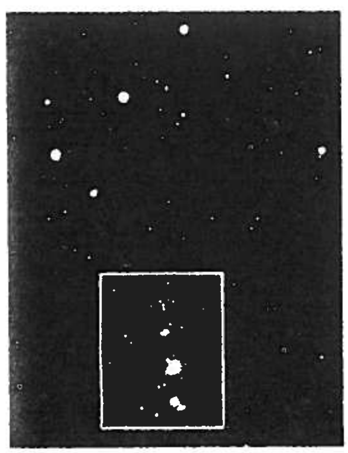
GUIDING. Star pictures require time exposures from 1 minute to 30 minutes or more. During the exposure period, the telescope must be guided. This is a continuous operation, somewhat like steering a car down a road where you keep on the right track with dozens of almost imperceptible movements of the steering wheel. Many beginners get the idea that the clock motor drives the telescope automatically. To a degree, it does, but not with the exact precision needed for taking pictures.

In the usual "starter" outfit, you will be shooting with a camera of modest focal length, using the telescope itself as a guide telescope, Fig. 1. An illuminated, grid-type reticle is an aid since it is



) ORIENTATION OF RETICLE
MOVE TELESCOPE IN R.A. AND ROTATE EYEPIECE TO MAKE GRID LINES FOLLOW THE STAR

③ MOVEMENT OF GUIDE STAR
ANY MOVEMENT ALONG THE RA LINE IS A DRIVE ERROR WHICH YOU CAN CORRECT WITH SLOW-MOTION CONTROL



ORION. 5 MIN. EXPOSURE ON TRI-X WITH 6" F.L. LENS

18" F.L. CAMERA LENS GIVES A CLOSER VIEW OF NEB M42. 30 MIN. EXP. SHOWS FAINT STARS

HOW TO FIND ④

GUIDING TOLERANCE

YOU START WITH THE GENERAL IDEA THAT A STAR MOVEMENT OF .003" (1/333") IN ANY DIRECTION FROM CENTER OF STAR IMAGE WILL BE PRACTICALLY INVISIBLE IN A PHOTO PRINT

FOLLOW THESE RULES:

PRINT E.F.L. = F.L. CAMERA × PT. ENLARGEMENT

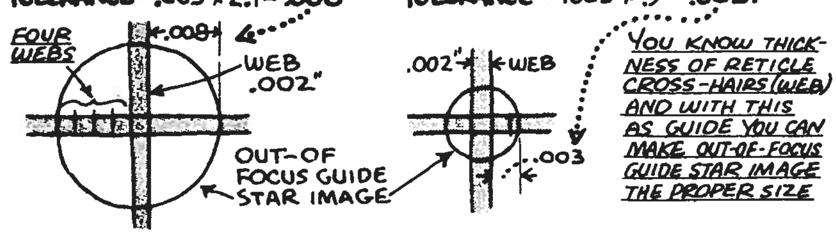
GUIDE SCOPE M. = $\frac{\text{GUIDE SCOPE E.F.L.}}{\text{PRINT E.F.L.}}$

GUIDING TOLERANCE = .003 × GUIDE SCOPE M.

Calculations for GUIDING TOLERANCE

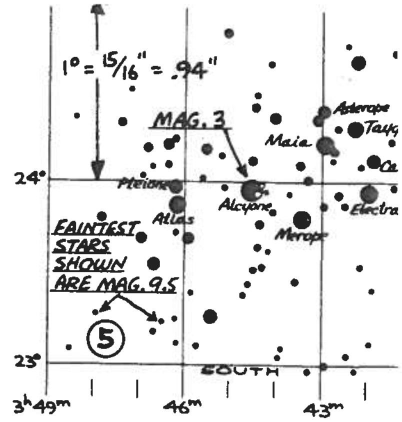
6" TIMES 3X	18" TIMES 3X
PRINT E.F.L. = 18"	PRINT E.F.L. = 54"
GUIDE SCOPE M. = $\frac{48}{18}$ = 2.7X	GUIDE SCOPE M. = $\frac{48}{54}$ = .89X
TOLERANCE = .003 × 2.7 = .008"	TOLERANCE = .003 × .9 = .0027"

(6" REFLECTOR)

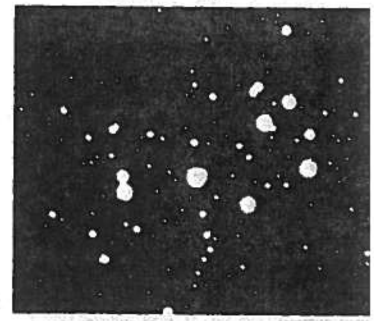


easily visible and allows you to position the guide star at any of the multiple intersections of cross lines. Do some practice guiding before attempting actual shooting. Pick up any bright star and locate it near the center of field. Now, move the telescope back and forth by hand in RA only and note the movement of the star. Rotate the eyepiece to make any reticle grid line parallel with this movement, as shown in Fig. 2. Fix in your mind that this is the RA line. Any movement of the guide star along the RA line, Fig. 3, means the drive is too fast or too slow, and you can correct this with the compensating slow-motion. Any movement away from the RA line means an error in setting the telescope to the pole. The ideal way to correct such an error is to have a slow-motion on the declination shaft. Lacking this you can sometimes get the needed correction by moving the telescope in declination by hand, preferably stopping the exposure while doing this and resuming exposure after the guide star is seen to be riding right on the wire. The drift away from the RA line is always a slow, steady movement, always one way, requiring correction at long intervals. The preferable way to solve declination drift is by accurate setting to the pole position; if the polar axis of your telescope is no more than 1/2 degree off the pole, you can make exposures up to 30 minutes without appreciable elongation of the star images.

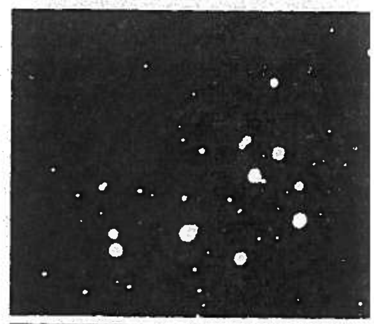
Practice until you can guide smoothly, never once letting the bead off the wire. Actually, the way the guiding tolerance is applied, you do not let the out-of-focus guide star encroach on the reticle line; a crossover is a definite guiding error in excess of the permissible tolerance. The guiding tolerance is about .003 inch as applied to a photo print viewed at a distance of 10 inches, this being about the limit of visual acuity, corresponding to about 1 minute of arc. Fig 4 explains how this tolerance

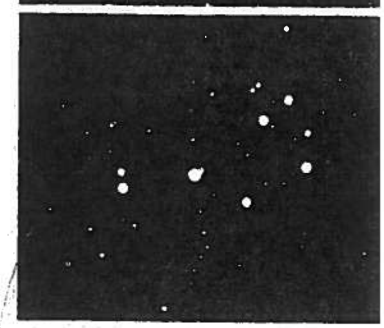


THE PLEIADES. PICS BELOW WITH 18" F.L., 2¼" DIA. ACHROM 35mm TRI-X. PRINTS ENLARGED AND SHOWN HERE FULL-SIZE BUT CROPPED ABOUT 50%



↑ 30 MIN. EXPOSURE ↓ 12 M





↑ 3 MIN. ↓ 1 MI

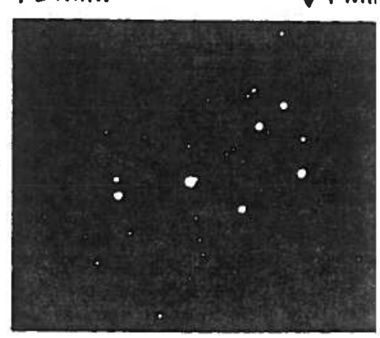
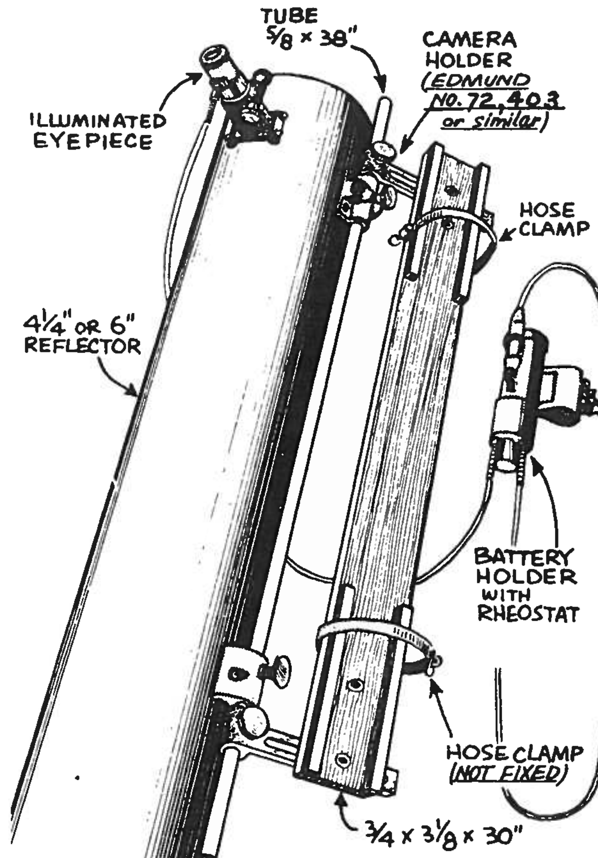


TABLE 6 — MAGNITUDE of Faintest Star

APERTURE (CAMERA OR TELESCOPE)	VISUAL WITH TELESCOPE	NORMAL PHOTOGRAPHIC RANGE — EXPOSURE TIME					FOG LIMIT		
		1 MIN.	3 MIN.	9 MIN.	27 MIN.	81 MIN.	f/3	f/5	f/7
½"	7.3	4.5	5.5	6.6	7.6	8.6	10.7	11.4	12.0
¾"	8.2	5.4	6.4	7.4	8.5	9.5	11.4	12.3	13.0
1"	8.8	6.0	7.0	8.0	9.1	10.1	12.0	12.9	13.5
1¼"	9.3	6.5	7.5	8.5	9.6	10.6	12.4	13.5	14.0
1½"	9.7	6.9	7.9	8.9	10.0	11.0	12.8	13.9	14.4
1¾"	10.0	7.2	8.2	9.3	10.3	11.3	13.2	14.2	14.8
2"	10.3	7.5	8.5	9.6	10.6	11.6	13.5	14.5	15.1
3"	11.2	8.4	9.4	10.4	11.5	12.5	14.4	15.4	16.0
4"	11.8	9.0	10.1	11.1	12.1	13.2	15.1	16.0	16.6
5"	12.3	9.5	10.5	11.5	12.6	13.6	15.7	16.6	17.1
6"	12.7	9.9	10.9	11.9	13.0	14.0	16.1	17.0	17.4
8"	13.3	10.5	11.5	12.6	13.6	14.6	16.6	17.4	17.9
10"	13.8	11.0	12.0	13.1	14.1	15.1	16.8	17.7	18.1
12"	14.2	11.4	12.4	13.4	14.5	15.5	17.0	17.9	18.3
	BASED ON ABILITY OF NAKED EYE TO SEE MAG. 6.2	FOR AVERAGE FILMS AND CLEAR ATMOSPHERE. WITH VERY FAST FILM AND "GOOD SEEING," YOU MAY GAIN ONE OR TWO MAGNITUDES FAINTER					EXPOSURE TIME LIMIT IS REACHED WHEN SKY BACKGROUND BECOMES NEARLY AS BRIGHT AS STAR IMAGES		

⑥ CONVERSION OF PLATE SCALE TO E.F.L.*		
SCALE GIVEN	Formula for E.F.L.	Examples
SECONDS OF ARC PER MILLIMETER	E.F.L. (inches) = $\frac{8127}{\text{SEC. OF ARC PER MM}}$	EX: 1100 SEC. PER MM E.F.L. = $\frac{8127}{1100}$ = 7.4" (inches)
INCHES PER DEGREE	E.F.L. (inches) = LINEAR SIZE OF 1° IN INCHES × 57.3	EX: 1° = .13" (inches) E.F.L. = .13 × 57.3 = 7.45" (inches)
...to FIND PLATE SCALE WHEN E.F.L. IS KNOWN		
You WANT TO FIND	FORMULA	Example (AS ABOVE)
PLATE SCALE IN SEC. OF ARC PER MM.	SEC. OF ARC PER MM = $\frac{8127}{\text{E.F.L. (inch)}}$	$\frac{8127}{7.4}$ = 1100" (Seconds)
PLATE SCALE IN INCHES PER DEGREE	INCHES PER DEGREE = $\frac{\text{E.F.L.}}{57.3}$	$\frac{7.45}{57.3}$ = .13" (Inches)
PLATE SCALE OF SOME POPULAR MAPS		
MAP OR ATLAS	PLATE SCALE (ALL APPROX.)	Corresponding E.F.L.*
NORTON'S STAR ATLAS	1° = .13 inch	.13 × 57.3 = 7.45"
BECVAR SKALNATE PLESO ATLAS OF THE HEAVENS	1° = .3 inch	.3 × 57.3 = 17.19"
BECVAR ATLAS ECLIPTICALIS	1° = .8 inch	.8 × 57.3 = 45.85"
VEHRENBERG PHOTOGRAPHIC STAR ATLAS	1° = .6 inch	.6 × 57.3 = 34.38"

* E.F.L. CAN BE ANY COMBINATION OF CAMERA F.L. times PRINT ENLARGEMENT



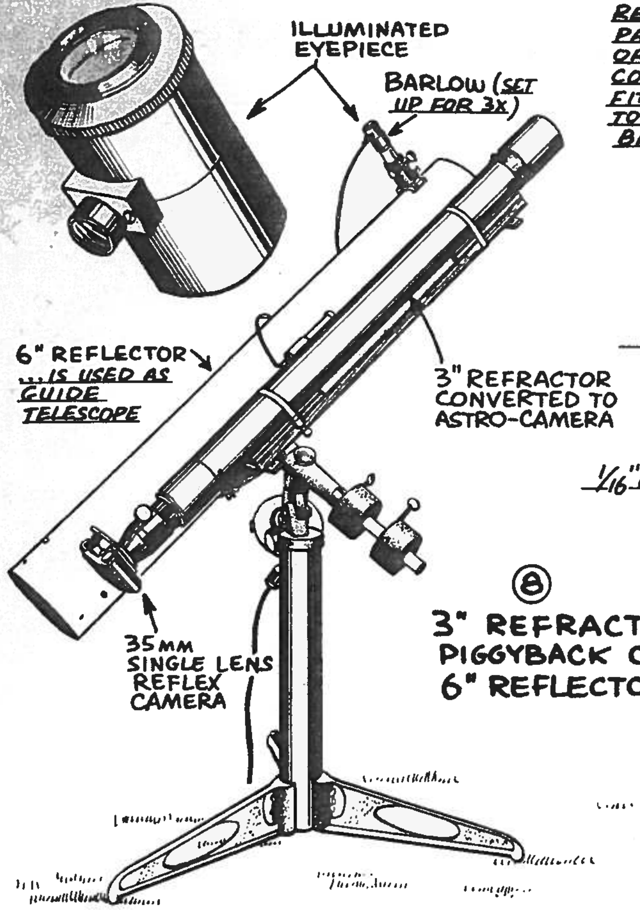
⑦ DOUBLE BRACKET MOUNT for CAMERA OR GUIDE TELESCOPE

is applied to the movement of the guide star itself. Previously, you should measure the lines or wires of the eyepiece reticle, using a measuring magnifier. This known dimension can then be used to measure the approximate diameter of an out-of-focus star image as well as its movement. Putting the guide star slightly out of focus has the added advantage of making it easier to see--the minimal point image of a star can very easily get lost behind a thick crosswire or grid line.

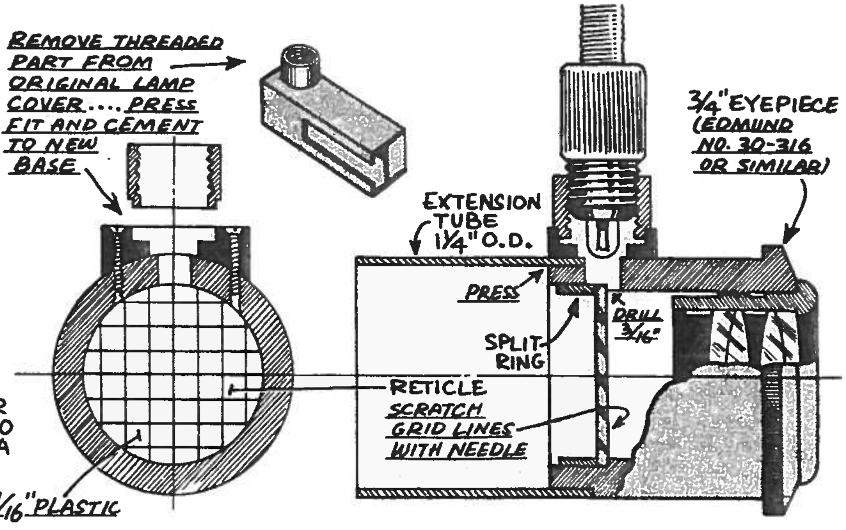
Preferably the guide scope should be of longer focal length than the print e.f.l. In any case, the guide scope magnification (see Fig. 4 and examples) should not be allowed to drop much below unity, i.e., you should not try to guide with a guide scope of shorter f.l. than the print focal length of the actual photo prints. In the setup shown in Fig. 1 where the camera is 18 in. f.l., the print e.f.l. will be 54 inches when prints are enlarged 3x. This is greater than the focal length of the guide telescope, which in this case is the reflector itself of 48 in. f.l., a little shy of unity M but still workable. Preferably for this setup, a positive or negative projection system would be used to increase the guide scope magnification, a 2x Barlow being most common. Image quality in a guide star is of no importance, making it practical to use extreme projection or even inferior optics as needed, the sole aim being to increase the equivalent focal length of the guide telescope.

FAINTEST STAR. Table 6 shows about what you can expect in star pictures with various apertures and exposures. The general idea is that increased exposure will bring faint stars into the picture while making bright stars bigger. This is illustrated by the top and bottom pics of the Pleiades on previous page. It will be noted from the table that an exposure increase of about three times is needed to gain one additional star magnitude. That is, if with any outfit and any film you are able to capture 8th magnitude stars with an exposure of 1 minute, you will need 3 minutes exposure to capture stars of 9th magnitude, and 9 minutes to capture 10th magnitude.

You can reduce exposure time with faster film or larger aperture. When you are shooting pictures of extended objects, the light pick-up of a lens depends solely on its f/value, i.e., the ratio of lens aperture to focal length. Any lens rated, say, f/4, will pick up exactly as much light as any other lens rated f/4 even if one is much larger than the other in aperture. On the



⑧ 3" REFRACTOR PIGGYBACK ON 6" REFLECTOR



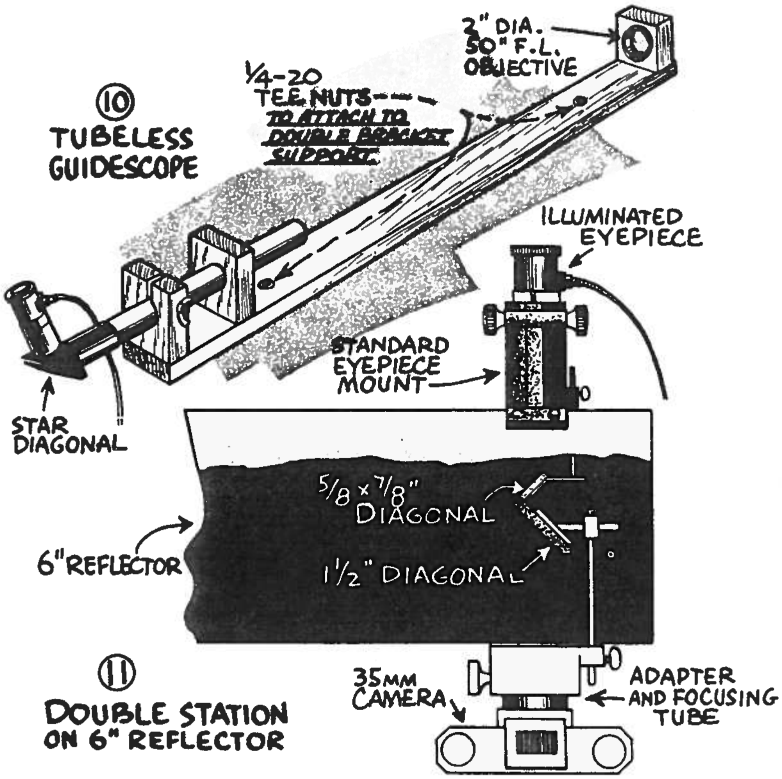
⑨ ILLUMINATED EYEPIECE

other hand, the light pick-up from luminous point objects (stars) depends entirely on the aperture of the lens. A fairly fast f/4 camera lens of 2 inches focal length is a comparatively "slow" lens for star photography for the simple reason it is only 1/2 inch diameter. Most star pics are taken with lenses of 1 inch or more aperture; 2 in. or a little more is a comfortable size for average astro cameras like the one shown in Fig. 1. In any case, the lens will pick up just as much starlight whether it is f/32 or f/4.

PLATE SCALE. Most star pictures must be planned. You must know what you are going to shoot, how to find it, what size it will be on film, how long to expose, etc. In particular, you must be sure that the target object will fit the film area. Tables 1 and 2 will be found useful. The plate scale of a map or photo often enters into the problem; this can be determined by applying the formulas given in Fig. 6. The scale of most star maps is not large. If you plan 3x enlargement, the scale of Norton's atlas can be obtained with a lens of only 2-1/2 inches focal length. One of the larger atlases in physical size is Becvar's Atlas Eclipticalis covering 30 degrees north and south from the celestial equator. Even its comparatively huge scale of about 4/5 of an inch per degree is exceeded by the modest outfit shown in Fig. 1 when negatives are enlarged 3x as is standard procedure for 35mm film.

EQUIPMENT. A good starter is an astro camera of 12 to 20 in. focal length and 2 in. or more clear aperture. This is the kind of outfit shown in Fig 1. If eventually you plan to use bigger equipment, the double bracket support shown in Fig. 7 may be installed at the start since it will handle both large and small astro cameras. One common combo has a 3-inch refractor piggyback on a 6-inch reflector, Fig. 8. In this drawing, the reflector is the guide telescope while the "camera" is the converted 3-inch refractor used as a direct objective. With the standard 3x print enlargement, the print e.f.l. becomes 135 inches. This is matched by the 3x Barlow on the reflector, making the two scopes practically a 1:1 match--the guiding tolerance reverts to the basic .003 inch. It is also practical to use the refractor with elbow erector as the guide scope, shooting with the reflector. For this setup, the reflector main mirror must be set forward to make the image plane accessible.

A full-size section of a typical illuminated eyepiece is shown in Fig. 9. This uses a standard purchased eyepiece which must be machined to accomodate the plastic reticle and lamp. The lamp is a grain-of-wheat lamp operating from a single 1-1/2 volt (size D) battery. This lamp is made for 3 volts and at 1-1/2 volts will burn dim yet bright enough for reticle illumination. The battery case specified has a rheostat which is needed to fade out the light a little in order to see the star images. The reticle must be in the focal plane of the eyepiece; check this with or



(10) TUBELESS GUIDESCOPE

(11) DOUBLE STATION ON 6" REFLECTOR

without your glasses, duplicating your regular method of using the eyepiece in actual observing. Recheck this in actual use--the star image should stay put on the reticle line when you move your head from side to side.

A long focal length guidescope for use with a reflector can be tubeless, as shown in Fig. 10. This is conveniently mounted on the double bracket support shown on a previous page. Another common setup with a reflector is the double station, Fig. 11, which has separate optical systems for guiding and shooting.

SHOOTING HINTS. In most cases you will have no trouble finding a suitable guide star. It is not necessary to use the object being photographed as the guide star. In fact, you can point the guidescope at random to any star in the vicinity and it will guide just as perfectly as on the object itself. However, it is always more convenient to guide on the same object you shoot for the simple reason that the guide scope then serves as a finder--you know that whatever you see in the eyepiece is duplicated at the camera. This is sometimes a must when objects are too dim to be seen on the camera ground glass. Most 35mm cameras have a built-in magnifier and this is always used in focusing. Sharp focus is just a matter of making the star image as small as possible. If the object is too dim to focus easily, turn the camera toward a bright star and focus on that.

In guiding, always let the drive run several minutes to take out any lost motion. Try to avoid jockeying back and forth in guiding. With short f.l. cameras, the guiding tolerance is comfortable and you can even let the drive run unattended for several minutes. Anything over 100 inches print e.f.l. needs constant and careful guiding. You can get some nice pictures with as little as 5 minutes exposure and almost all of the open star clusters can be photographed in a half hour or less, using ordinary ASA 400 film.

equivalent EXPOSURES

TABLE 7 is three tables in one. The main body of the table gives equivalent exposures for a wide range of f/values. The two right hand columns give the linear resolution of a perfect optical system. The third table is a general exposure guide based on ASA speed index.

EQUIVALENT EXPOSURES are mathematically exact. The bug in any such table is "reciprocity failure," which is a technical term applied to film emulsions. It means simply that for extreme cases the film does not respond or reciprocate in exact mathematical ratio to the amount of light received. You can rely on equivalent exposures over a moderate range, say, about from f/4 to f/64. Beyond these limits, additional exposure time may be necessary.

RESOLUTION can be related to f/value, and the resolution columns in the table give the lines per millimeter which a perfect lens of a specified f/value is able to resolve. Most films also have a resolution value in lines per millimeter. The general idea is that a film should be selected which is capable of registering the degree of detail which the camera lens is able to resolve. Obviously there is no point in using a film of high resolving power, say, 200 lines per mm., if the camera lens itself is able to resolve only, say, 24 lines per mm. On the other hand, if the astro camera has high resolving power, it becomes necessary to use film of high resolution in order to realize the full potential of the astro camera.

It should be noted that the tabulated resolution values are for perfect optical systems where the resolution is limited only by the physical nature of light. Most films--even the fast ones--will resolve 60 lines per mm., and this kind of resolution is satisfactory for most astro cameras and subjects. The human eye can resolve (barely) 6 lines per millimeter. Hence, a print of this resolution will appear sharp because the eye can't quite resolve its graininess of 6 lines per millimeter. At 3 lines per millimeter, you can see the "pattern" and the picture looks soft or "wooly." Since pictures are usually enlarged from the negative, the negative must show greater resolution. For example, a negative resolving 18 lines per mm. will be 6 lines per mm. when enlarged three times. As already mentioned, this is the borderline case for true sharpness. From the table you can see this limits astro camera systems to about f/80 if you plan 3x enlargements.

ASA NUMBERS are keyed into the table at about the level currently recommended by film manufacturers. This leads to a minimum exposure value--more exposure time may be required. An easy way to relate ASA numbers to exposure is that the exposure at f/16 is equal to the ASA number expressed as a fraction. This is for a daytime object in bright sun. Example: ASA 400 means 1/400 second at f/16 for a distant object in bright sun.

TABLE 7

EQUIVALENT EXPOSURES IN SECONDS FOR VARIOUS f/VALUES

USE ANY VERTICAL COLUMN. Example. 1/400 SEC. AT f/8 = 1/20 SEC. AT f/36*

f/														MAXIMUM RESOLUTION LINES PER MM	LINES PER INCH
3.2	1/24000	1/16000	1/12000	1/9600	1/7200	1/4800	1/3800	1/2400	1/2000	1/1500	1/1200	1/1000	1/800	458	11600
4	1/16000	1/10000	1/8000	1/6400	1/4800	1/3200	1/2600	1/1600	1/1300	1/1000	1/800	1/600	1/500	366	9300
4.5	1/13000	1/8300	1/6400	1/5000	1/3800	1/2600	1/2000	1/1300	1/1000	1/800	1/600	1/500	1/400	325	8300
5.6	1/8000	1/5200	1/4000	1/3200	1/2400	1/1600	1/1300	1/800	1/600	1/500	1/400	1/300	1/250	261	6650
6.3	1/6400	1/4200	1/3200	1/2500	1/1900	1/1300	1/1000	1/600	1/500	1/400	1/300	1/250	1/200	232	5900
8	1/4000	1/2600	1/2000	1/1600	1/1200	1/800	1/600	1/400*	1/300	1/250	1/200	1/160	1/125	183	4650
9	1/3200	1/2100	1/1600	1/1300	1/1000	1/600	1/500	1/300	1/250	1/200	1/160	1/125	1/100	163	4125
11.3	1/2000	1/1300	1/1000	1/800	1/600	1/400	1/300	1/200	1/160	1/125	1/100	1/80	1/60	130	3300
12.5	1/1600	1/1000	1/800	1/600	1/500	1/300	1/250	1/160	1/125	1/100	1/80	1/60	1/50	117	2950
16	1/1000	1/650	1/500	1/400	1/300	1/200	1/160	1/100	1/80	1/60	1/50	1/40	1/30	91	2325
18	1/800	1/500	1/400	1/320	1/240	1/160	1/125	1/80	1/60	1/50	1/40	1/30	1/25	81	2050
22.6	1/500	1/325	1/250	1/200	1/150	1/100	1/80	1/50	1/40	1/30	1/25	1/20	1/16	67	1650
25	1/400	1/260	1/200	1/160	1/120	1/80	1/60	1/40	1/30	1/25	1/20	1/16	1/13	59	1500
28	1/320	1/200	1/160	1/125	1/100	1/60	1/50	1/30	1/25	1/20	1/16	1/12	1/10	52	1325
32	1/250	1/150	1/125	1/100	1/75	1/50	1/40	1/25	1/20	1/16	1/12	1/10	1/8	46	1175
36	1/200	1/125	1/100	1/80	1/60	1/40	1/30	1/20*	1/16	1/13	1/10	1/8	1/6	41	1025
40	1/160	1/100	1/80	1/60	1/50	1/30	1/25	1/16	1/13	1/10	1/8	1/6	1/5	37	925
45	1/125	1/80	1/60	1/50	1/35	1/25	1/20	1/12	1/10	1/8	1/6	1/5	1/4	32	825
50	1/100	1/65	1/50	1/40	1/30	1/20	1/16	1/10	1/8	1/6	1/5	1/4	1/3	29	750
55	1/80	1/50	1/40	1/32	1/24	1/16	1/13	1/8	1/6	1/5	1/4	1/3	2/5	27	675
60	1/70	1/45	1/35	1/28	1/20	1/14	1/11	1/7	1/5	1/4	1/3	1/3	1/2	24	625
64	1/60	1/40	1/30	1/24	1/18	1/12	1/10	1/6	1/5	1/4	1/3	2/5	1/2	23	575
71	1/50	1/30	1/25	1/20	1/15	1/10	1/8	1/5	1/4	1/3	1/2	1/2	2/3	21	500
80	1/40	1/25	1/20	1/16	1/12	1/8	1/6	1/4	1/3	2/5	1/2	2/3	4/5	18	475
90	1/30	1/20	1/15	1/12	1/9	1/6	1/5	1/3	2/5	1/2	2/3	4/5	1	16	400
100	1/25	1/16	1/12	1/10	1/8	1/5	1/4	1/2	1/2	2/3	1	1	1 1/3	14	375
128	1/15	1/10	1/7	1/6	1/5	1/3	1/2	2/3	5/6	1	1 1/3	1 2/3	2	11	300
	ASA 1000	ASA 650	ASA 500	ASA 400	ASA 300	ASA 200	ASA 160	ASA 100	ASA 80	ASA 64	ASA 50	ASA 40	ASA 32		

THE ASA NUMBERS ARE KEYED INTO THE TABLE FOR A BRIGHT SUN, AVERAGE SUBJECT, FRONT LIGHTED, AT MEDIUM LONG DISTANCE (20 TO 100 YARDS)

BLACK and WHITE FILM DATA 1966

		ASA SPEED INDEX	RES. LINES PER MM	AVAILABILITY 35 MM	ROLL	SHEET	MAIN FEATURE
AGFA	ISOPAN IFF	25	130	✓			FINE GRAIN
	ISOPAN IF	100	100	✓			GOOD CONTRAST
	ISOPAN ISS	200	80	✓			ALL-PURPOSE
	ISOPAN ULTRA	400	70	✓			ALL-PURPOSE
	ISOPAN RECORD	1250	60	✓			VERY HIGH SPEED
ANSCO	VERSAPAN	125	100	✓	✓	✓	FINE GRAIN
	SUPER HYPAN	500	80	✓	✓	✓	HIGH SPEED
KODAK	HI CONTRAST COPY [1]	5 [2] ESTIMATED	220	✓			GOOD FOR FULL MOON
	PANATOMIC-X	32	120	✓			FINE GRAIN
	PLUS-X	125	100	✓	✓	✓	FINE GRAIN
	VERICHROME	125	100		✓		ALL-PURPOSE
	INFRARED	50 [3]	NO DATA	✓			INFRA RED
	TRI-X	400	80	✓	✓	✓	HIGH SPEED
	ROYAL-X	1250	60		#120 ✓ ONLY		VERY FAST

[1] *FORMERLY "MICRO-FILE"* [2] *NOT FOR GENERAL WORK AND HAS NO ASA NO. FOR SUCH* [3] *WITHOUT FILTER*

Action of FILTERS

WRATTEN NUMBER	COLOR OF FILTER	EXP.* FACTOR	Action of FILTERS
K1	LIGHT YELLOW	1.5	ABSORBS SOME ULTRAVIOLET AND BLUE-VIOLET. NOT EFFECTIVE WITH ACHROMATS
K2	YELLOW	2	BETTER THAN K1 IN ABSORBING BLUE-VIOLET. PENETRATES HAZE. GOOD WITH ACHROMATS
AERO 1	LIGHT YELLOW	1.5	ABSORBS U-V, VIOLET AND SOME BLUE. PENETRATES SLIGHT HAZE
AERO 2	YELLOW	2	LIKE A1 BUT STRONGER. GOOD HAZE PENETRATION. GOOD WITH ACHROMATS
K3	DEEP YELLOW	2	REMOVES MORE BLUE THAN K2. CUTS THROUGH HAZE. GOOD FOR FAR OBJECTS
G	DEEP YELLOW	3	ALMOST COMPLETE ELIMINATION OF BLUE. EXCELLENT HAZE PENETRATION
X1	LIGHT GREEN	3	ABSORBS VIOLET, SOME BLUE AND SOME RED. GOOD FOR NATURAL COLOR TONES
X2	GREEN	5	SIMILAR TO X1 BUT ABSORBS MORE RED, HENCE MAKES RED OBJECTS DARKER
B	GREEN	8	ABSORBS VIOLET, MOST BLUE AND MOST RED LIGHT. TRANSMITS GREEN AND YELLOW
A	RED	8	TRANSMITS RED AND ABSORBS BLUE AND GREEN. PENETRATES HAZE
C5	BLUE	5	ABSORBS RED, YELLOW AND GREEN. TRANSMITS BLUE... INCREASES HAZE

**FOR PAN FILM AND DAYLIGHT. MULTIPLY NORMAL EXPOSURE BY FACTOR*

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