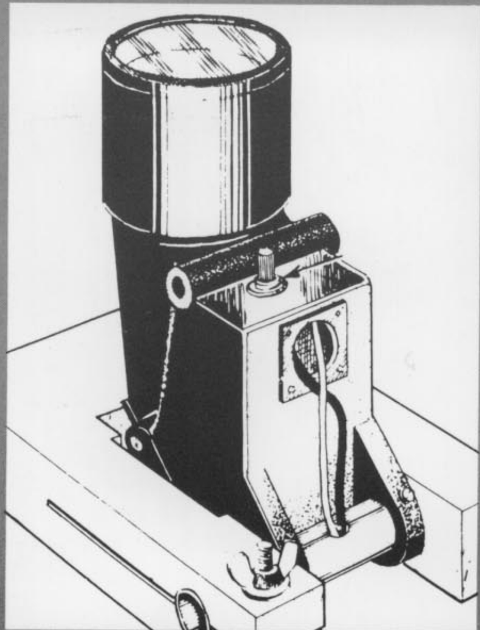
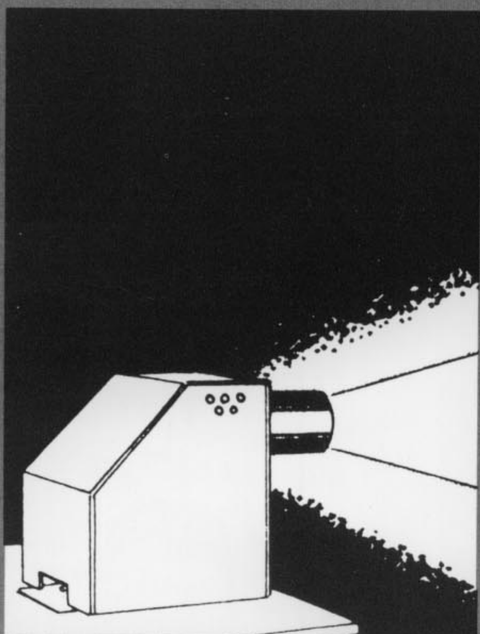
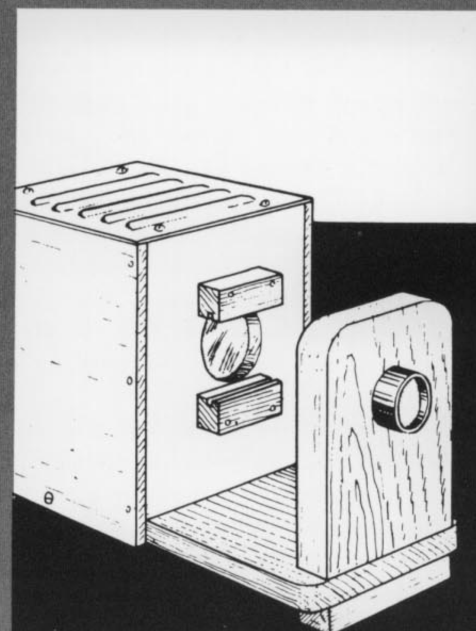




## How To
# CONDENSE AND PROJECT LIGHT

No. 9044

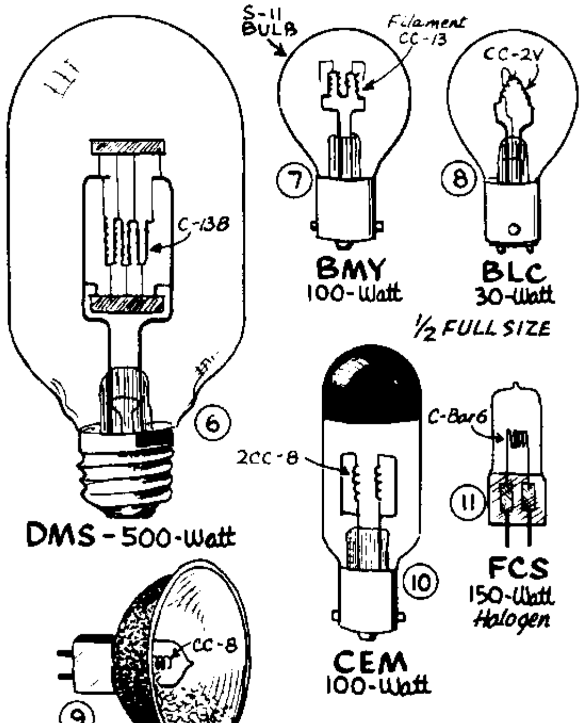
**Please Note!**

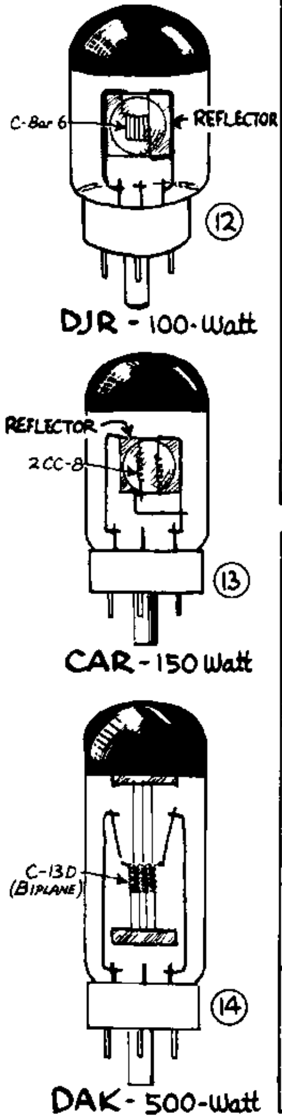
Many of the parts listed in this book may not be currently available because of stock changes over the years. Before you start your project, please check the current Edmund Scientific catalog for current pricing and availability of the various parts listed in the instructions.

Popular Optics Library

Edmund Scientific

# all kinds of LAMPS



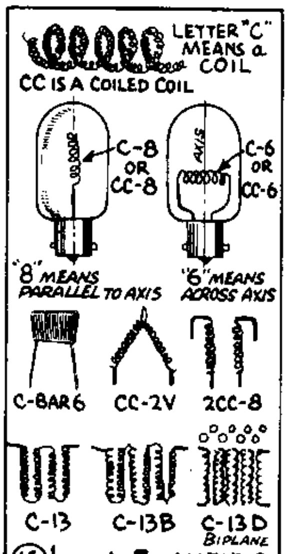

(15) LUMENS per Watt to °KELVIN *

| LUMENS per Watt | °KELVIN |
|---|---|
| 4 | 2175° |
| 8 | 2460 |
| 12 | 2675 |
| 16 | 2850 |
| 20 | 3000 |
| 24 | 3125 |
| 28 | 3250 |
| 32 | 3350 |
| 36 | 3500 |

(APPROX. RANGE for PROJECTOR LAMPS: 20–28)

*Approximate

TO GET LUMENS-per-watt, DIVIDE LUMEN RATING OF LAMP by NUMBER of WATTS



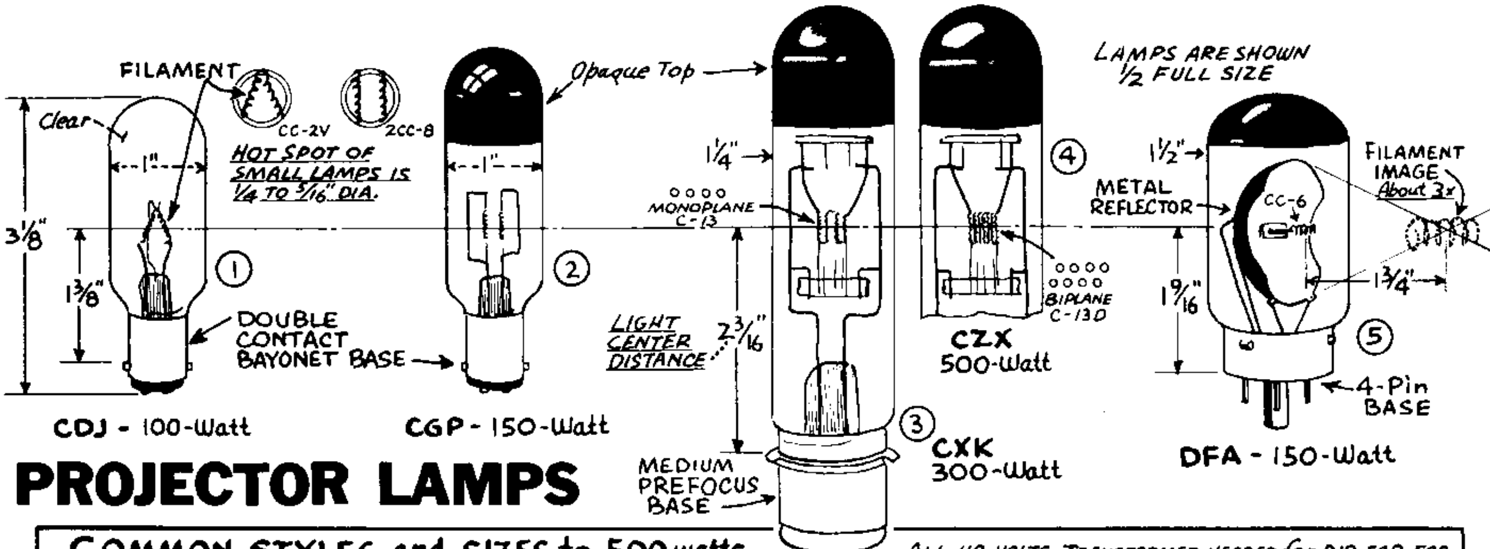

(16) Lamp FILAMENTS

IF YOU want to condense or project light, the lamp you need will probably have a small filament of intense brightness enclosed in a clear glass bulb. Such lamps are used in slide and movie projectors, and they are usually called projector or projection lamps from this application. The table on opposite page lists a few of the hundreds of kinds available. All have an ANSI code number which identifies the lamp completely. The individual letters have no meaning. Different companies may make the same Ansi-coded lamp, but the lamp must conform in all important specifications. Only minor variations are permissible, as, for example, if the lamp has an opaque end, no distinction is made between a blue color (Sylvania) or a gold color (General Electric).

FILAMENTS. Lamp filaments are made of tungsten wire, sometimes used in a straight length but more often formed into a coil, or a coiled coil, Fig. 16. This drawing shows the various common filament styles. The better (and more expensive) filaments have close-spaced coils to secure a bright, uniform light. Least expensive are the wide-spaced CC-2V and 2CC-8 filaments, and these are entirely practical for many applications, such as slide projectors. When you want a filament with minimal visible structure, the C-BAR 6 is a first choice in small lamps, while the C-13D is almost a universal choice for lamps of 500 watts or more.

WATTAGE. Like household lamps, the more watts the more light. You can of course get a little more technical and say the output of luminous energy is so-many lumens. Here again, the more lumens the more light. If your interest is photography or the projection of slides, you may be interested in the color temperature of the lamp. Lamps over 3000 degrees Kelvin are needed for best color photography or projection. The Kelvin scale is not based on how hot the lamp is; it is a temperature scale keyed to a sequence of colors ranging from red to orange to yellow to white as observed if you heat a piece of iron in a fire. This is not an exact description, but it explains the general idea--the higher the color temperature, the brighter, whiter the light. There is a relationship between color temperature and lumens; if you know one you can calculate the other to a near approximation, Fig. 15. For example, a 100-watt inside frosted household lamp is rated 1740 lumens, or 17.4 lumens per watt. From Fig. 15 data you can call this about 2900 degrees Kelvin--the lamp has a color temperature in the high yellow.

HALOGEN LAMPS. The top feature of the halogen lamp is its small size--compare Fig. 11 with the others. Conventional filament lamps are filled with a harmless gas, usually argon, which permits the filament to burn brighter, last longer. However, the lamp eventually fails because particles of tungsten are thrown off by the hot filament, causing the filament to



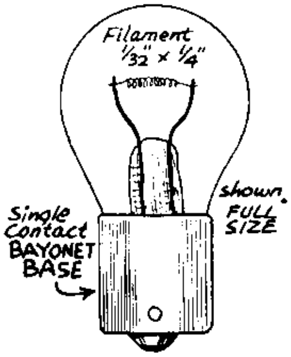

# PROJECTOR LAMPS

## COMMON STYLES and SIZES to 500 watts

*ALL 110-VOLTS. TRANSFORMER NEEDED for DJR, FCR, FCS*

| *ANSI CODE | WATTS | FILAMENT NO. | FILAMENT Wd. and Ht. | BASE | MEASUREMENTS DIA. | MEASUREMENTS LT. CEN. | MEASUREMENTS OVERALL | HOURS LIFE | LUMENS | COLOR TEMP. °KELVIN | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BMY | 100 | CC-13 | .33"×.30" | S.C.Bay. | 1 3/8" CLEAR | 1 3/8" | 2 3/8" | 50 | 1860 | 2950° | SMALL S-11 BULB – see drawing → (7) |
| CEM | 100 | 2CC-8 | .30×.38 | S.C.Bay. | 1" Opaque | 1 3/8 | 3 1/8 | 200 | 1950 | 3000 | 75 watt CBJ OR CBC CAN SUB (10) |
| DJR | 100 | C-Bar 6 | .25×.31 | 4-PIN | 1/2" Opaque | 1 5/16 | 3 3/16 | 50 | 1800 Est. | 2850 | NEEDS 12-VOLT TRANSFORMER. INTERNAL REFLECTOR. NO SUB (12) |
| FCR | 100 | C-Bar6 | .20×.12 | 2-PIN | 7/16" CLEAR | 1 3/16 | 1 3/4 | 50 | 2900 | 3300 | HALOGEN. NEEDS 12-VOLT TRANS. FDX CAN SUB...has stronger base |
| CAR | 150 | 2CC-8 | .29×.34 | 4-PIN | 1 1/4" Opaque | 1 5/16 | 3 1/8 | 15 | 3300 | 3150 | INTERNAL REFLECTOR (13) |
| CEW | 150 | 2CC-8 | .33×.38 | S.C.Bay. | 1" Opaque | 1 3/8 | 3 5/8 | 25 | 3500 | 3100 | CFC IS SAME |
| CSH | 150 | 2CC-8 | .29×.40 | 4-PIN | 1 1/4" Opaque | 1 5/16 | 4 | 500 | 2300 | 2850 | LONG-LIFE... but less bright. SUB DFF IS SAME BUT WITH INT. REFL. |
| FCS | 150 | C-Bar 6 | .30×.13 | 2-PIN | 1/2" CLEAR | 1 3/16 | 2 | 50 / 100 | 4500 / 3400 | 3400 / 3250 | HALOGEN. NEEDS 24-VOLT TRANS. ← FDV SUB HAS 100-HR. LIFE (11) |
| CGW | 200 | 2CC-8 | .35×.40 | S.C.Bay. | 1" Opaque | 1 3/8 | 3 5/8 | 25 | 4700 | 3150 | CGT IS SUB. Also can use 150-watt CEW (see above) |
| CXK | 300 | C-13 | .43×.44 | Medium Prefocus | 1 1/4" Opaque | 2 3/16 | 5 3/4 | 25 | 7200 | 3150 | CXY CAN SUB... is same except sub has C-13D filament (3) |
| CYK | 400 | C-13D | .37×.37 | 4-PIN | 1 1/4" Opaque | 1 9/16 | 4 | 200 | 9800 Est. | 3125 Est. | LONG-LIFE SUB FOR DAK 500-Watt...also is cooler |
| CZX | 500 | C-13D | .41×.39 | Medium Prefocus | 1 1/4" Opaque | 2 3/16 | 5 3/4 | 25 | 12750 | 3250 | SUB DAB. ALSO 300-watt CXK can be used (see above) (4) |
| DAK | 500 | C-13D | .37×.37 | 4-PIN | 1 1/4" Opaque | 1 9/16 | 4 | 25 / 30 | 13200 / 12500 | 3200 / 3200 | USED IN 35MM SLIDE PROJECTORS. ← DAY CAN SUB. See also CYK above (14) |
| DMS | 500 | C-13B | .44×.49 | Medium SCREW | 2 1/2" CLEAR | 3 | 5 1/2 | 50 | 13200 | 3200 | OLD-TIMER HAS SCREW BASE SAME AS ORDINARY HOUSE LAMPS (6) |
| **DOUBLE CONTACT BAYONET** | | | | | | ← ALL SAME LIGHT CENTER DISTANCE | | | | | |
| BLC | 30 | CC-2V | .27"×.27" | D.C.Bay. | 1 3/8" CLEAR | 1 3/8" | 2 3/8" | 50 | 400 | 2775° | CLEAR TOP. USED IN FILM VIEWER. BLX, 50 watt can sub. (8) |
| CAX | 50 | CC-13 | .29×.24 | D.C.Bay. | 1" CLEAR | 1 3/8 | 3 1/8 | 50 | 790 | 2875 | CC-13 FILAMENT IS GOOD FOR UNIFORM IMAGE. CAW is same OPAQUE |
| CDJ | 100 | CC-2V | .27×.27 | D.C.Bay. | 1" CLEAR | 1 3/8 | 3 1/8 | 50 | 2000 | 2975 | CAN BE USED WITH NATURAL VENTILATION. CEB IS SUB. (1) |
| CEL | 100 | 2CC-8 | .30×.38 | D.C.Bay. | 1" Opaque | 1 3/8 | 3 1/8 | 200 | 1950 | 3000 | LONG LIFE IS MAIN FEATURE |
| BMG | 100 | CC-2V | .32×.29 | D.C.Bay. | 1 3/8" CLEAR | 1 3/8. | 2 3/8 | 25 | 2000 | 3000 | SMALL S-11 BULB, like BLC. Sub BMH |
| CGP | 150 | 2CC-8 | .33×.38 | D.C.Bay. | 1" Opaque | 1 3/8 | 3 5/8 | 25 | 3500 | 3075 | GOOD STOCK LAMP FOR 35mm SLIDE PROJECTOR. Sub CGF or CFK (2) |
| BEC | 150 | 2CC-8 | .33×.38 | D.C.Bay. | 1 1/2" CLEAR | 1 3/8 | 2 5/8 | 25 | 3500 | 3100 | SMALL BULB SIMILAR TO BLC |
| CEM | 200 | 2CC-8 | .36×.40 | D.C.Bay. | 1" Opaque | 1 3/8 | 3 5/8 | 25 | 4200 | 3075 | CHD IS SUBSTITUTE |
| FEV | 200 | CC-2V | .30×.30 | D.C.Bay. | 1/2" CLEAR | 1 3/8 | 2 7/16 | 50 | 5500 | 3200 | HALOGEN...if you want to switch |
| **FOCUSED REFLECTOR** *(SEE DFA EXAMPLE AT TOP RIGHT)* | | | | | | | | | | | |
| DFA | 150 | CC-6 | .31"×.11" | 4-PIN | 1 1/2" Opaque | 1 9/16" | 3 9/16" | 15 | 4200 EST. | 3200 | LAMP IMAGE FOCUSED AT 1 3/4" for 8mm MOVIE PROJECTOR (5) |
| ELH | 300 | CC-8 | 3/16×3/8 | OVAL 2-PIN | 7/16" | ON AXIS | 1 3/4 | 35 | 9000 EST. | 3350 | HALOGEN. IMAGE AT 5 1/2". DICHROIC REFLECTOR 2" DIA. (9) |
| ENH | 300 | SAME | SAME | SAME | SAME | SAME | SAME | 175 | 8100 EST. | 3200 | AS ABOVE, BUT LONG-LIFE. Also costs a little more |

*AMERICAN NATIONAL STANDARDS INSTITUTE




NO.93 - 12-V. LAMP
...NEEDS TRANSFORMER for 110-V. POWER SOURCE

## (17) SELECTED AUTOMOTIVE LAMPS (HI-INTENSITY LAMPS)

| 12-VOLT | | | | | | 6-VOLT | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TRADE NO. | CANDLE POWER | BASE | VOLTS | AMPS. | Overall LENGTH | TRADE NO. | CANDLE POWER | BASE | VOLTS | AMPS. | Overall LENGTH |
| 93 | 15 | S.C.Bay. | 12.8 | 1.04 | 1⅞" | 87 | 15 | S.C.Bay. | 6.8 | 1.91 | 2" |
| 94 | 15 | D.C.Bay. | 12.8 | 1.04 | 1⅞ | 88 | 15 | D.C.Bay. | 6.8 | 1.91 | 2 |
| 1141 | 21 | S.C.Bay. | 12.8 | 1.44 | 2 | 209 | 15 | S.C.Bay. | 6.5 | 1.78 | 1¾ |
| 1142 | 21 | D.C.Bay. | 12.8 | 1.44 | 2 | 210 | 15 | D.C.Bay. | 6.5 | 1.78 | 1¾ |
| 199 | 32 | S.C.Bay. | 12.8 | 2.25 | 2 | 1129 | 21 | S.C.Bay. | 6.4 | 2.63 | 2 |
| 1295 | 50 | S.C.Bay. | 12.5 | 3.0 | 2 | 1133 | 32 | S.C.Bay. | 6.2 | 3.91 | 2¼ |

become smaller until it breaks. In addition, the tungsten particles deposit on the glass, turning it black.

Tungsten halogen lamps contain a small amount of a halogen, such as bromine, chlorine or iodine. The halogen teams up with the tungsten to create a regenerative cycle--particles of tungsten thrown off by the filament combine with the halogen to form a gas which is attracted to the hot filament and attaches to the filament. However, the lost particles of tungsten do not re-deposit in exactly the same place, so the filament eventually develops thin spots and fails as before. The important feature is that the particles of tungsten collected by the filament are prevented from depositing on the glass--you get rid of the black film.

Halogen lamps are hot and they must run hot to keep the regenerating cycle going--nothing less than 500 deg. F. will do. For comparison, a 100-watt household lamp is never hotter than about 450 degrees, meaning this degree of heat is too cold for a halogen lamp. Ordinary glass does not stand the higher temperature needed, so all halogens are made of special glass or of quartz. In fact, the halogen lamp is now perhaps better known as a quartz lamp. It should be kept in mind that the quartz glass passes the ultraviolet and the halogen lamp produces a good bit of ultraviolet. This is not a dangerous situation --just something to remember if you contemplate any installation where the bare light may strike the eye at short range.

INTERNAL REFLECTORS. Some projection lamps have metal reflectors mounted inside the bulb. One style is the simple spherical mirror, Fig. 13, located at two focal lengths from the filament to send the light back again to form an image of the filament at the filament. Nearly double the light can be obtained in this manner if the filament is an open type, such as the vee or twin-eight; some gain is possible with even close-spaced coils. A reflector of this kind is known as a spherical reflector, or a proximity reflector. Another type of metal reflector is larger and may be either spherical or ellipsoidal. This kind of reflector forms an enlarged image of the filament a short distance in front of the lamp, Fig. 5. Lamps of this kind take the place of the usual condenser system; they are commonly used in 8mm movie projectors and also in slide projectors. In some cases the filament image is treated as the actual light source, which is then directed through condensers in the usual manner. The main advantage of this setup is that it puts the lamp at a greater distance from the slide; the longer light path can be folded if desired by using a plane mirror; if this is made dichroic it can eliminate a lot of heat from its back surface.

In a third style of reflectorized lamp, the reflector is the glass body housing the lamp itself. This is a common construction for halogen lamps from 50 to 500 watts. Even with reflector, the lamp is still very small, as can be seen in Fig. 9 example. All lamps of this kind form an enlarged image of the filament ahead of the lamp, as already described. The reflector itself may be dichroic (color selective) on one or both surfaces. Fig. 9 example has the filter film on the back of the reflector, and its job is to pass the hot infrared while reflecting all of the visible light.

HI-INTENSITY LAMPS. These have been on the scene for many years, being none other than the 6 and 12-volt lamps used for automotive lighting. Low-voltage lamps can be used on standard household current by using a small and inexpensive transformer to reduce the usual 110-volts to the required level. With the transformer concealed, the end product can be an attractive miniature lamp useful for study or spotlighting. Some of the cheaper fixtures on sale are a fair buy just for the parts--switch, lamp bulb, transformer, socket, and sometimes a condensing lens--all of which can be rebuilt as needed for other applications. Fig. 17 lists a few of the 50 or so lamp bulbs available. They cost about the same as household lamps--two for less than a dollar. The spotlight beam of the 15-candle-power size is about the same intensity as a bare 100-watt household lamp at the same distance.

High-intensity lamps are also available in various sizes in the hard glass PAR bulb, Fig. 18. These lamps have screw or lug terminals and need an outer cover.

RIBBON FILAMENTS. In some optical systems, the image of the lamp is formed in the plane of the work, i.e., the lamp image is right on the microscope slide, film, etc. This is an excellent lighting system providing the source is uniform. A uniform light source without visible structure is obtained with a ribbon filament, Fig. 19. Ribbon filaments range from 3/4mm to 4mm wide and up to 2 in. in length. 5 to 20-ampere ribbons are used in recorders, oscillographs and microscope illuminators.

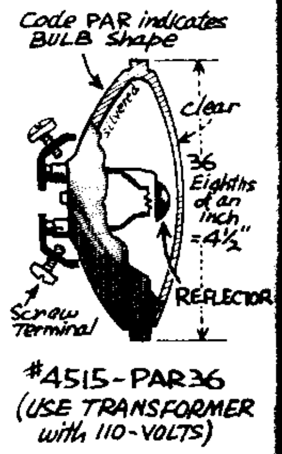
ENCLOSED ARC. All of the brilliance of the open carbon arc can now be obtained in the enclosed arc lamp. Most of the lamps use a zirconium electrode for maximum brightness. Both the lamp and the special equipment needed to operate it are expensive. The small A2 size is popular as an optical target, being about .005 in. diameter--at 60 ft. or more this is a true artificial star. Although the light is too intense to view at close range, the A2 is a mere baby in candlepower at 1/3 of one candle. Sometimes you will see this lamp advertised at 15,000 candlepower, but this is only a comparative value: a source 1 in. sq. of the same intensity would rate 15,000 candles, but the light spot itself is only a fraction of this area.

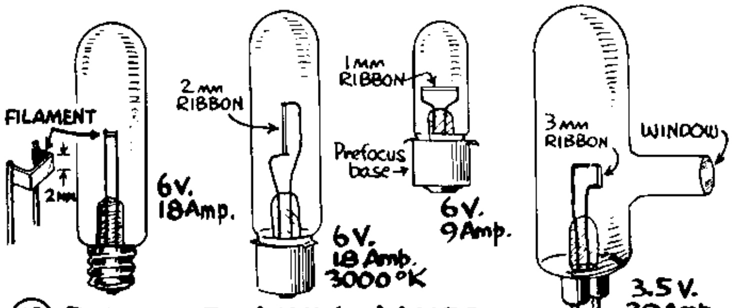
LASER LIGHT. This is usually a bright red and is monochromatic at about 6300 angstroms. The tube is filled with a mix of helium and neon gas. When stimulated with electric current, the gas is converted to small bulletlike particles of light which increase in energy when they are shunted back and forth by the two mirrors of the optical system, as shown in the diagram. The light is also stimulated by one particle touching another, producing a high level of intensity which remains very bright at only 1% transmission as provided by the semi-silvered front lens. The emergent beam has a modest divergence of about 6' of arc. The narrow monochromatic beam has many uses but many applications are made impractical by the $100 price tag. A compensating feature is guaranteed lamp life of at least 1000 hours.

PARTIAL LIST
⑱ SEALED-BEAM AUTO LAMPS

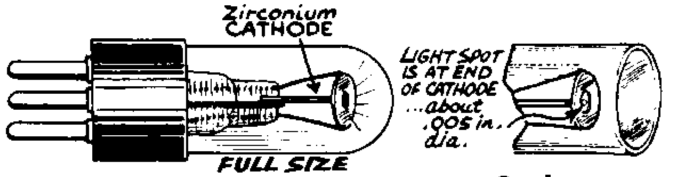
| TRADE NO. | Intended USE | WATTS | VOLTS | BULB | Overall LENGTH |
|---|---|---|---|---|---|
| 4535 | SPOT-LIGHT | 30 | 6.4 | PAR46 | 3¾" |
| 4515 | SPOT-LIGHT | 30 | 6.4 | PAR36 | 2¾ |
| 4516[1] | SPOT-LIGHT | 30 | 6.4 | PAR36 | 2¾ |
| 4013 | TRACTOR | 25 | 6.4 | PAR46 | 3¾ |
| 4419 | TRACTOR | 35 | 12.8 | PAR46 | 3¾ |
| 4404 | SPOT-LIGHT | 30 | 12.8 | PAR36 | 2¾ |

[1] LIKE 4515 BUT NO INTERNAL REFLECTOR




⑲ RIBBON FILAMENT LAMPS



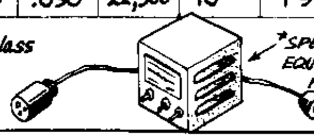

2-Watt (A2) Zirconium Arc

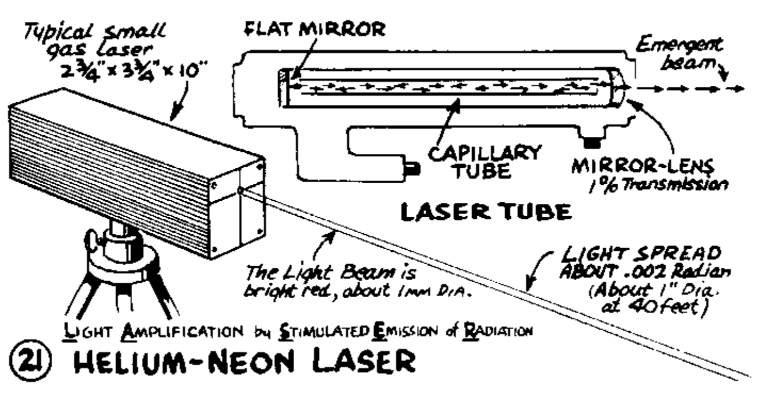
C2 is same with flat window

PARTIAL LIST
⑳ ENCLOSED CONCENTRATED ARC LAMPS*

| TRADE NO. | VOLTS | AMPS. | LIGHT DIA. | Candlepower per Sq.In. | Candlepower AXIAL | BULB | Hrs. LIFE |
|---|---|---|---|---|---|---|---|
| A2 | 38 | .06 | .005" | 15,000 | .3 | T5 | 150 |
| A2T | 27 | .09 | .007 | 11,300 | .3 | T5 | 150 |
| A5 | 20 | .25 | .010 | 24,000 | 1.9 | T9 | 450 |
| C10 | 20 | .50 | .015 | 29,300 | 4.7 | T9 | 450 |
| C25 | 20 | 1.25 | .030 | 22,500 | 16 | T9 | 350 |

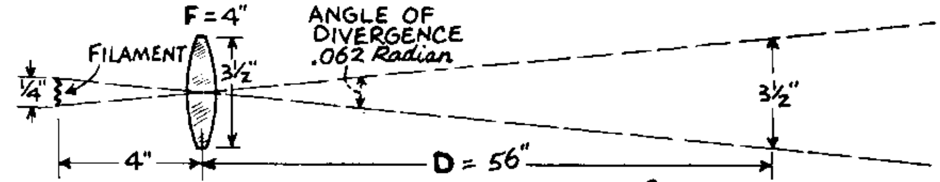
A – END LIGHT, blown glass
C – END LT., Flat glass
K – SIDE LIGHT
T – TUNGSTEN




㉑ HELIUM-NEON LASER

# Light TALK




① ANGLE OF DIVERGENCE = $\frac{\text{LIGHT SIZE}}{\text{LT. DISTANCE}}$ Ex: $\frac{.25}{4} = .062$ *Radian*

② D to MAKE DIA. of LIGHT BEAM SAME AS LENS = $\frac{\text{LENS DIA.}}{\text{ANGLE}}$ Ex: $\frac{3.5}{.062} = 56"$

③ BEAM DIA. AT GREATER DISTANCE THAN Above = ANGLE × D Ex: D = 96" $.062 \times 96 = 5.95"$

ANGLE OF DIVERGENCE. The spread of a light beam after passing through a lens. See Fig. 1. The smaller the light source, the smaller the angle of divergence. The angle is also diminished by using a longer focal length lens.

ANSI. American National Standards Institute. An industry-wide association to establish standards. Most projection lamps have an ANSI code number which identifies the lamp completely.

BEAM ANGLE. The angular spread of a light beam from a lamp or fixture. Normally it is taken 10% less than zero illumination. Beam angle ranges from 15-deg. for a narrow spot to 130-deg. for a floodlight.

COMPLETE FLASH. Said of a slide or film projection system when the image of the lamp filament completely fills the entrance pupil of the projection lens.

CANDLE. The unit of luminous intensity. For many years an ordinary wax candle about an inch in diameter was used as the standard, but present methods are more scientific. One candle directed to a surface one foot square one foot from the candle, Fig. 5, will produce a uniform flow of light (flux) which is described as one LUMEN.

CANDLEPOWER. Light intensity expressed in candles. When a lamp is rated by candlepower, it means the light intensity is measured in one direction over a certain angle, usually unit solid angle, Fig. 5. Since the lamp is equally bright in all of the surrounding space, the total flux of a candle-rated lamp is about 12 times as much, Fig. 5.

EFFICACY. The effectiveness of a lamp in converting electric power to luminous flux expressed in lumens per watt. Ex: A certain 150 watt projection lamp is rated at 3600 lumens total flux. Its efficacy is 3600/150 or 24 lumens per watt. Lamps are not efficient--only about 15% of the input energy is returned as visible light.

FRESNEL, Augustin. French scientist (1788-1827), the inventor of the lens bearing his name. The French way to say it is fray-NELL, but if you are talking lenses or spotlights, the Americanized version is FRAY-nel. Fresnel lenses are molded to shape and are used only as condensers although large plastic ones work well as low-power magnifiers.

GLOW LAMP. A low-wattage, long life lamp providing a small amount of light from the glow around the electrodes in the lamp. Usually less than 1 watt operating on 110 volts AC or DC. If the gas fill is neon, the light is red-orange; if argon, light blue in the ultraviolet.

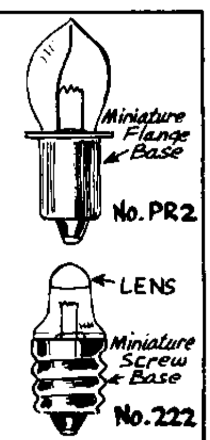
INTENSITY of a light source. Symbol I. The radiant flux emitted by the source per unit solid angle, i.e., lumens or ft.-candles per steradian.

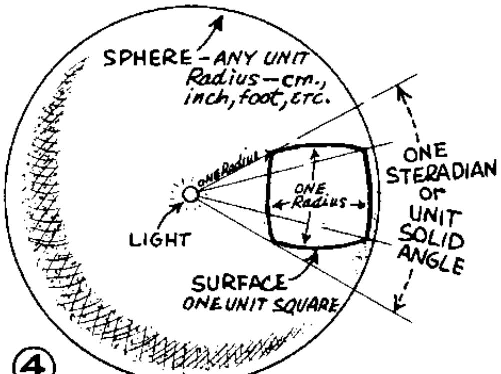
INVERSE SQUARE LAW. The illumination on a surface varies inversely as the square of the distance. Example: If the light to surface distance is

## MINI LAMPS

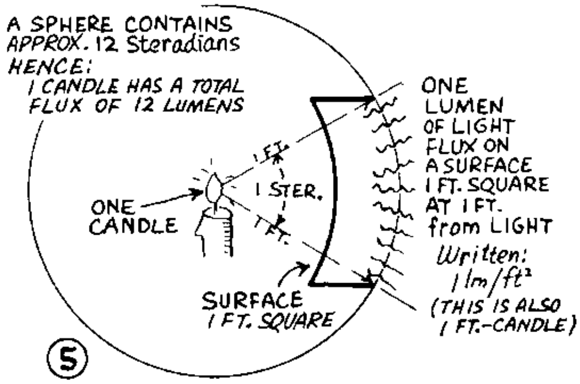
Most mini lamps are battery-powered but it is practical and inexpensive to light-up fully bright with a step-down transformer of suitable capacity.

| TRADE NO. | CANDLE POWER | VOLTS | AMPS | BASE | Overall LENGTH | HRS. LIFE | Intended USE |
|---|---|---|---|---|---|---|---|
| 63<br>64 | 3 | 7 | .63 | S.C. Bay.<br>D.C. Bay. | 1 7/16" | – | AUTO |
| 81<br>82 | 6 | 6.5 | 1.02 | S.C. Bay.<br>D.C. Bay. | 1 7/16 | – | AUTO |
| PR2 | .8 | 2.4 | .5 | S.C. MIN. FLANGE | 1 1/4 | 15 | FLASHLT. |
| 14 | .5 | 2.5 | .3 | MINI. SCREW | 15/16 | 15 | FLASHLT. |
| 44 | .9 | 6.3 | .25 | MINI. BAY. | 1 3/16 | 3000 | — |
| 51 | 1 | 6.5 | .22 | MINI. BAY. | 15/16 | 1000 | FLASHLT. |
| 194 | 2 | 14 | .27 | WEDGE | 1 1/16 | 2500 | — |
| 222 | 5 | 2.3 | .25 | MINI. SCREW | 15/16 | 5 | PEN FLASHLT. |

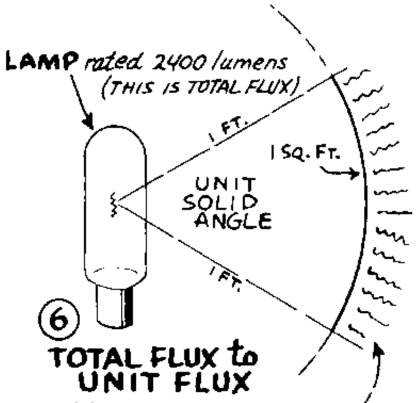





**④ ONE STERADIAN (UNIT SOLID ANGLE)**




**⑤ 1 Candle = 1 lumen/ft²**




**⑥ TOTAL FLUX to UNIT FLUX**

Example: $\frac{2400}{12} = 200$ Candles per Sq. Ft.

3 ft., the square of this is 9, which is 1/9 when inverted--the light at 3 ft. is only 1/9 as much as at 1 ft. The Inverse Square Law is expressed by the formula given in Fig. 7.

LASER is an acronym from Light Amplification by Stimulated Emission of Radiation. It is exactly what it says--supplied with an electric current, the laser is self-stimulating, producing an intense narrow-beam monochromatic light of purest red.

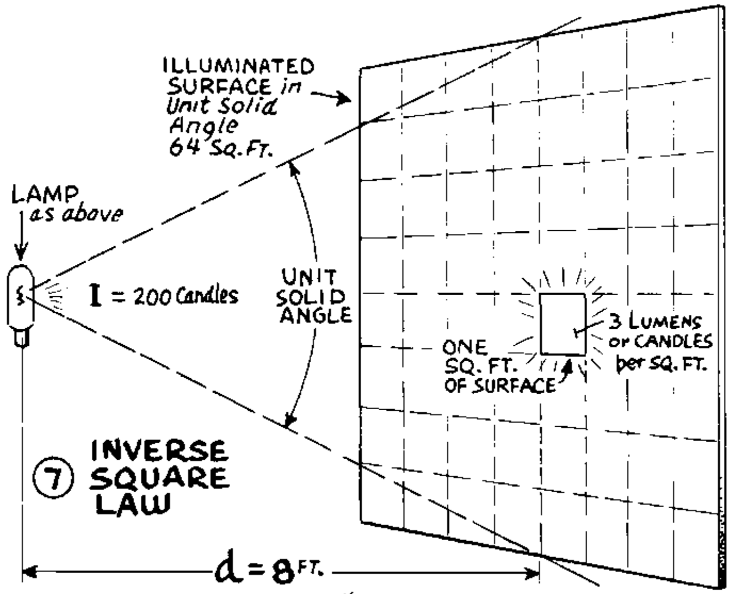
LUMEN (1m.). The unit of luminous flux measuring the flow or quantity of light. The light on a surface 1 ft. square located 1 ft. from a 1-candle source is 1 lumen. See Fig. 5. The same illumination is also called 1 ft.--candle because it is the light from one candle 1 ft. from the surface.

MILLIAMPERE (mA). One thousandths of an ampere. Example: 500mA is 500 thousandths-of-an-ampere or .5 or 1/2 ampere.

PHOTOMETRY is measurement of visible light in quantity (flux) and brightness (intensity). Light can be measured directly with various kinds of light meters. The illumination can also be calculated but few amateurs care to get into this beyond the simple rules applying to a point source of light.

STERADIAN. A solid angle of a sphere embracing an area on the surface of the sphere equal to the square of the radius of the sphere. The radius is usually some unit, such as a ft., making the area 1 sq. ft. One steradian is often called unit solid angle, the unit being the radius of the sphere. See Fig. 4. There are 12.56 steradians in a sphere.

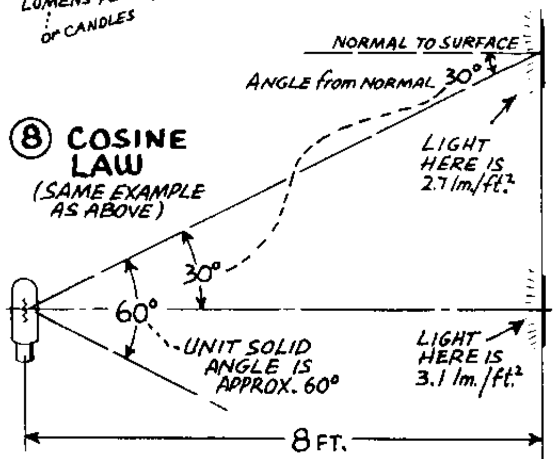
TOTAL FLUX. A lamp rated in lumens means the total flux emitted by the lamp in all directions. Opposite to this, a candlepower rating means the light intensity in some specific direction, usually the light in unit solid angle. See Figs. 5 and 6. Various other ways of rating lamps often have a touch of ballyhoo, making the lamp appear brighter than it really is.




**⑦ INVERSE SQUARE LAW**

Formula: $E = \frac{I}{d^2}$ (I ... INTENSITY PER UNIT SOLID ANGLE; d ... DISTANCE IN FT.; E ... ILLUMINATION IN LUMENS PER SQ. FT. or CANDLES)

Ex: $E = \frac{200}{8^2} = 3.1$ lm/ft²




**⑧ COSINE LAW** (SAME EXAMPLE AS ABOVE)

FOR LIGHT NORMAL TO SURFACE: E = 3.1 LUMENS PER SQ. FT. (from FIG. 7)

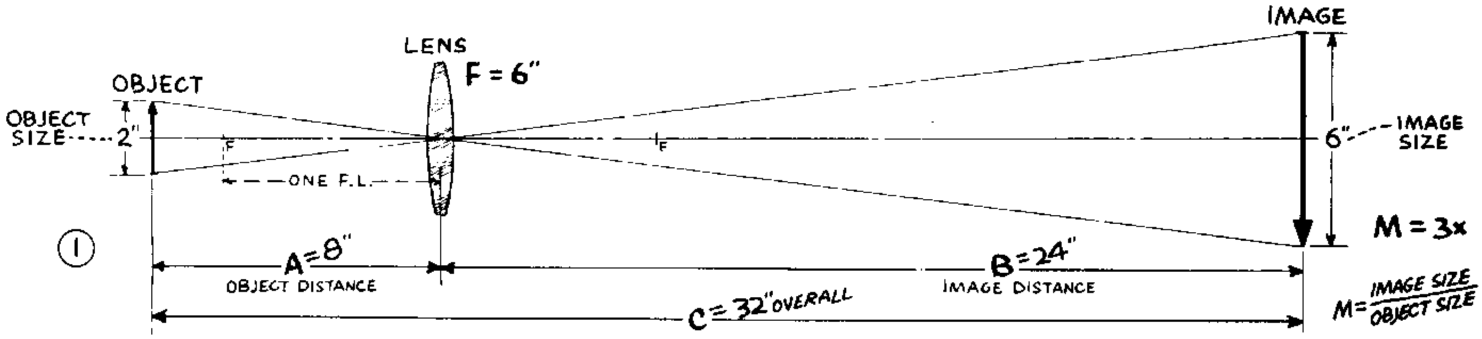
FOR LIGHT 30° from NORMAL: E = 3.1 × .87 (cos 30°) = 2.7 LUMENS PER SQ. FT.

**COSINE LAW COMBINED with INVERSE SQUARE LAW:**

$E = \frac{I \times \cos}{d^2}$ Ex: $\frac{200 \times .87}{8^2} = \frac{174}{64} = 2.7$

**COSINE FACTORS**

| ANGLE | COS |
|---|---|
| 10° | .98 |
| 20° | .94 |
| 25° | .91 |
| 30° | .87 |
| 35° | .82 |
| 40° | .77 |
| 45° | .71 |
| 50° | .64 |
| 55° | .57 |
| 60° | .50 |
| 65° | .42 |
| 70° | .34 |
| 75° | .26 |
| 80° | .17 |
| 85° | .08 |
| 90° | .00 |




# OBJECT-IMAGE MATH

BY FAR the most common object-image situation is where the object is more than one focal length from the lens, as shown in Fig. 1 example. We call this a Case 1 situation. Case 1 problems are easily solved by simple arithmetic--if you know any two of the four quantities involved, you can calculate the other two. A and B dimensions are interchangeable, and when you do this the overall distance, C, remains the same but the magnification becomes the reciprocal of the original magnification. In the 3x example shown in Fig. 1, M. would become 1/3x if you switched the dimensions. Usually Case 1 is a projection problem--you want the image larger than the object.

LIMIT FOR CASE 1. The limit for Case 1 is where the object is one f.l. from the lens, Fig. 2. From the nature of the simple diagram used to illustrate this, you may get the idea that a spotlight arranged in this fashion would produce a parallel "beam" of light. This would be true

**Case I** OBJECT MORE THAN ONE F.L. from LENS

| | | Example AS ABOVE |
|---|---|---|
| 1 | $B = (M+1) \times F$ | $B = (3+1)6 = 4 \times 6 = 24''$ |
| 2 | $B = \frac{F \times A}{A - F}$ | $B = \frac{6 \times 8}{8-6} = \frac{48}{2} = 24''$ |
| 3 | $B = A \times M$ | $B = 8 \times 3 = 24''$ |
| 4 | $A = \frac{B}{M}$ | $A = \frac{24}{3} = 8''$ |
| 5 | $A = \frac{F}{M} + F$ | $A = \frac{6}{3} + 6 = 2+6 = 8''$ |
| 6 | $A = \frac{F \times B}{B - F}$ | $A = \frac{6 \times 24}{24-6} = \frac{144}{18} = 8''$ |
| 7 | $M = \frac{B}{A}$ | $M = \frac{24}{8} = 3\times$ |
| 8 | $M = \frac{F}{A - F}$ | $M = \frac{6}{8-6} = \frac{6}{2} = 3\times$ |
| 9 | $M = \frac{B - F}{F}$ | $M = \frac{24-6}{6} = \frac{18}{6} = 3\times$ |
| 10 | $F = \frac{A \times M}{M+1}$ | $F = \frac{8 \times 3}{3+1} = \frac{24}{4} = 6''$ |
| 11 | $F = \frac{B}{M+1}$ | $F = \frac{24}{3+1} = \frac{24}{4} = 6''$ |
| 12 | $F = \frac{A \times B}{A + B}$ | $F = \frac{8 \times 24}{8+24} = \frac{192}{32} = 6''$ |

*Formulas* INVOLVING *Overall* **C** . . . MAY SHOW SLIGHT ERRORS SINCE A *Plus* B DOES NOT ALWAYS EQUAL C

| | | |
|---|---|---|
| 13 | $A = \frac{C}{M+1}$ | $A = \frac{32}{3+1} = \frac{32}{4} = 8''$ |
| 14 | $B = \frac{M \times C}{M+1}$ | $B = \frac{3 \times 32}{3+1} = \frac{96}{4} = 24''$ |
| 15 | $F = \frac{C \times M}{(M+1)^2}$ | $F = \frac{32 \times 3}{(3+1)^2} = \frac{96}{16} = 6''$ |
| 16 | $C = \frac{F(M+1)^2}{M}$ | $C = \frac{6(3+1)^2}{3} = \frac{\overset{2}{\cancel{6}} \times 16}{\cancel{3}} = 32''$ |
| 17 | $C = \frac{B(M+1)}{M}$ | $C = \frac{24(3+1)}{3} = \frac{\overset{8}{\cancel{24}} \times 4}{\cancel{3}} = 32''$ |
| 18 | $C = A \times (M+1)$ | $C = 8(3+1) = 8 \times 4 = 32''$ |

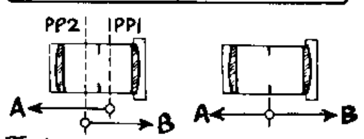
**OBJECT-IMAGE INDEX**

| IF you Know | FIND with |
|---|---|
| F and A | M . . . 8<br>B . . . . 2 |
| F and B | M . . . 9<br>A . . . . 6 |
| F and M | A . . . . 5<br>B . . . . 1 |
| M and A | F . . . . 10<br>B . . . . 3 |
| M and B | F . . . . 11<br>A . . . . 4 |
| A and B | M . . . 7<br>F . . . . 12 |

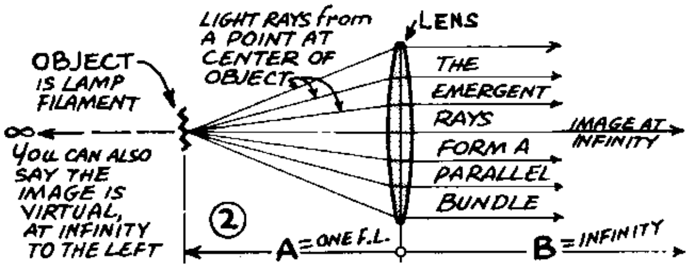
*USE THIS INDEX FOR BASIC EQUATIONS NO. 1 to NO. 12 for either CASE 1 or CASE 2*

**. . . for EQUATIONS with C - you must know M**

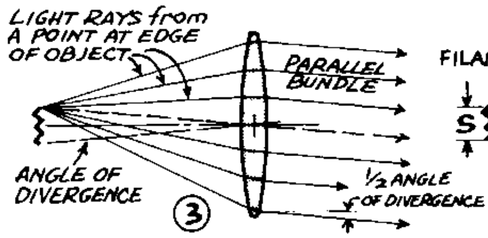
| IF you KNOW | FIND with |
|---|---|
| C and M | A . . . . 13<br>B . . . . 14<br>F . . . . 15 |
| F and M | C . . . . 16 |
| B and M | C . . . . 17 |
| A and M | C . . . . 18 |

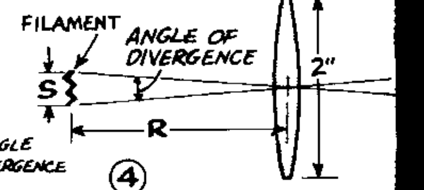



*Technically, A and B SHOULD BE SET OFF from the PRINCIPAL PLANES, but MEASURING TO CENTER OF LENS SYSTEM IS USUALLY CLOSE ENOUGH*




**LIMIT for CASE 1 or CASE 2: A = F**




**Angle of Divergence** = $\frac{S}{R}$ *Radians*

**Example:** S = ¼" and R = 6" ········> $6\overline{).25}$ .04 Rad.

**IF** *the light is projected, say,* 10 FT. (120")

*then* **LIGHT SPREAD** = 120 × .04 = 4.8 *in.*

*Plus Lens Diameter* 2.0 *in.*

*DIA. OF LIGHT BEAM at 10 ft.* 6.8 *inches*

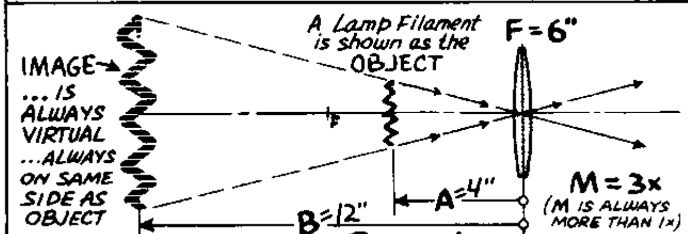
only if you had a true "point" source of light. Of course there is no such thing--any lamp filament however tiny must have physical size to be seen at all. Now, the light rays from a point at the edge of the filament will produce another bundle of parallel rays, but this bundle will not be parallel to the axial bundle, Fig. 3. You can see that the whole cone of light will be diverging, but the light itself is optically parallel or collimated light. An optical bench collimator is a familiar example of an instrument using parallel light.

The whole angle of divergence is embraced by lines drawn from the lamp filament to the center of the lens, Fig. 4. One-half of this is the divergence on one side of the axial bundle. Using a simple radian calculation, you can calculate the divergence in radians and then convert this to linear measure in the manner shown. Radian values should be carried out to four decimal places for exactness, but two places is good enough for a first approximation.

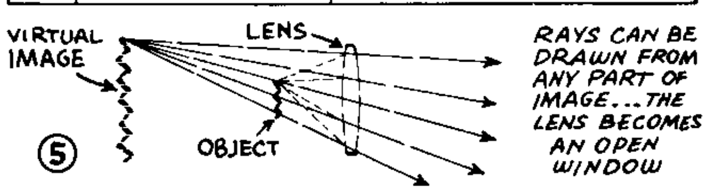
CASE 2. This covers the situation where the object is less than one focal length from the lens. A common example is the optical system of a spotlight or floodlight--the emergent rays are definitely spreading, including also the axial bundle. For the Case 2 situation, A and B dimensions are not reversible; M. is always more than 1x, and the image is always a virtual one. A virtual image is not real--you can see it and you can see that the light rays seem to come from it, but you can't touch it and you can't capture the image on a sheet of paper or film. You see a virtual image everytime you look in a mirror.

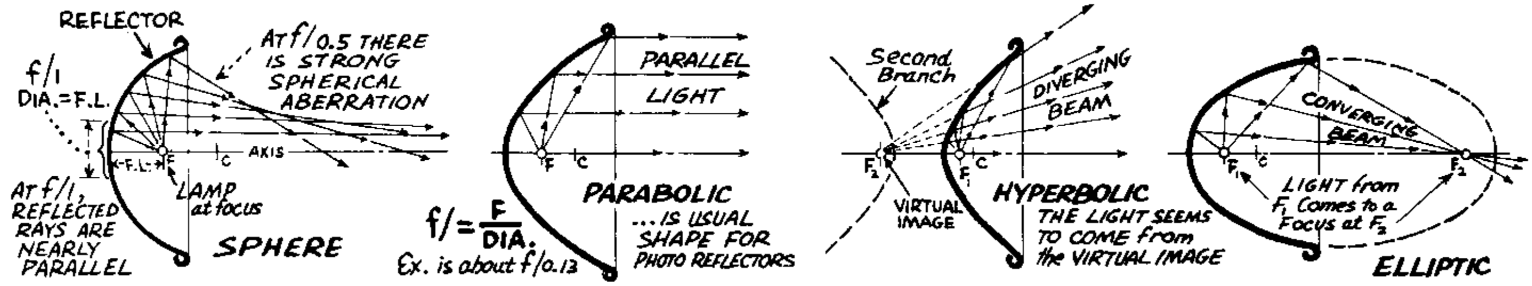
It can be seen that the limit for Case 2 is identical with Case 1. The various equations become useless but also unnecessary. If you want an extreme but workable example of Case 2, you would make the object distance, A, just a hair less than one focal length. Then the virtual image would be highly magnified and far off to the left. Similarly, an extreme example of Case 1 is where object distance A is a trifle more than one focal length. Then you get a real image highly magnified and far off to the right.

## Case 2 — OBJECT LESS THAN ONE FOCAL LENGTH from LENS



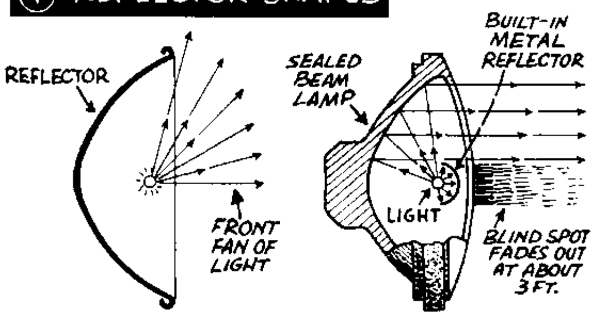

| | | Example |
|---|---|---|
| 1 | $B = (M-1) \times F$ | $B = (3-1)6 = 2 \times 6 = 12''$ |
| 2 | $B = \frac{F \times A}{F - A}$ | $B = \frac{6 \times 4}{6-4} = \frac{24}{2} = 12''$ |
| 3 | $B = A \times M$ | $B = 4 \times 3 = 12''$ |
| 4 | $A = \frac{B}{M}$ | $A = \frac{12}{3} = 4''$ |
| 5 | $A =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



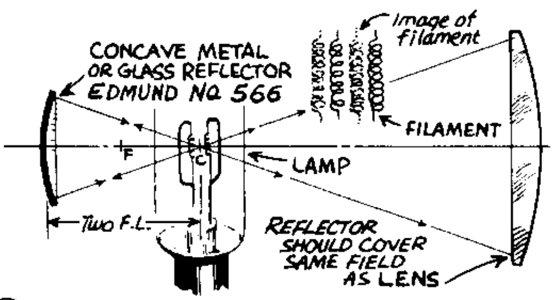



① REFLECTOR SHAPES

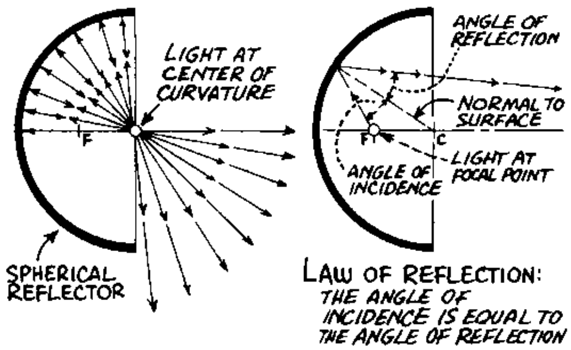
# REFLECTORS and Condensers




② TINY REFLECTOR CAPTURES FRONT FAN




③ PCX SPOT USES REFLECTOR AT LAMP




④ SPHERICAL REFLECTOR for WIDE FLOOD

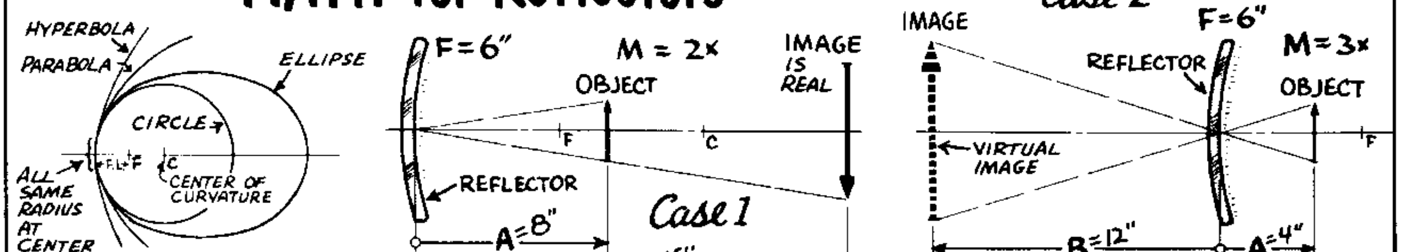
IN THE same manner as a lens, if you put a light at the primary focal point of either a spherical or parabolic reflector, the emergent beam will be a parallel bundle. If the lamp is placed ahead of the focal point, you have a Case 1 situation and the filament image position can be calculated with Case 1 equations. If the lamp is placed inside focus, the optical situation is Case 2.

Everybody knows there is only one shape for a circle. Less known is the fact that all parabolas have the same shape--the only variable is size. However, hyperbolic and elliptic reflectors vary in shape--fat to skinny--as well as size. Commercial reflectors as used for photography, store and street lighting, etc., also use the four standard shapes shown in Fig. 1, but usually with no great degree of precision. In fact, few photographers even know their parabolic reflectors have a focal length at all.

PARALLEL BEAM. While the parabolic reflector can produce a parallel beam, it will be apparent there is a wide fan of front light which spoils the effect, Fig. 2. One remedy for this fault is a small metal reflector placed ahead of the filament. Lamp manufacturers do this to produce narrow-beam spotlights; the blind spot caused by the small reflector is not seen except very close to the lamp.

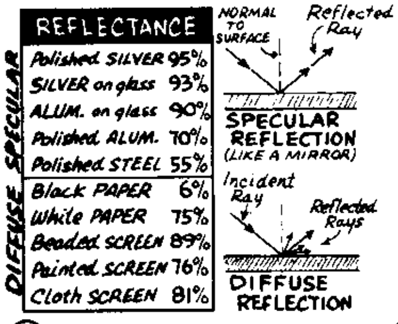
This same idea is also used for spotlights, Fig. 3, where it nearly doubles the light output. The small reflector is located two focal lengths from the lamp filament and so

## OBJECT-IMAGE MATH for Reflectors

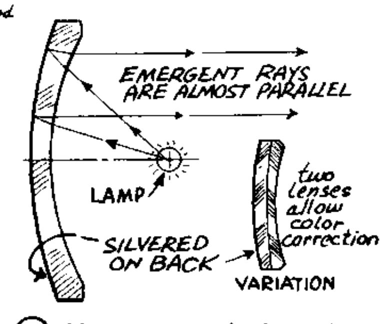



THE F.L. OF ANY REFLECTOR—SPHERE, ELLIPSE, PARABOLA OR HYPERBOLA—IS ½ THE RADIUS AT THE CENTER ZONE

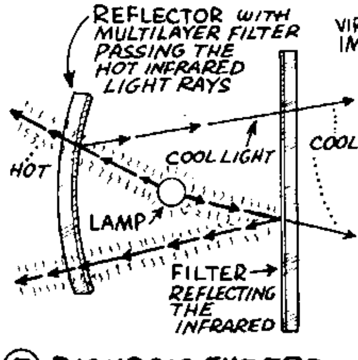
*USE OBJECT-IMAGE EQUATIONS Nos. 1 to 12 as NEEDED*



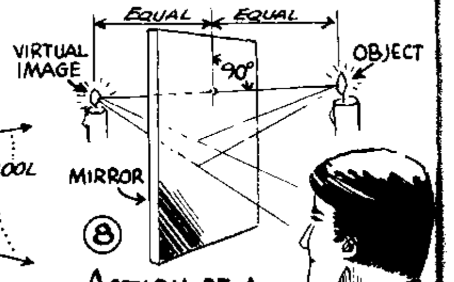

⑤ KIND OF SURFACE




⑥ MANGIN MIRROR




⑦ DICHROIC FILTERS



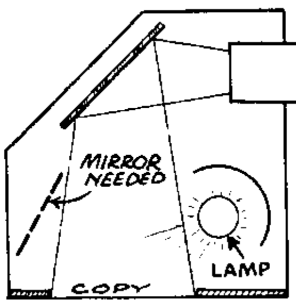

ACTION OF A PLANE MIRROR
THE IMAGE IS DIRECTLY OPPOSITE OBJECT and AS FAR BEHIND THE MIRROR AS OBJECT IS IN FRONT OF IT

reflects light directly back to the filament, forming an image of the filament on the filament itself. If you apply this same idea to a large open reflector, the result is an extremely wide beam, Fig. 4. If you move the light back to the focal point, the emergent light will be parallel, subject to spherical aberration. Almost everybody knows the law of reflection, and if you apply this with compass to a scale diagram of a spherical reflector, you can see exactly how S.A. increases for the marginal rays, Fig. 4.

SURFACE FINISH. Glass and highly-polished metal produce a specular reflection, that is, a reflection like a mirror, hard and sharp. The opposite to this--a soft diffuse reflection with more or less scattering of light is obtained with semi-polished metal, frosted glass, paint, cloth, etc. The approximate reflectance of some common finishes is listed in Fig. 5.

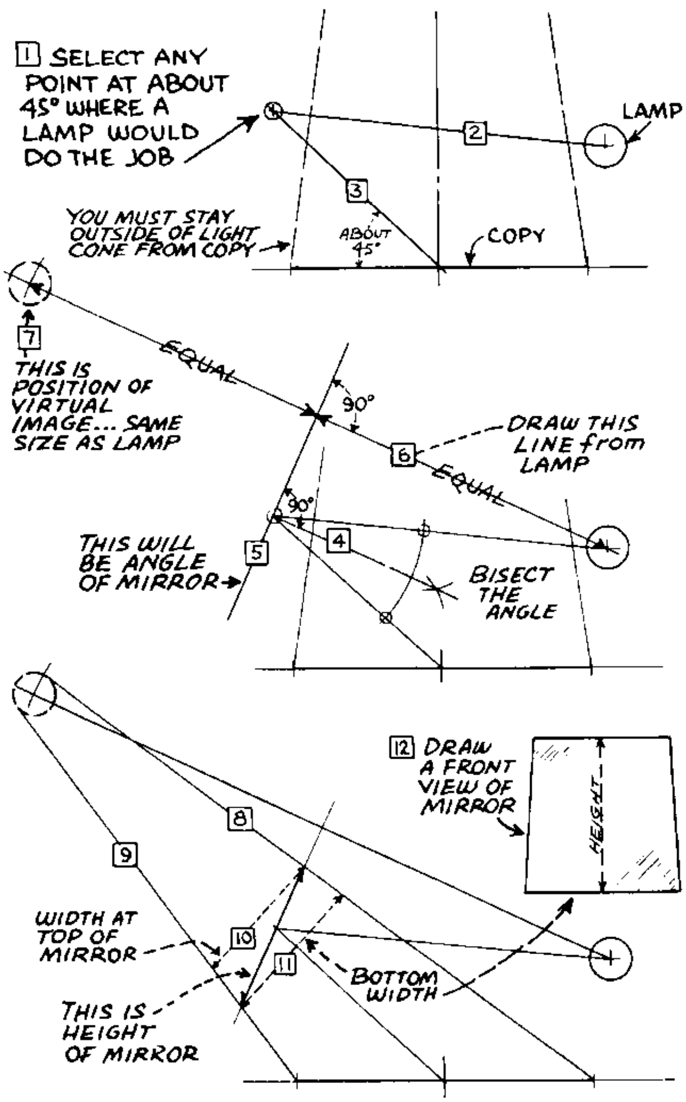
THE MANGIN MIRROR. Some optical systems consist of both refracting and reflecting surfaces. Simplest of such catadioptric systems is the Mangin mirror, Fig. 6, which is a meniscus lens of special shape silvered on its back side. The mirror itself is spherical, and as such would show spherical aberration; the lens is curved to minimize this fault. The net result is a narrow beam suitable for a lensless spotlight.

DICHROIC FILTERS. The word dichroic (dye-CROW-ick) means two colors. Filters of this kind can transmit one or more colors while saying "no go" to other colors. As applied to reflectors, the main application is getting rid of the hot infrared light rays in movie and still projectors. The typical example shown in Fig. 7 shows the reflector passing the infrared while reflecting the visible rays; the flat front filter does just the opposite, passing the visible but bouncing the infrared. All this is done by optical **interference**, using a **multilayer** coating of various materials. An ordinary filter gets rid

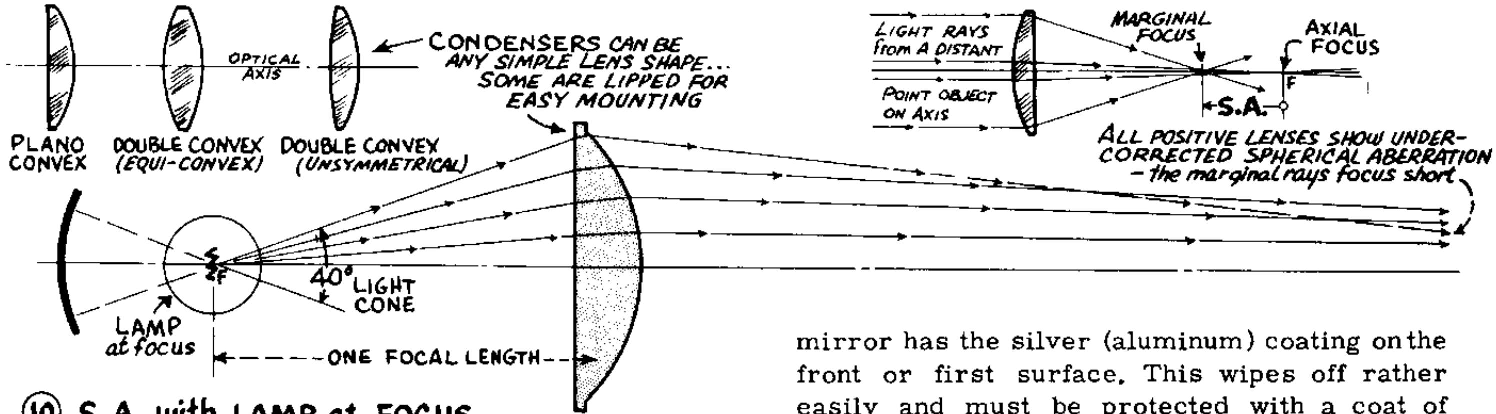



THIS TABLETOP OPAQUE PROJECTOR HAS A SINGLE LAMP IN THE POSITION SHOWN

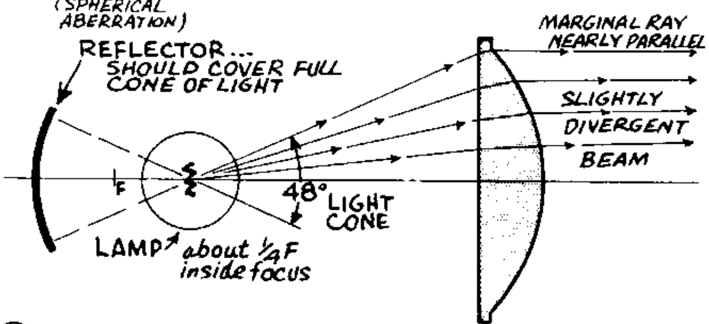
Problem: WHERE WOULD YOU PLACE A MIRROR TO LIGHT FAR SIDE OF COPY?



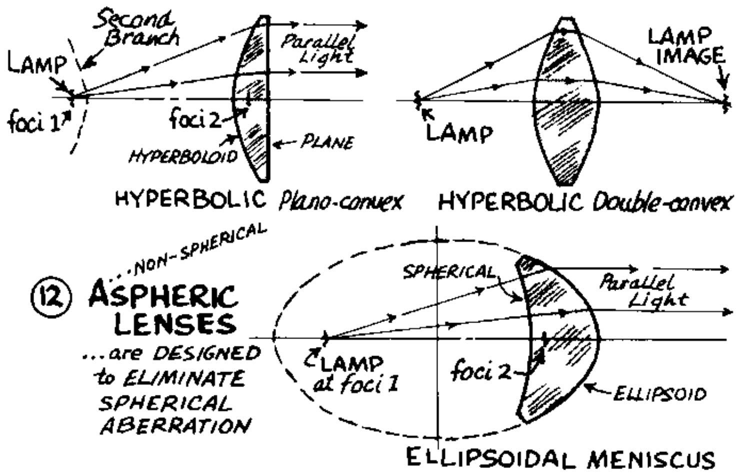

⑨ POSITION and SIZE of a PLANE REFLECTOR




(10) S.A. with LAMP at FOCUS
(SPHERICAL ABERRATION)




(11) CONDENSER ACTION with LAMP INSIDE FOCUS
THE SPHERICAL FAULT IS COUNTERBALANCED BY DIVERGING ACTION OF LENS IN THIS POSITION




(12) ASPHERIC LENSES ...are DESIGNED to ELIMINATE SPHERICAL ABERRATION

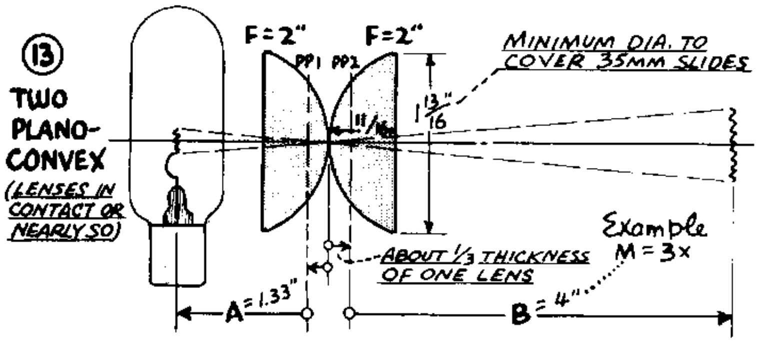
of heat by absorbing it, and in doing this it becomes very hot itself. The dichroic filter keeps its cool, changing the spectral characteristics of the light in such a way as to shunt the infrared out of the system--no light is absorbed by the filter. Dichroic filters are built-in on many projection lamps.

PLANE REFLECTORS. Plane reflectors are usually mirrors. The conventional mirror has the silvering on the back surface, protected by a copper or paint coating. This kind of mirror --second surface--is satisfactory when you are dealing only with illumination. If there is a projected image involved, a first surface mirror is preferable. Like it sounds, a first surface mirror has the silver (aluminum) coating on the front or first surface. This wipes off rather easily and must be protected with a coat of silicon monoxide or magnesium fluoride. With the overcoat, a first surface mirror will last indefinitely if treated like fine china.

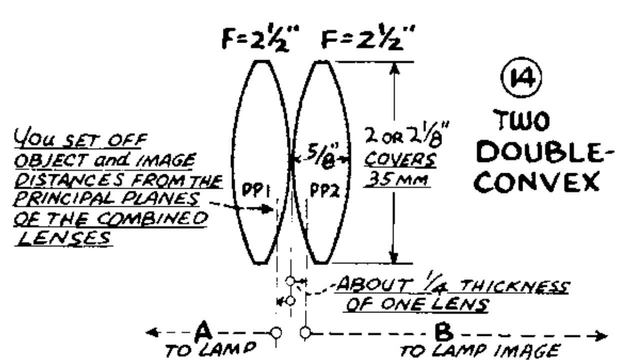
The action of a plane mirror in producing an image is shown in Fig. 8. The image is virtual and is directly opposite the object; the image is as far behind the mirror as the object is in front of it; the light seems to come from the virtual image. How this action is applied to an actual job is shown in Fig. 9, which shows the placement and size of a plane mirror reflector for an opaque projector. Obviously the mirror gets rid of a second lamp and so eliminates a good measure of heat from the instrument.

CONDENSERS. Condensers are simple lenses and differ from other simple lenses only in that they are usually the cheapest kind of lenses, usually just moulded to shape sans polishing, centering or edging. It is true you can buy precision-ground condensing lenses--but you pay for them. There is also another side to this story--low-grade moulded and fire polished condensers are sometimes sold as precision lenses. The usual condenser is plano-convex although the double convex is nearly as popular. The lenses are often sold in pairs, often mounted.

The worst fault of the average condensing lens is that it has lots of spherical aberration. S.A. is measured by the axial intercepts of a distant point object, as shown in the small sketch, Fig. 10. In the usual application, the light direction is reversed, starting at the primary focus where the light source is located, Fig. 10. As can be seen, the marginal rays converge much more than light rays nearer the axis. The criss-crossing light rays reinforce at various distances, producing zonal defects in the light pattern. Now, if you put the lamp about 1/4 of the focal length inside focus, you will have the familiar case where the light should in theory diverge in a wide fan. But now it has to fight the S.A., and the sum of the two faults is a fairly clean beam of light, Fig. 11. The needed lamp adjustment is provided in most spotlights.




E.F.L. = ½ F.L. OF ONE LENS Ex: ½ of 2" = 1"




E.F.L. = ½ F.L. OF ONE LENS Ex: ½ OF 2½" = 1¼"

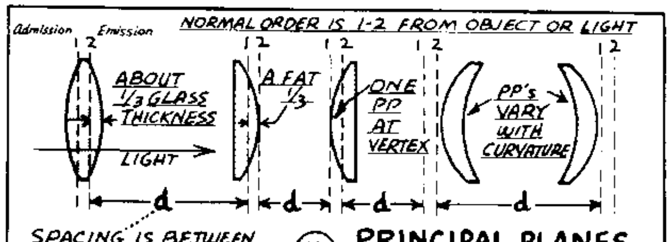
ASPHERIC LENSES. Non-spherical curves are used to eliminate spherical aberration in simple condensers. A few of the common shapes are shown in Fig. 12, the hyperbolic plano-convex being the most popular. As shown in the diagram, if a lamp is placed at one of the conjugate focal points, the emergent light will be parallel--no spherical aberration. While ordinary condensers can be used with any pair of conjugate distances, the aspheric lens should be used only for the specific foci it is designed for. If you depart from this condition, the S.A. will reappear. Of course the aspheric surface shows color faults just like an ordinary lens; also, the aspheric will show bad zonal defects if not mounted in proper alignment. Aspheric condensers while sound in theory are still a long way from popular acceptance.

PAIRED CONDENSERS. When you put two condensers together in contact, you cut the focal length in half and the S.A. is only a quarter as much, Fig. 13. This is the lighting system of a small 35mm slide projector. When condensers are this close to the lamp, it is a good idea to have at least the closest one of heat absorbing glass.

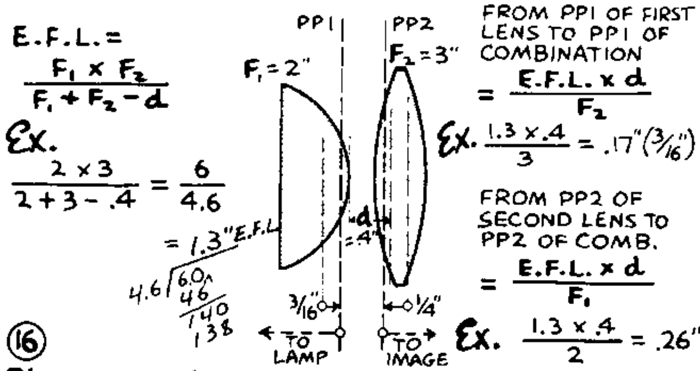
Double-convex lenses, Fig. 14, will usually permit larger-diameter lenses. Lenses can be an odd pair, Fig. 16. This example also gives the formulas for finding tne e.f.l. of any two lenses and also the location of the principal planes which are used for measuring purposes.

Lamp filament magnification in the afocal setup, Fig. 17, is obtained by the difference in focal lengths. The space between lenses is free optical space and can be any distance needed. This kind of system is often used for overhead projectors.

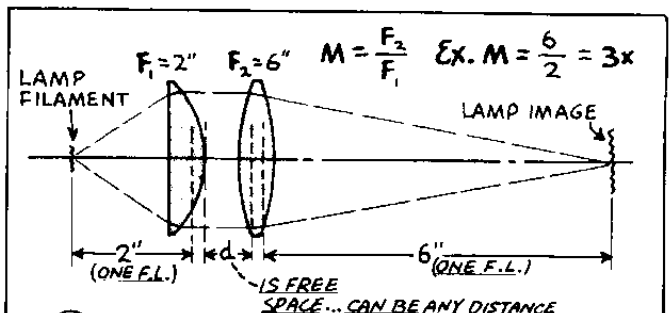
A common problem in condenser systems is to get a two-lens combination big enough yet short enough in f.l. for the job. Sometimes you will have to use three lenses, Fig. 13. If in contact, the e.f.l. can be easily calculated by the method shown.



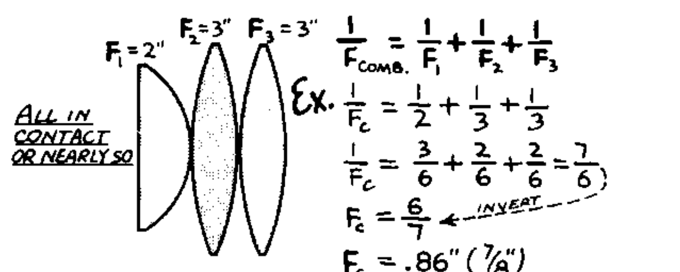

15 PRINCIPAL PLANES OF SIMPLE LENSES



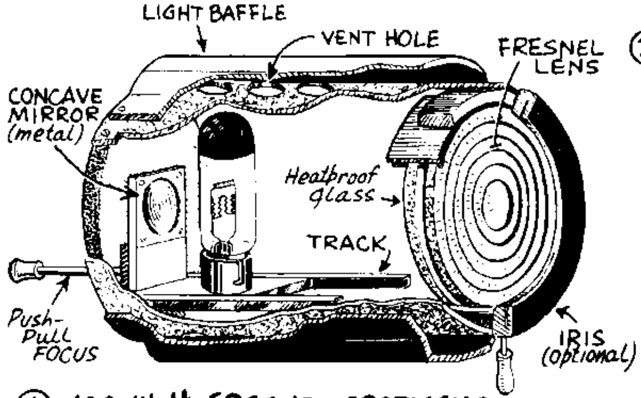

The General Case:
E.F.L. and PP's of TWO LENSES




17 AFOCAL CONDENSER SYSTEM




18 THREE LENSES CAN BE USED

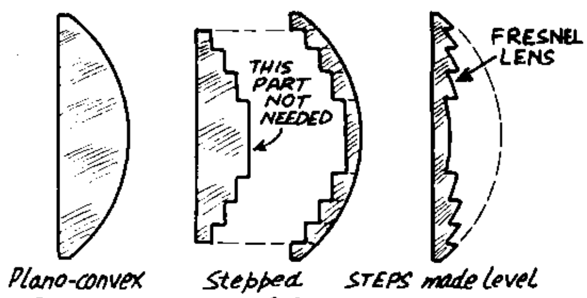



① 100-Watt FRESNEL SPOTLIGHT

② Larger Condensers

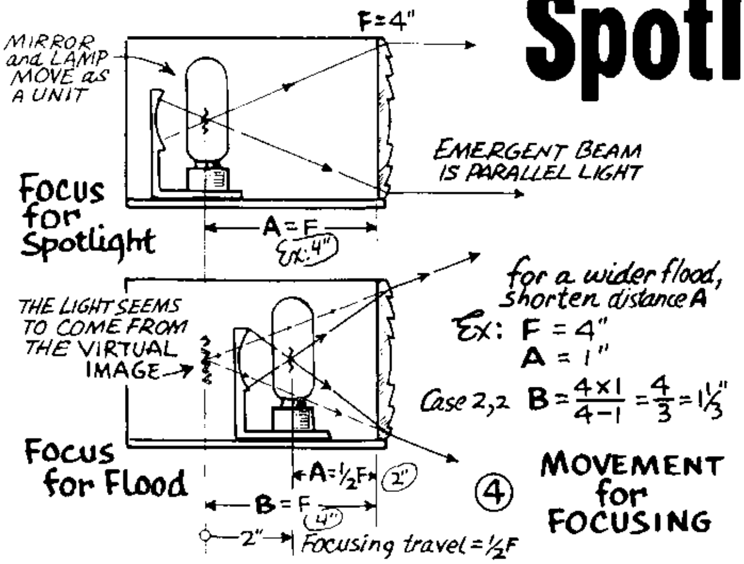
| Plano-convex DIA. | Plano-convex F.L. | FRESNEL DIA. | FRESNEL F.L. |
|---|---|---|---|
| 3" | 4" 4½ | 3" | 2¼" 3 |
| 3½" | 5 | 4½" | 4 4¼ |
| 4½" | 6½ | 5" | 3½ |
| 5" | 7 8 | 6" | 3½ |
| 6" | 9 | 8" | 4½ |
| 6½" | 10 | ...also many LARGER SIZES in Plastic | |
| 7"* | 10 | | |

*also LARGER SIZES




③ EVOLUTION of the FRESNEL LENS

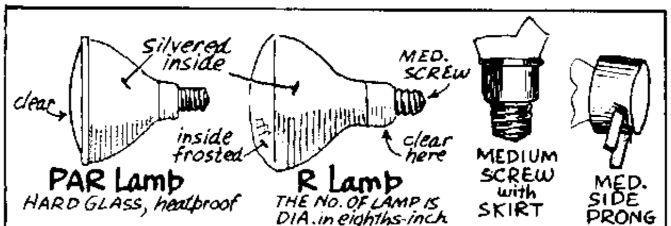
# Spotlights and Floods




④ MOVEMENT for FOCUSING

IN THE familiar PAR and R reflectorized lamps, you have the simplest kind of spotlight or floodlight--all you need is a socket. Fig. 5 is a partial list selected from about 60 available lamps. Since the lamps are silvered on the inside, the use of a standard reflector contributes nothing. Some sockets for reflectorized lamps have a partial shade which is deep enough to cover the bare glass seen at the necks of some lamps. This minor fault is eliminated in some lamps by a skirt on the base itself.

FRESNEL SPOTLIGHT. The Fresnel spotlight is common in stage lighting, the 6 to 12-in. diameter sizes being most popular. The lens itself is collapsed in shape to get the same optical effect as a thick plano-convex without the bulk, Fig. 3. Fresnel spotlights produce a soft light which is often further softened by a textured surface on the flat side of the lens. The




⑤ Reflectorized PAR and R LAMPS

**PAR SPOTLIGHTS**

| WATTS | BULB | BASE | O.A. LENGTH | BEAM | LUMENS in BEAM | TOTAL LUMENS | AXIAL Candles | HRS. LIFE |
|---|---|---|---|---|---|---|---|---|
| 75 | PAR 38 | MED SKIRT | 5 5/16" | 30° | 465 | 750 | 3800 | 2000 |
| 150 | PAR38 △3 | MED SKIRT | 5 5/16 | 30° | 1100 | 1725 | 11000 | 2000 |
| 150 | PAR 38 | SIDE PRONG | 4 5/16 | 30° | 1100 | 1725 | 11000 | 2000 |
| 200 | PAR46 | SIDE PRONG | 4 | 17°×23° | 1200 | 2325 | 32000 | 2000 |
| 250 | PAR38 △2 | MED SKIRT | 5 5/16 | 26° | 1600 | 3200 | 25000 | 4000 |

**PAR FLOODLIGHTS**

| WATTS | BULB | BASE | O.A. LENGTH | BEAM | LUMENS in BEAM | TOTAL LUMENS | AXIAL Candles | HRS. LIFE |
|---|---|---|---|---|---|---|---|---|
| 75 | PAR38 | MED SKIRT | 5 5/16" | 60° | 570 | 750 | 1500 | 2000 |
| 150 | PAR 38 △3 | MED SKIRT | 5 5/16 | 60° | 1350 | 1725 | 3700 | 2000 |
| 150 | PAR 38 | SIDE PRONG | 4 5/16 | 60° | 1350 | 1725 | 3700 | 2000 |
| 200 | PAR46 | SIDE PRONG | 4 | 20°×40° | 1300 | 2300 | 11000 | 2000 |
| 250 | PAR38 △2 | MED SKIRT | 5 5/16 | 60° | 2400 | 3200 | 6500 | 4000 |

**R SPOTLIGHTS**

| WATTS | BULB | BASE | O.A. LENGTH | BEAM | LUMENS in BEAM | TOTAL LUMENS | AXIAL Candles | HRS. LIFE |
|---|---|---|---|---|---|---|---|---|
| 75 | R30 | MED SCREW | 5 3/8" | 50° | 400 | 850 | 1700 | 2000 |
| 150 | R40 | MED SCREW | 6½ | 37° | 825 | 1825 | 7000 | 2000 |
| 300 | R40 | MED SCREW | 6½ | 35° | 1800 | 3600 | 13000 | 2000 |
| 300 | R40 △1 | MED SCREW | 6 7/8 | 35° | 1800 | 3600 | 13000 | 2000 |

**R FLOODLIGHTS**

| WATTS | BULB | BASE | O.A. LENGTH | BEAM | LUMENS in BEAM | TOTAL LUMENS | AXIAL Candles | HRS. LIFE |
|---|---|---|---|---|---|---|---|---|
| 75 | R 30 | MED SCREW | 5 3/8" | 130° | 610 | 850 | 425 | 2000 |
| 150 | R40 | MED SCREW | 6½ | 110° | 1550 | 1825 | 1200 | 2000 |
| 300 | R40 | MED SCREW | 6½ | 115° | 3000 | 3600 | 2500 | 2000 |
| 300 | R40 △1 | MED SCREW | 6 7/8 | 115° | 3000 | 3600 | 2500 | 2000 |

△1 HEAT-RESISTING
△2 HALOGEN
△3 Also with DICHROIC REFLECTOR

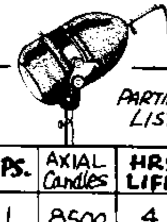
LARGER SIZES TO R60 and PAR64 (1000 Watts) ARE USUALLY MOGUL BASE, HALOGEN light is usually spotty in a short-range focus, hence the usual focusing range is made all "flood" or diverging, the "spotlight" being merely the narrowest flood. A practical focusing range can be obtained in a movement of one-half the focal length of the lens, Fig. 4.

PHOTOFLOOD LAMPS. For photography, ordinary or standard photofloods are still very much in use despite newer and brighter lamps. Photofloods are simply inside-frosted household lamps, but over-volted to get more light. Of course they also burn out much faster. The lamps should be used in reflectors for best light pickup and distribution. However, spotlights using a condensing lens system usually have dark interiors, the whole light pickup being done by the lens. Focusing is done with a push-pull slide action of the lamp, the focusing movement being the same as for Fresnel spotlights.

ELLIPSOIDAL SPOTLIGHT. This is a stage spotlight, named from the fact it has an ellipsoidal reflector. The second foci some distance in front of the lamp becomes the source for the condensing system or other front lens. This kind of spotlight can be used for pattern or shadow effects and it will project a clean disk of light with sharp edges if fitted with an iris or aperture a little behind the second foci.

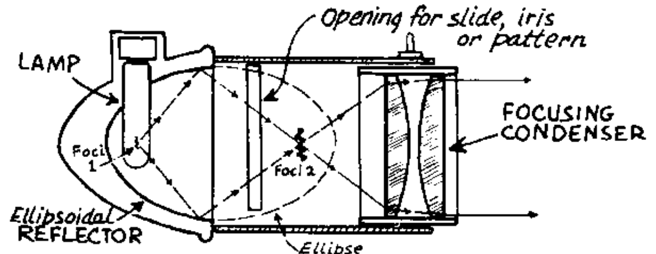
BLOWER NEEDED. When you get up to 500 watts or more, it is usually necessary to use a blower. An exception is certain large-diameter lamps like the 500-watt DMS which can be used without a fan. The more common "skinny" projection lamp is often consumed by its own heat, causing it to bulge and blow. Fig. 8 shows a blower directing cooled air toward the lamp; equally effective is a blower exhausting at the side or top of the lighthouse and thus drawing cool air from below. Edmund fan motors Nos. 101 and 60,689 may be used.

⑥ Photoflood LAMPS — PARTIAL LIST



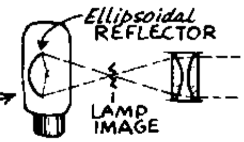
| | TRADE No. ANSI | TRADE No. other | WATTS | BASE | AMPS. | AXIAL Candles | HRS. LIFE |
|---|---|---|---|---|---|---|---|
| standard *inside frosted* | BBA | #1 | 250 | Med. Sc. | 2.1 | 8500 | 4 |
| | EBV | #2 | 500 | Med. Sc. | 4.2 | 17000 | 8 |
| Photocopy [1] | — | C-300 Syl. | 300 | Med. Sc. | 2.5 | — | 20 |
| Reflector-ized | DAN | R-20 | 200 | Med. Sc. | — | 7500 | 4 |
| | BEP [2] | R-30 | 300 | Med. Sc. | 3.1 | 16000 | 4 |
| | — | R-32 | 375 | Med. Sc. | 3.3 | 14000 | 15 |
| | FAE | — | 550 | Med. Sc. | — | 18000 | — |

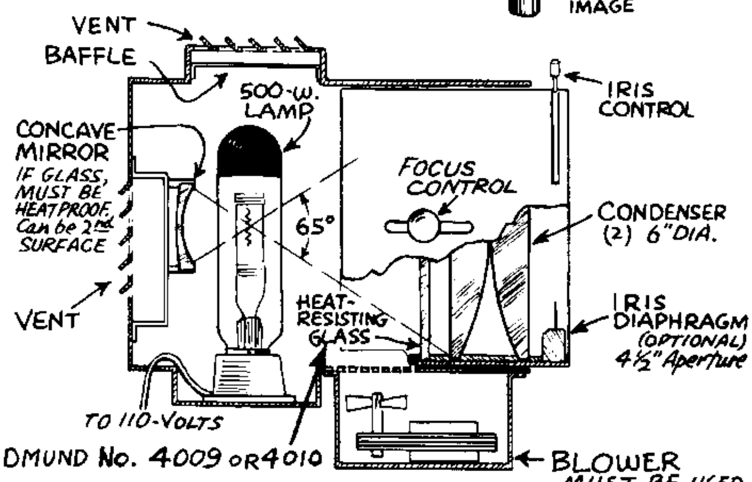
[1] LIKE No. 1 but longer life [2] EBR is similar




⑦ ELLIPSOIDAL SPOTLIGHT or Pattern Spotlight

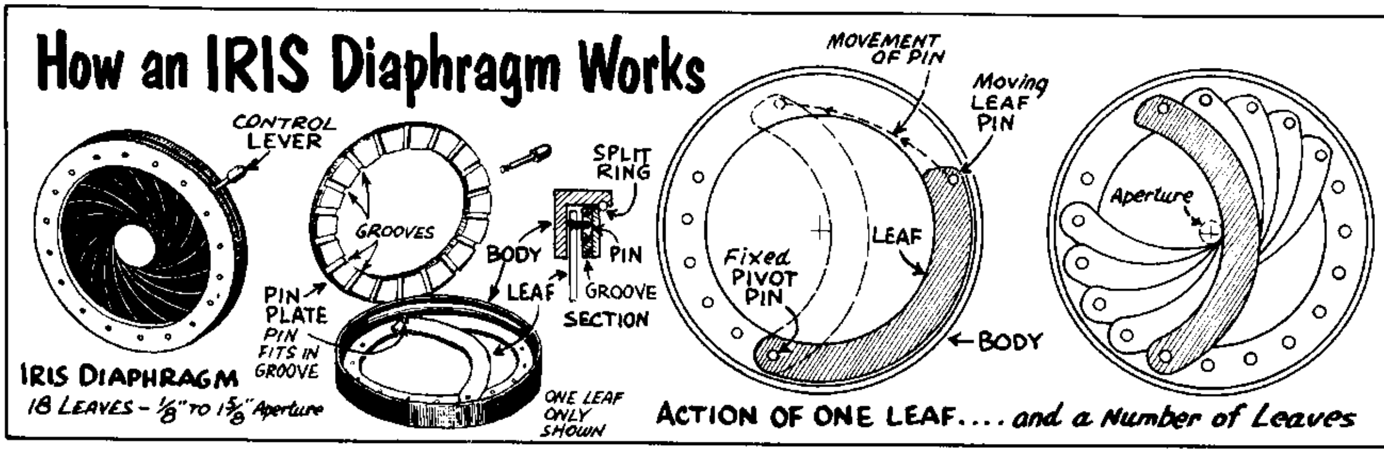
A SIMILAR SETUP CAN BE MADE WITH CERTAIN PROJECTION LAMPS



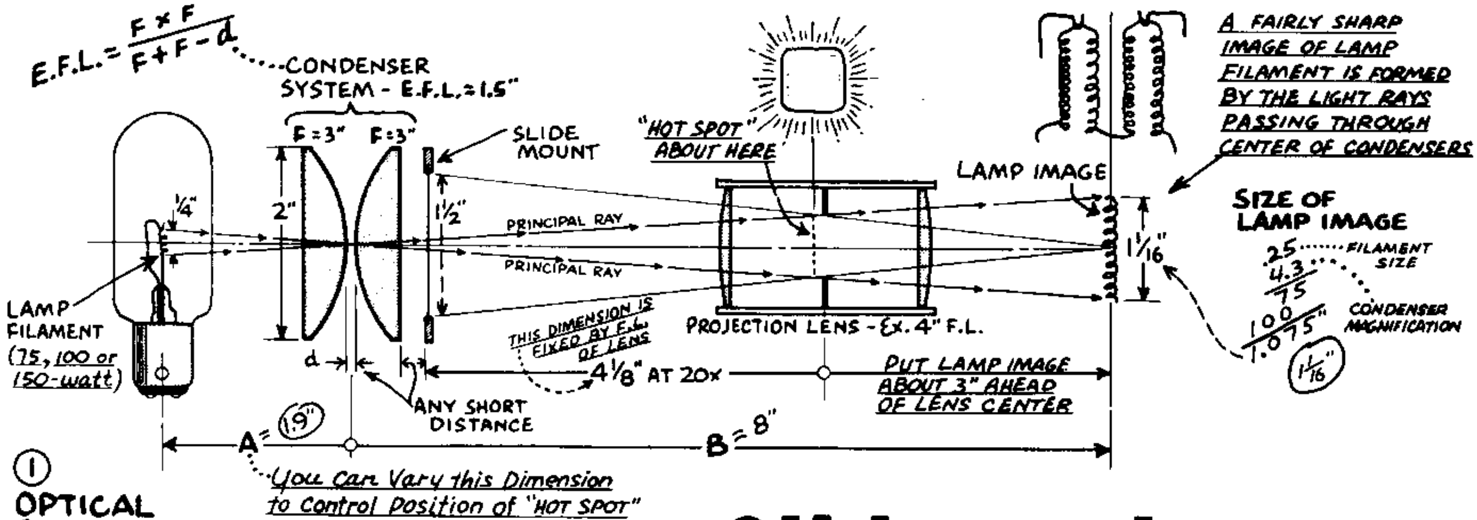




⑧ 500-WATT SPOTLIGHT

# How an IRIS Diaphragm Works

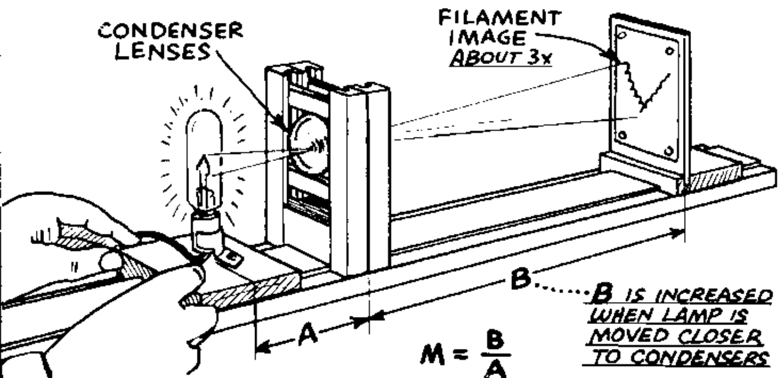



ACTION OF ONE LEAF.... and a Number of Leaves

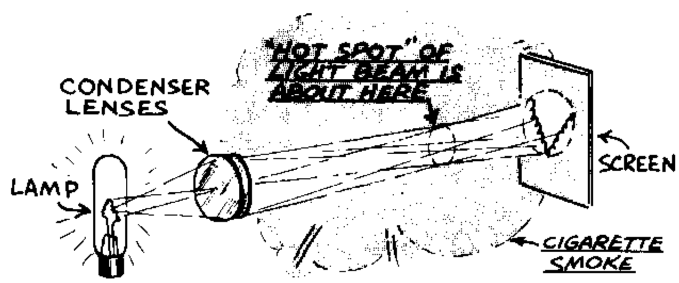



① OPTICAL SYSTEM

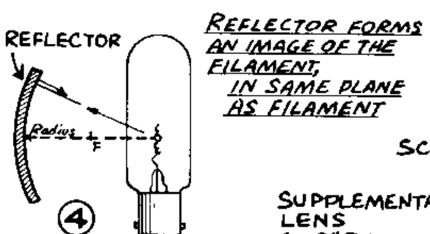
# Slide projectors



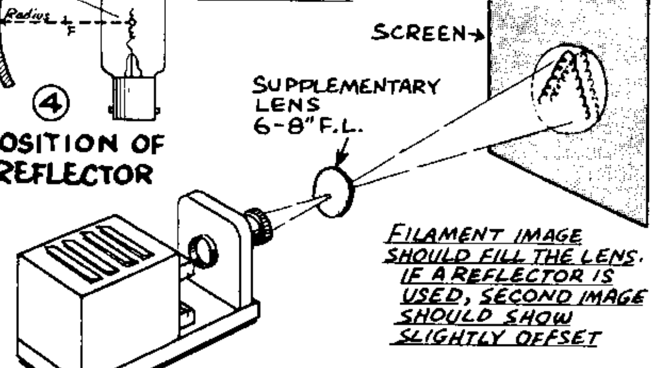

② TEST SETUP SHOWS ACTION OF CONDENSERS




③ SMOKE REVEALS SHAPE OF LIGHT CONE




④ POSITION OF REFLECTOR




⑤ TESTING WITH SUPPLEMENTARY LENS

THE FAMILIAR slide projector has two projection systems, one of which projects the slide picture to the screen, while the other handles the more prosaic job of putting the image of the lamp filament into the projector lens itself.

LIGHTING SYSTEM. The ideal lighting system picks up a wide cone of light from the lamp and puts all of the beam through the slide and into the projector lens, where the image of the lamp filament should fill the entrance pupil. The general idea is simply that you flood the lens with light--the whole cone of light should fill the lens facing the slide.

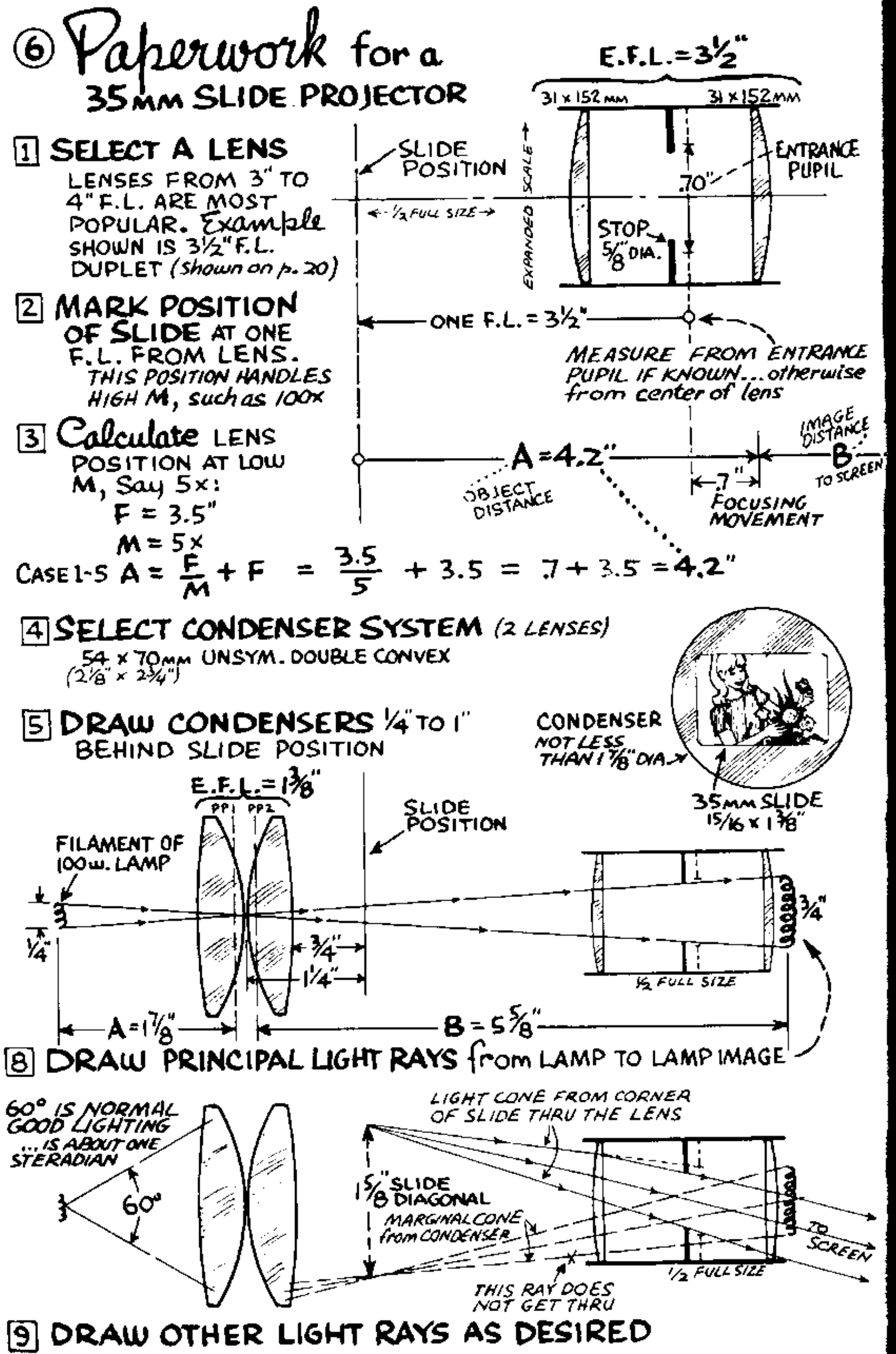
On the practical side, you can test-and-see exactly how condenser lenses perform, Fig. 2. If the lamp filament is a simple vee, you can get a fairly good image on a paper screen; if a more complex and compact filament, the image may be only a blur of light through which the wires of the filament are barely visible. Of course, the poor image is caused by spherical aberration. Usually the best image will be formed by the rays passing through the center of the lens. If you smoke or can produce smoke, it is instructive to view the whole cone of light, Fig. 3. You will see that the smallest and brightest part of the beam is some distance inside the image plane, Fig. 3. This poses a little problem: Since this is the smallest and brightest part of the light beam, wouldn't it be best to locate this "hot spot" at the entrance pupil?

Fig. 1 shows the lighting system with the hotspot inside the lens. The alternate and exact theoretical solution is to put the lamp image at the entrance pupil. If this is done, you will lose some of the marginal rays to spherical aberration, but on the other hand if you put the hotspot in the lens, you are going to lose some marginal light anyhow. This situation is shown in Fig. 6, Step 9, where it can be seen that the misplaced filament image will keep some of the marginal light from passing through the lens.

ALIGNMENT. This can be checked easily with a supplementary lens, Fig. 5, which itself must be held on the optical axis to show the true situation. Another testing method can be done with a No. 4 sun filter or No. 10 or 11 welding glass, either of which will permit comfortable direct viewing right into the blazing eye of the projector lens. By either method, if not aligned, the lamp image will appear off-center; a too-small or too-large filament image will be apparent.

SLIDE PROJECTOR DESIGN. Fig. 6 takes you through the various steps of designing your own slide projector. The instrument used as an

⑥ Paperwork for a 35MM SLIDE PROJECTOR




6 **Condenser M.**

100-WATT PROJECTOR LAMP HAS A FILAMENT ¼" WIDE

THE PROJECTOR LENS HAS ENTRANCE PUPIL OF .70" (Say ¾")

So...

$\text{COND. } M = \frac{3/4}{1/4} = 3\times$

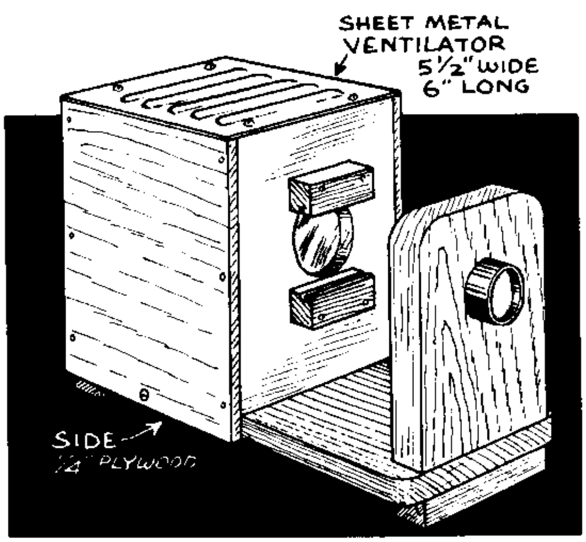
7 **Calculate LAMP OBJECT-IMAGE AT 3x**

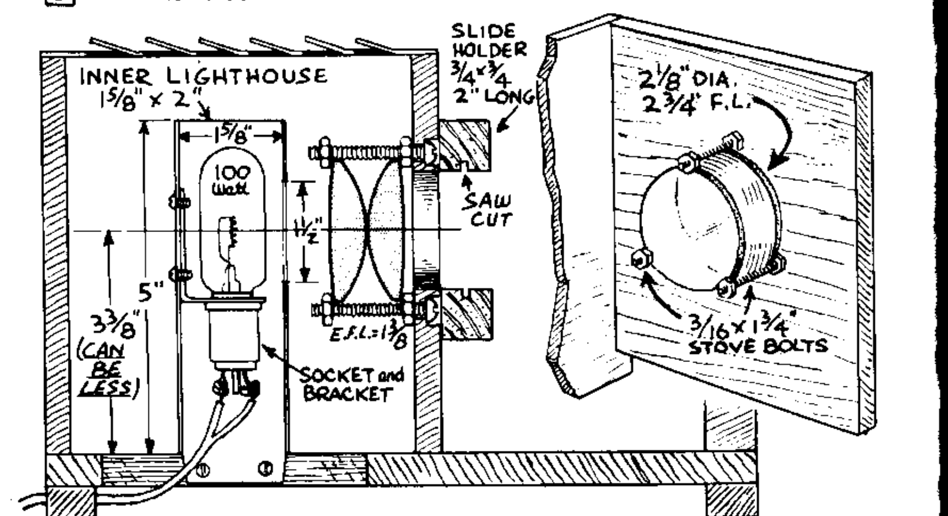
$F_{\text{CONDENSER}} = 1.4'' (1\tfrac{3}{8}'')$

$M = 3\times$

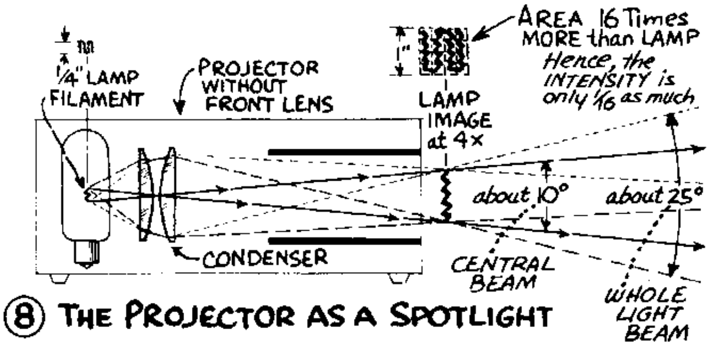
CASE 1-1 $B = (M+1) \times F = 4 \times 1.4 = 5.6''$

CASE 1-4 $A = \frac{B}{M} = \frac{5.6}{3} = 1.87''$

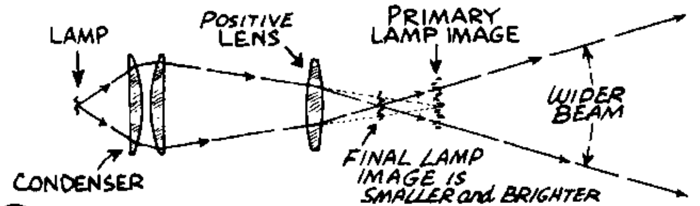


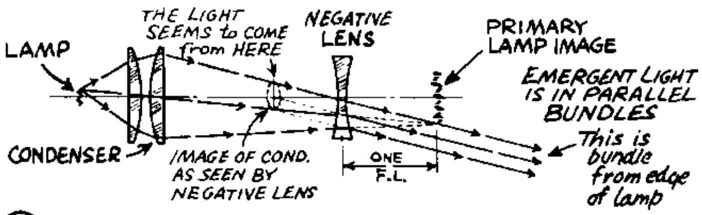

⑦ Construction -- 35MM UTILITY SLIDE PROJECTOR




⑧ **THE PROJECTOR AS A SPOTLIGHT**




⑧A *A POSITIVE LENS INSIDE THE PRIMARY LAMP IMAGE will FORM A WIDER BEAM*




⑧B *A NEGATIVE LENS ONE F.L. INSIDE THE LAMP IMAGE WILL PRODUCE PARALLEL LIGHT IN A WIDE BEAM*

example is a small utility type using a 100-watt lamp. If you are making a drawing of this or other design, it is simpler to forget about spherical aberration and put the lamp image right inside the projection lens where it is supposed to be. When this is done, the light cone from the lamp and the light cone from the slide are identical. Then, to adjust the whole system for "best light" after it is built, you push the lamp about 1/4 in. closer to the condensers.

In case you decide to put the lamp image ahead of the projection lens, you will draw separate light cones, one for the slide and the other for the condensers. Step 9 shows that when you put the lamp image ahead of the lens, you will lose a little of the marginal light. Of course, exactly the same thing would happen if you pushed the lamp closer to the condensers after construction. At any rate, the light loss is minimal.

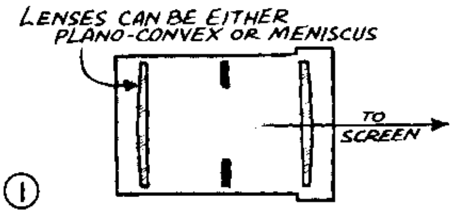
Fig. 7 gives mechanical details of the construction. The lamp mounting bracket shown does not allow the use of a reflector behind the lamp although it can be bent in the opposite direction if you want this feature. The fairly large condensers permit the slide to be some distance ahead of the condensers. The body of the projector can be constructed of 1/4 in. plywood. The 1/2 in. plywood base has a 2 x 4-in. opening to provide ventilation and also support for the extended side of the thin sheet metal inner lighthouse. The condenser mount is made of three stove bolts, as shown. This puts the two condensers in contact, but a little free play should be allowed.

PROJECTOR AS A SPOTLIGHT. A slide projector without its front lens is sometimes useful as a spotlight. At close range the light beam will show a bright center, but at distances over 10 ft. the beam becomes fairly uniform. Fig. 8 is a diagram of a typical condenser working at 4x magnification, this being the magnification of the lamp filament. Since the usual lamp filament will be about 1/4 inch square, the image of the filament at 4x magnification will be 1 inch square. The 1-in. lamp image is only 1/16 as bright as the lamp itself, but it is still a blazing hotspot which may be used for direct illumination.

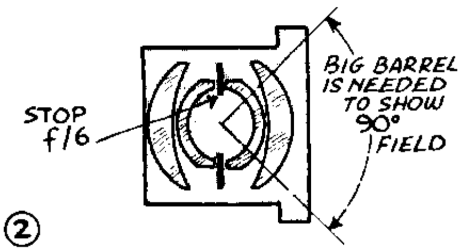
If you want to add lenses to make the projector a spotlight, the general idea is to treat the magnified lamp image as the light source itself. You can put another lens condenser in front of the lamp image and space it as needed to get the desired beam. The general rules for doing this are exactly the same as for a real source, i.e., with condenser one f.l. from source, the emergent light will be a parallel (but divergent) beam; at less than one f.l., the beam will be a wide fan; at more than one f.l., the final lamp image can be projected to any desired distance. The last-mentioned is the system to use if you want a hot spot as a distance of 15 ft. or more.

The "image" nature of the new light source also allows the use of either a positive or negative lens inside focus. The action of any positive lens is to converge the light still more, forming a smaller and brighter final image, as shown in Fig. 8A. This bright hotspot can sometimes be used for direct illumination, such as a fiber optics illuminator, but if the light is allowed to go ahead it will form a wide fan as shown. The math work is what we call a Case 4 system, which is not described in this booklet but is explained in other Edmund literature.

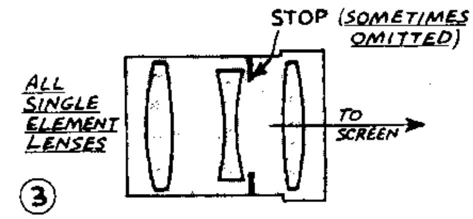
A negative lens inside focus acts much the same as a Barlow lens in a telescope. If the spacing is less than one f.l., the final lamp image will be projected forward. If the lens spacing is exactly one f.l., the emergent beam will be parallel light, Fig. 8B. You can also use a spacing of more than one f.l., in which case the image will be virtual and to the left. The math for this can be done with Case 1 equations but remembering the final image is virtual and to the left.



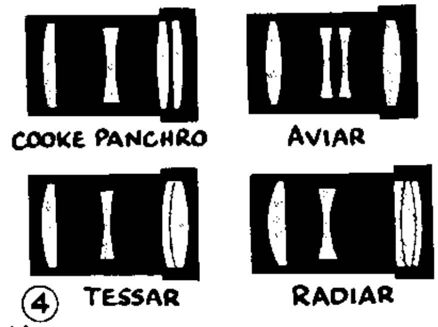

**SYMMETRICAL DUPLET** MADE OF MENISCUS OR PLANO-CONVEX LENSES. SHARP AT f/7 OR f/8 OVER 30° FIELD
*SEE SPECIFICATIONS ON FOLLOWING PAGES*



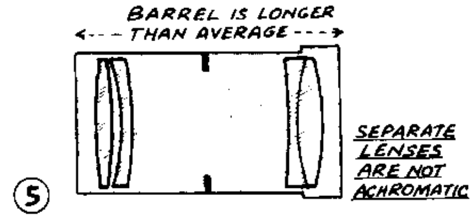

**METROGON** IS EXTREME EXAMPLE OF SYMMETRICAL CONSTRUCTION. MAIN FEATURE IS WIDE FIELD OF 90°



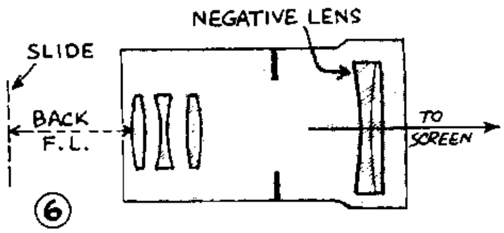

**COOKE TRIPLET** IS MOST POPULAR PROJECTION LENS. USUALLY f/3.5 WITH GOOD FIELD TO 45°




**VARIATIONS** OF THE COOKE TRIPLET




**PETZVAL** IS AN OLD-TIMER, STILL POPULAR. VERY SHARP AT CENTER OF FIELD BUT LESS SHARP AT EDGE. ABOUT 30° FIELD, f/2 TO f/4.5

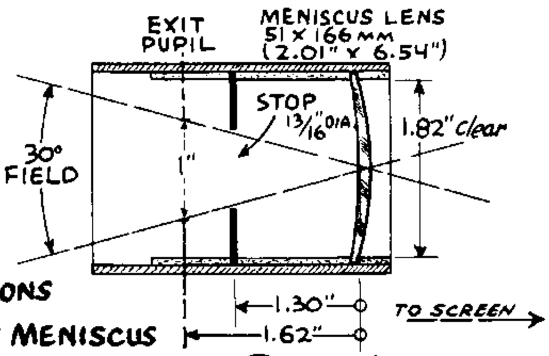



**REVERSED TELEPHOTO** IS USED FOR MANY SHORT F.L. LENSES. THE LONGER-THAN-AVERAGE BACK F.L. PROVIDES AMPLE CLEARANCE EVEN AT ¼" F.L.

# PROJECTOR Lenses

PROJECTOR lenses do not differ greatly from camera lenses. You want something fast for a bright screen image; you want high resolution for a sharp picture. Standard photo objectives can be used. The lens orientation for a projector is the same as for a camera--the lens points out and away from the instrument, i.e., it faces the longer of the two conjugate distances.

TRIPLET MOST POPULAR. Of various stock lenses, the simple lens triplet, Fig. 3, is the most popular choice, mainly from the fact it can be manufactured cheaply. Despite the mercenary incentive, the lens does perform nicely and is wire sharp over fields up to 40 or 45 degrees. It is usually no faster than f/3.5, but that is fast enough. Some variations of the triplet, Fig. 4,

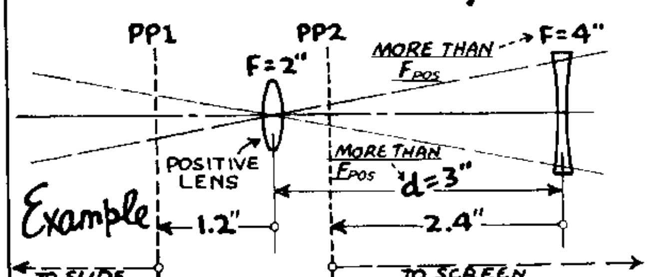



**Suggested SPECIFICATIONS**
**f/6.5 FRONT MENISCUS**

**TABLE 1** — *Example*

| | 1" F.L. | 6.5" F.L. |
|---|---|---|
| CLEAR APERTURE | .28" | .28 × 6.5 = 1.82" |
| LENS TO STOP | .20" | .20 × 6.5 = 1.30" |
| STOP DIAMETER | .123" | .123 × 6.5 = .80" |
| LENS TO EXIT PUPIL | .25" | .25 × 6.5 = 1.62" |
| EXIT PUPIL DIA. | .154" | .154 × 6.5 = 1.00" |

## Reversed TELEPHOTO
### for Short E.F.L. Objectives




**Formulas:**

$$E.F.L. = \frac{F_{POS} \times F_{NEG}}{F_{NEG} + d - F_{POS}}$$

$$PP1 = \frac{E.F.L. \times d}{F_{NEG}}$$ (*LEFT, from POS. Lens*)

$$PP2 = \frac{E.F.L. \times d}{F_{POS}}$$ (*LEFT, from NEG. Lens*)

**Example:**

$$\frac{2 \times 4}{4+3-2} = \frac{8}{5} = 1.6'' \text{ POSITIVE}$$

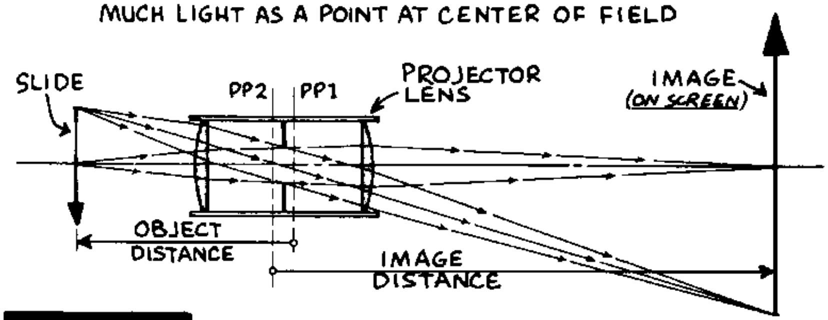
$$\frac{1.6 \times 3}{4} = \frac{4.8}{4} = 1.2''$$

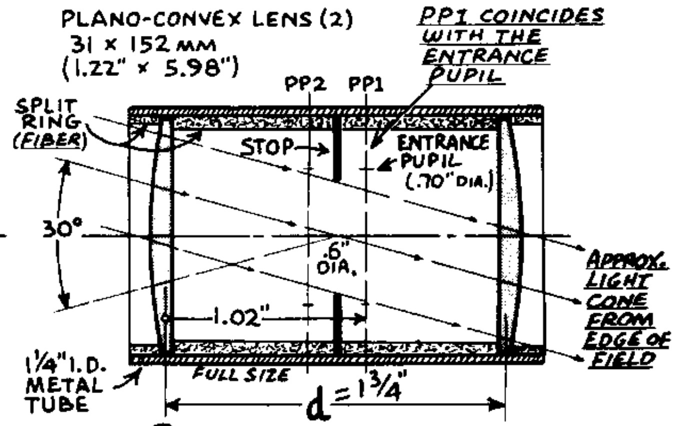
$$\frac{1.6 \times 3}{2} = \frac{4.8}{2} = 2.4''$$

*THE FORMULAS ARE ARRANGED FOR SIMPLE ARITHMETIC ... MINUS SIGN MEANS ONLY SUBTRACTION*

## (7) HOW LIGHT PASSES THRU A DUPLET

A POINT AT EDGE OF SPECIFIED FIELD GETS JUST AS MUCH LIGHT AS A POINT AT CENTER OF FIELD




## TABLE 2

**SHORT F.L. Symmetrical DUPLETS**
**30° FIELD • SPEED: f/5**

| E.F.L. | F.L. of EACH LENS [1] | CLEAR APERTURE | SPACE (d) | STOP DIA. | PRINCIPAL PLANES SPACE | PRINCIPAL PLANES DIA. |
|---|---|---|---|---|---|---|
| ½" | .85" 22 MM | .16" 4 MM | .25" | .09" | .15" | .10" |
| ¾" | 1.28 33 MM | .23 6 MM | .37 | .13 | .22 | .15 |
| 1" | 1.71 44 MM | .31 8 MM | .50 | .17 | .29 | .20 |
| 1¼" | 2.14 54 MM | .39 10 MM | .62 | .21 | .36 | .25 |
| 1½" | 2.56 65 MM | .46 12 MM | .75 | .25 | .44 | .30 |
| 1¾" | 2.99 76 MM | .54 14 MM | .87 | .30 | .51 | .35 |
| 2" | 3.42 87 MM | .62 16 MM | 1.00 | .34 | .58 | .40 |
| 2¼" | 3.85 98 MM | .70 18 MM | 1.12 | .38 | .65 | .45 |
| 2½" | 4.28 109 MM | .77 20 MM | 1.25 | .42 | .73 | .50 |
| 2¾" | 4.70 120 MM | .85 22 MM | 1.37 | .47 | .80 | .55 |
| 3" | 5.13 131 MM | .93 24 MM | 1.50 | .51 | .87 | .60 |
| Example 3½" | 5.98 152 MM | 1.08 28 MM | 1.75 | .60 | 1.02 | .70 |
| 4" | 6.84 174 MM | 1.24 32 MM | 2.00 | .68 | 1.16 | .80 |
| 4½" | 7.70 196 MM | 1.40 36 MM | 2.25 | .78 | 1.30 | .90 |
| 5" | 8.55 218 MM | 1.55 40 MM | 2.50 | .85 | 1.45 | 1.00 |
| 5½" | 9.40 239 MM | 1.70 43 MM | 2.75 | .94 | 1.60 | 1.10 |
| 6" | 10.26 261 MM | 1.86 47 MM | 3.00 | 1.02 | 1.74 | 1.20 |

[1] A VARIATION OF UP TO 10% OF SPECIFIED F.L. OR DIA. IS PERMISSIBLE ... USE ALL OTHER SPECIFICATIONS AS IS

IF YOU LIKE, YOU CAN Calculate SPECIFICATIONS FOR LENSES NOT LISTED:

$$\text{E.F.L.} = \frac{\text{F.L. OF YOUR LENSES}}{1.71 \ (\text{F.L. FOR } 1'' \text{ E.F.L.})}$$

**Sample:** LENSES YOU HAVE ARE 160MM (6.30") F.L.

$$\text{E.F.L.} = \frac{6.30}{1.71} = 3.7''$$

**Then:** MULTIPLY ALL "SPECS" FOR 1" E.F.L. (from TABLE) BY 3.7

*Like:* SPACE = .50 × 3.7 = 1.85" ETC.

**from TABLE 2 Example: 3½" E.F.L.**

CHECK $f/\text{RATING} = \frac{\text{E.F.L.}}{\text{ENT. PUPIL DIA.}} = \frac{3.5}{.70} = f/5$ (OK)

CHECK $\text{E.F.L.} = \frac{F \times F}{F+F-d} = \frac{6 \times 6}{6+6-1\frac{3}{4}} = \frac{36}{10\frac{1}{4}} = 3.5''$ (OK)

are a little sharper and faster, but not by much. The simple lens triplet has a good feature in that the single elements are not harmed by heat--you should always be a little slow in putting a cemented lens in the path of a hot projection lamp.

A common choice for the homemade projector is the simple lens duplet, Fig. 1. These do surprisingly well over fields of 30 degrees or less. War surplus achromats in a similar construction are usually no better for the simple reason most such achromats are narrow-field glasses intended to cover at most 10 degrees. When you use such lenses to cover a wide field, the performance is often poor--not even as good as a single simple lens. Of course there are achromatic duplets made for wide fields, such as the old Rapid Rectilinear, but you will not find these lenses in surplus merchandise.

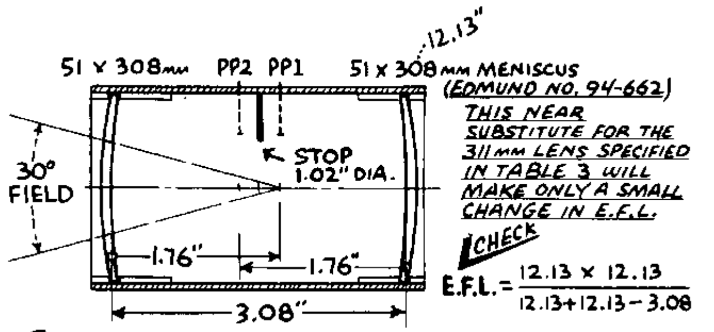
METROGON FOR WIDE FIELD. If you want to cover big slides or transparencies, the best lens may be a Topogon or Metrogon. These are the most extreme type of symmetrical construction, the whole lens being very nearly a round ball. Each side of the lens has a positive and negative element which provides correction for color and spherical faults. The lens is also completely free of distortion, this feature being highly essential for its original use as an aerial mapping camera. Faults are slow speed (f/6.3) and a hair less sharpness overall than other objectives. The field can be as much as 90 degrees, but as installed on cameras and projectors you will do best with about 75 degrees; even getting the light rays out of the barrel is somewhat of a problem at 90 degrees.

Another lens with a claim to "wide field" is the reversed telephoto, Fig. 6. You can buy lenses of this kind in commercial products, but the usual homemade job is an attachment--you combine a negative lens with any regular camera or projector lens. As you may know a true telephoto gives increased focal length and hence a larger image over a smaller field. The reversed telephoto is just the opposite--it decreases the focal length. However, the real reason for the reversed telephoto is its long back focal length, which provides extra working room between lens and slide. The extra space increases the linear size of the object field. In homemade combinations of this kind, the focal length is further reduced by increasing the spacing or using a shorter negative lens--study the example at bottom of page 19.

FRONT MENISCUS. This is the simplest and cheapest kind of homemade lens. It does quite well if you don't try for too much field, too much speed, too much magnification. You have to be content with a fairly slow f/6.5, a 20 to 30 degree field and top M. of about 20x. Suitable specifications are given in Table 1 for a lens of 1 in. focal length. You multiply these values by any focal length you desire.

SYMMETRICAL DUPLETS. Table 2 gives suitable specifications for short focal length symmetrical duplets using either plano-convex or meniscus lenses. The meniscus duplet has fair sharpness over the whole field; the plano-convex is a bit sharper at center but softer at corners. The suggested specifications have no particular merit, so if you want to change the aperture or spacing a little, you can be assured you are not hurting anything. Lenses smaller than those specified will work nearly as well, but will cover a smaller field than the specified 30 degrees. The way light passes through a duplet is shown in Fig. 7. You can see the diameter is needed for lighting at the edge of field; notice that a point at edge of specified field gets just as much light as a point at center of field.

Lenses of longer focal length are tabulated in Table 3. This differs from Table 1 in that lens diameters run a little smaller and the spacing a little less. Here again the specifications used have no particular merit other than being average, practical specifications. Many amateurs will construct a duplet without a stop to get more light, but the net result is only a bright center surrounded by darker edges, the overall definition much poorer. The only situation where a no-stop lens is of any use at all is where the copy is smaller than the diameter of the lens.




Example 7" F.L, f/6 $= \frac{147.14}{21.26} = 6.94"$

TABLE 3

**LONG F.L. Symmetrical DUPLETS**
**30° FIELD SPEEDS: f/6, f/7, f/8**

| E.F.L. | F.L. of EACH LENS | *CLEAR APERTURE f/6 | f/7 | f/8 | SPACE | STOP DIA. f/6 | f/7 | f/8 | POSITION OF PP's |
|---|---|---|---|---|---|---|---|---|---|
| 6" | 10.50"<br>267mm | 1.60"<br>41mm | 1.50"<br>38mm | 1.40"<br>36mm | 2.64" | .88" | .75" | .66" | 1.51" |
| 6½" | 11.37<br>289 | 1.73<br>44 | 1.62<br>41 | 1.51<br>38 | 2.86 | .95 | .81 | .72 | 1.63 |
| Ex. 7" | 12.25<br>311 | 1.86<br>47 | 1.75<br>45 | 1.63<br>41 | 3.08 | 1.02 | .87 | .77 | 1.76 |
| 7¼" | 12.69<br>322 | 1.93<br>49 | 1.81<br>46 | 1.69 | 3.19 | 1.06 | .91 | .80 | 1.82 |
| 7½" | 13.12<br>333 | 2.00<br>51 | 1.87<br>48 | 1.75<br>44 | 3.30 | 1.09 | .94 | .83 | 1.88 |
| 7¾" | 13.56<br>344 | 2.06<br>53 | 1.94<br>49 | 1.81<br>46 | 3.41 | 1.13 | .92 | .85 | 1.95 |
| 8" | 14.00<br>356 | 2.13<br>54 | 2.00<br>51 | 1.86<br>47 | 3.52 | 1.17 | 1.00 | .88 | 2.01 |
| 8¼" | 14.44<br>367 | 2.19<br>56 | 2.06<br>53 | 1.92<br>49 | 3.63 | 1.20 | 1.03 | .91 | 2.07 |
| 8½" | 14.87<br>378 | 2.26<br>57 | 2.12<br>54 | 1.98<br>50 | 3.74 | 1.24 | 1.06 | .94 | 2.13 |
| 8¾" | 15.31<br>389 | 2.33<br>59 | 2.19<br>56 | 2.04<br>52 | 3.85 | 1.28 | 1.09 | .96 | 2.20 |
| 9" | 15.75<br>400 | 2.39<br>61 | 2.25<br>57 | 2.10<br>53 | 3.96 | 1.31 | 1.12 | .99 | 2.26 |
| 9½" | 16.62<br>422 | 2.53<br>64 | 2.37<br>60 | 2.21<br>56 | 4.18 | 1.39 | 1.19 | 1.04 | 2.36 |
| 10" | 17.50<br>444 | 2.66<br>68 | 2.50<br>64 | 2.33<br>59 | 4.40 | 1.46 | 1.25 | 1.10 | 2.51 |
| 10½" | 18.37<br>467 | 2.79<br>71 | 2.62<br>67 | 2.45<br>62 | 4.62 | 1.53 | 1.31 | 1.15 | 2.64 |
| 11" | 19.25<br>489 | 2.93<br>75 | 2.75<br>70 | 2.56<br>65 | 4.84 | 1.61 | 1.37 | 1.21 | 2.76 |
| 12" | 21.00<br>533 | 3.19<br>81 | 3.00<br>76 | 2.80<br>71 | 5.28 | 1.75 | 1.50 | 1.32 | 3.01 |
| 13" | 22.75<br>578 | 3.46<br>88 | 3.25<br>83 | 3.03<br>77 | 5.72 | 1.90 | 1.62 | 1.43 | 3.26 |
| 14" | 24.50<br>622 | 3.72<br>95 | 3.50<br>89 | 3.26<br>83 | 6.16 | 2.04 | 1.74 | 1.54 | 3.52 |
| 1" | 1.75" | .266" | .250" | .233" | .44" | .146" | .125" | .110" | .251" |

* ADD 1/8" OR 3mm for MOUNTING

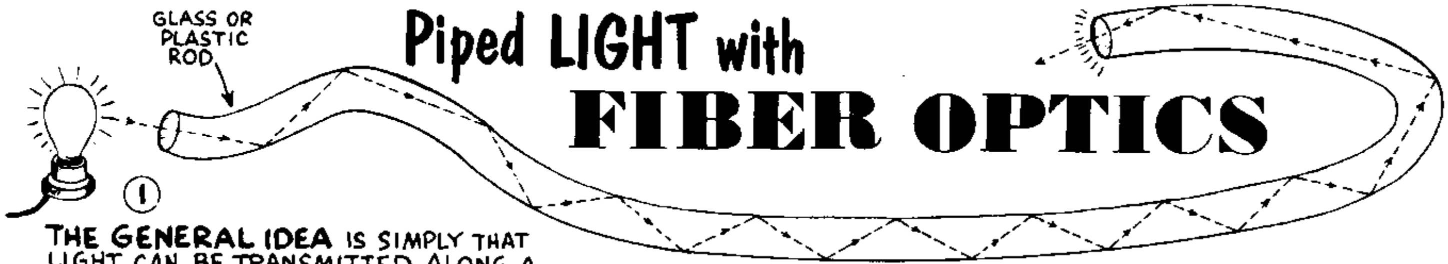
FOR E.F.L. NOT LISTED:
USE VALUES FOR 1" E.F.L. *(Above)* AND MULTIPLY BY E.F.L. YOU WANT

IF YOU HAVE A SET OF LENSES and WANT TO FIND E.F.L., Etc.
USE THE VALUES FOR 1" F.L. INDIVIDUAL LENS *(below)* AND MULTIPLY BY THE F.L. OF YOUR LENSES

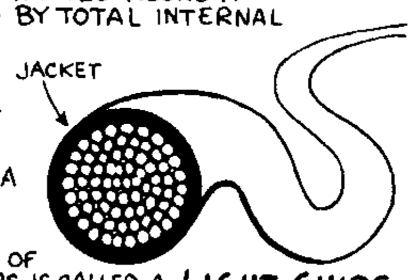
Sample: YOUR LENSES ARE 10½" F.L. then: E.F.L. = 10.5 × .57 = 5.99" Etc.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .57" | 1" | .152" | .143" | .133" | .25" | .083" | .071" | .063" | .143" |

# Piped LIGHT with FIBER OPTICS



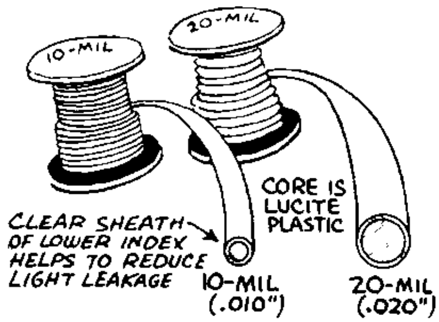

**THE GENERAL IDEA** IS SIMPLY THAT LIGHT CAN BE TRANSMITTED ALONG A TRANSPARENT ROD BY TOTAL INTERNAL REFLECTION.




② A BUNDLE OF SMALL FIBERS HAS MORE FLEX AND BETTER TRANSMISSION THAN A SINGLE ROD OF THE SAME DIAMETER.

SUCH A BUNDLE OF INDIVIDUAL FIBERS IS CALLED A **LIGHT GUIDE**

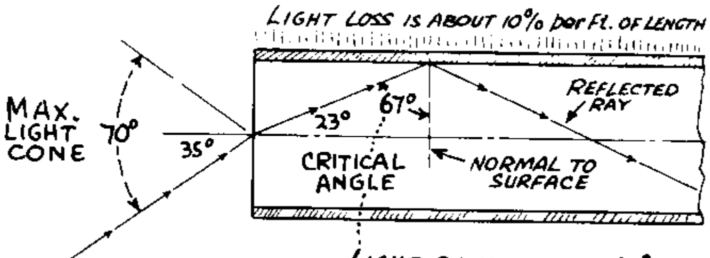
*IT MAY HAVE 16, 32, 48 OR 64 FIBERS*
*IT COSTS 50¢ TO 65¢ per ft. (1972)*




③ **SINGLE FIBERS** ARE MADE IN VARIOUS DIAMETERS OF WHICH THE 10-MIL and 20-MIL SIZES ARE MOST USEFUL

**1 MIL = .001 inch**

30-MIL (.030") 40-MIL (.040")




④ **LIGHT ACTION in a Single Fiber**

A LIGHT GUIDE BEHAVES IN THE SAME MANNER

*LIGHT RAYS UNDER 67° WILL BE REFRACTED OUT OF THE FIBER. RAYS STRIKING THE CORE WALL AT ANY ANGLE OVER 67° WILL BE TOTALLY REFLECTED*

ORDINARY light guides in a random arrangement of plastic fibers for piping light can be purchased for as little as 50¢ per foot. Glass fibers are a little more expensive. Image-conveying guides are much more expensive since they require an orderly arrangement of the individual fibers. The information given here applies only to plastic fiber optics in separate strands or made up as light guides containing 16 or more fibers in a random arrangement.

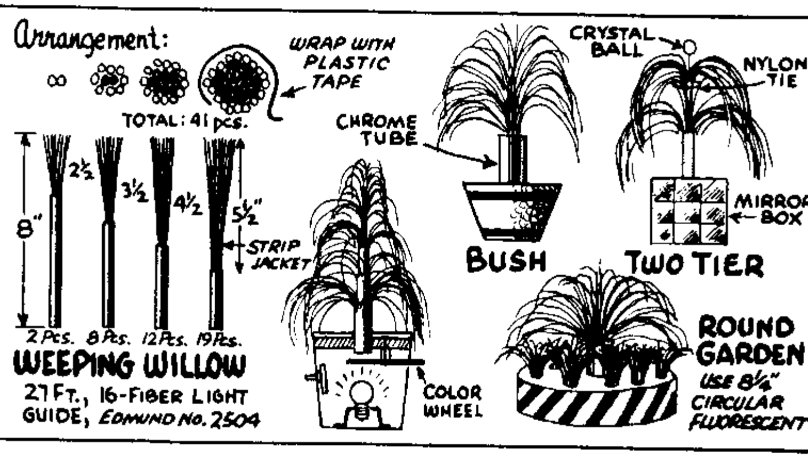
ORNAMENTAL WORK. Most amateur work is concerned with simple light piping for decorative use, such as making a light tree, as shown below. Usually no special lighting system is needed since the problem is merely to produce a moderate glow, which can be obtained from almost any kind of light. Plastic fibers will melt at about 300 degrees F., so you must avoid hot sources unless you use a blower or filter or both. The heat from an ordinary 100-watt household lamp is about 200 deg. at the side of the lamp, but more than twice as hot above the lamp. Glass fibers can stand much more heat.

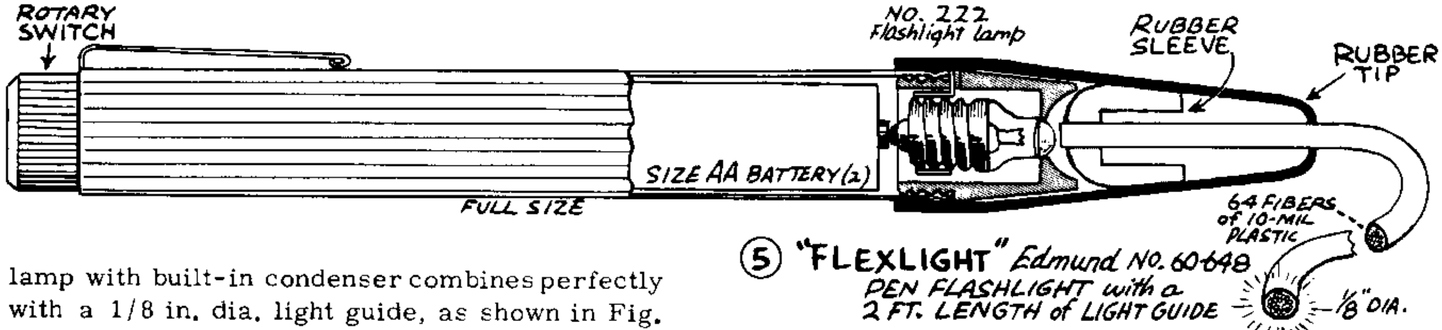
PLASTIC FIBER LIGHTS. Probably the most popular fiber optics light is the pen flashlight. This can be had in a commercial product, Fig. 5, or you can assemble your own from available parts. The light output will cover a 3 in. diameter circle bright enough to read.

In homemade construction, No. 222 flashlight

## FIBER OPTICS Ornamental TREES

The softly glowing branches and sparkling limb tips give the fiber optics light tree a beautiful appearance. The construction calls for 16-fiber light guides which are partially stripped to produce a multitude of strands which become the branches of your tree. The lighting is obtained from a lamp in a suitable flower pot or box base.

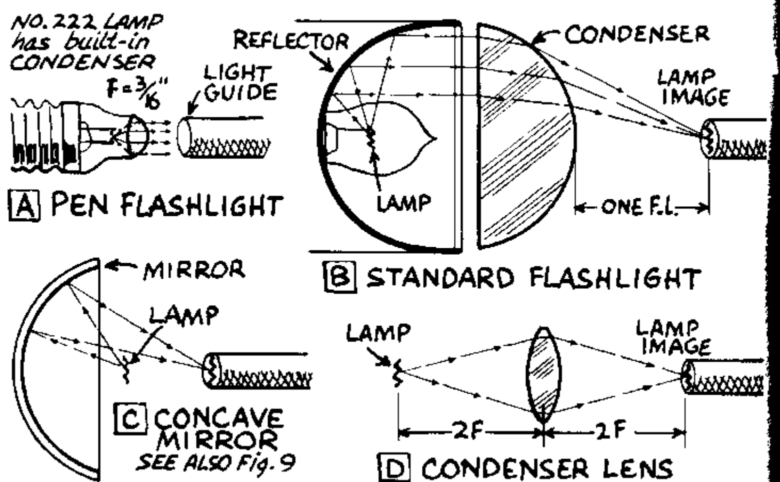




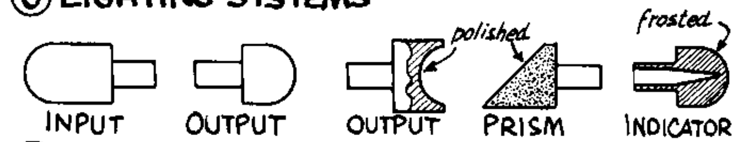

⑤ "FLEXLIGHT" *Edmund No. 60-648* PEN FLASHLIGHT with a 2 FT. LENGTH of LIGHT GUIDE

lamp with built-in condenser combines perfectly with a 1/8 in. dia. light guide, as shown in Fig. 6A. The same setup with a larger flashlight would waste a lot of light; it should be fitted with condenser lens about 2 in. dia. and 2 in. focal length, Fig. 6B. Mirror lighting like Fig. 6C is often used. This system is also available in some movie projector lamps as listed in Fig. 9 table. Needless to say, projection lamps are hot, hot and must be cooled with a blower plus heat-absorbing glass. The light output from a 150-watt projection lamp with 2 ft. of 1/8 in. light guide will cover a circle 3 ft. in diameter bright enough to work by. At any distance, the illuminated field is circular in shape, with a diameter about the same as the distance from work surface to light source. A terminal fitting can be used to spread the light if a wider field is needed.

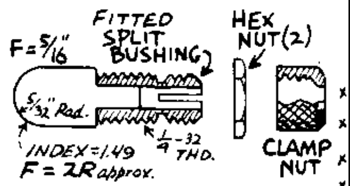
The most common optical system for lighting is the simple condenser, spaced at unity magnification or a little more or less as needed, Fig. 6D. Plastic lenses are available as terminal fittings, Fig. 7. They serve the same purpose as a lens and also provide a clamp for the fiber strands which tend to slide a little when the light guide is bent in a sharp curve. Fig. 10 shows a plastic terminal combined with a flashlight lamp to make a simple but useful desk unit. The adjustable transformer will handle any of the lamps listed in Fig. 8 table except the ones marked X, which take a 3-volt, 250mA transformer.




⑥ LIGHTING SYSTEMS




⑦ PLASTIC TERMINALS



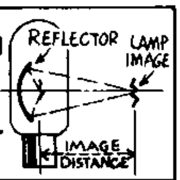

⑧ FLASHLIGHT and OTHER LAMPS of 1/2 AMP. OR LESS

| | TRADE NO. | VOLTS | AMPS | HRS. LIFE |
|---|---|---|---|---|
| x | 222 | 2.25 | .25 | 5 |
| x | 223 | 2.25 | .25 | 5 |
| x | 233 | 2.30 | .25 | 10 |
| x | PR4 | 2.30 | .25 | 10 |
| | PR2 | 2.40 | .50 | 15 |
| | PR6 | 2.50 | .30 | 30 |
| x | 14 | 2.50 | .30 | 15 |
| | 406* | 2.60 | .30 | 50 |
| | PR3 | 3.60 | .50 | 15 |
| | PR7 | 3.80 | .30 | 30 |
| | 13 | 3.80 | .30 | 15 |
| | 4546 | 4.70 | .50 | 100 |
| | PR13 | 4.75 | .50 | 15 |
| | PR15 | 4.80 | .50 | 30 |
| | 27 | 4.90 | .30 | 30 |
| | 407* | 4.90 | .30 | 50 |
| | 502 | 5.10 | .15 | 100 |
| | PR12 | 6.00 | .50 | 15 |
| | 605 | 6.20 | .50 | 15 |
| | PR18 | 7.20 | .50 | 3 |
| | PR20 | 8.60 | .50 | 15 |

* FLASHER

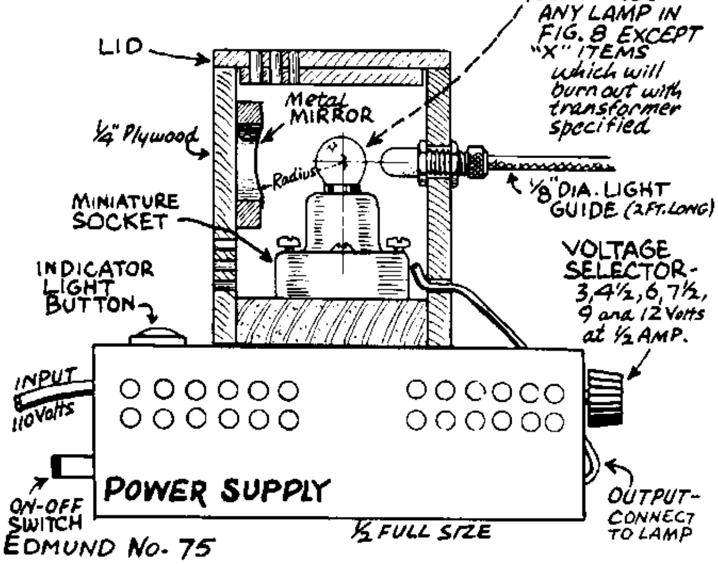
A TRANSFORMER OF 500 MILLIAMPS (1/2 AMP) and SUITABLE VOLTAGE MUST BE USED for 110-V. OPERATION

PARTIAL LIST
⑨ PROJECTION LAMPS with EXTERNAL FOCUS



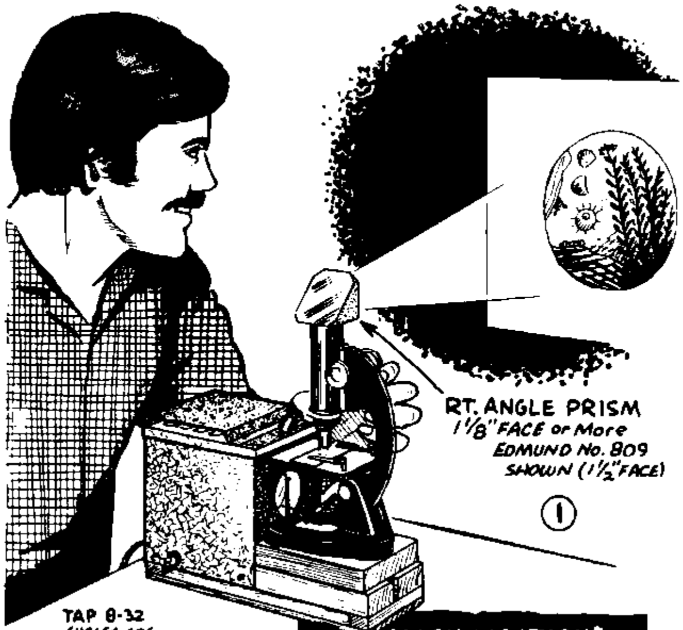

| | ANSI CODE | Watts | Volts | IMAGE Distance |
|---|---|---|---|---|
| | DFE | 80 | 30 (TRANSFORMER NEEDED) | 2 1/4" |
| | DFZ | 80 | 30 (TRANSFORMER NEEDED) | 1 3/4" |
| | DCA | 150 | 21 (TRANSFORMER NEEDED) | 1 3/4" |
| ★ | DCF | 150 | 21 (TRANSFORMER NEEDED) | 2 1/4" |
| | DCR | 150 | 21 (TRANSFORMER NEEDED) | 2 1/4" |
| ★ | DEF | 150 | 21 (TRANSFORMER NEEDED) | 1 3/4" |
| ★ | DKR | 150 | 21 (TRANSFORMER NEEDED) | 1 1/2" |
| | DCH | 150 | 110 | 2 1/4" |
| ★ | DCL | 150 | 110 | 2 1/4" |
| | DFA | 150 | 110 | 1 3/4" |

★ DICHROIC REFLECTOR




⑩ ILLUMINATOR Using Flashlight Lamp

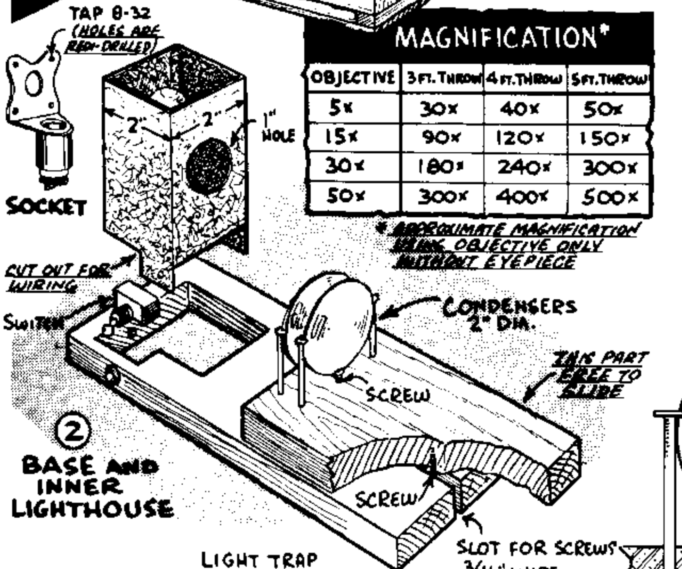
# Micro Projection

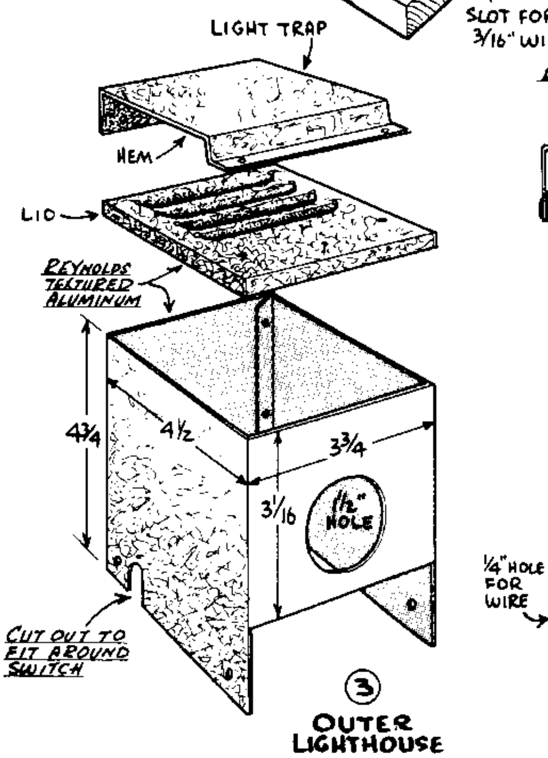


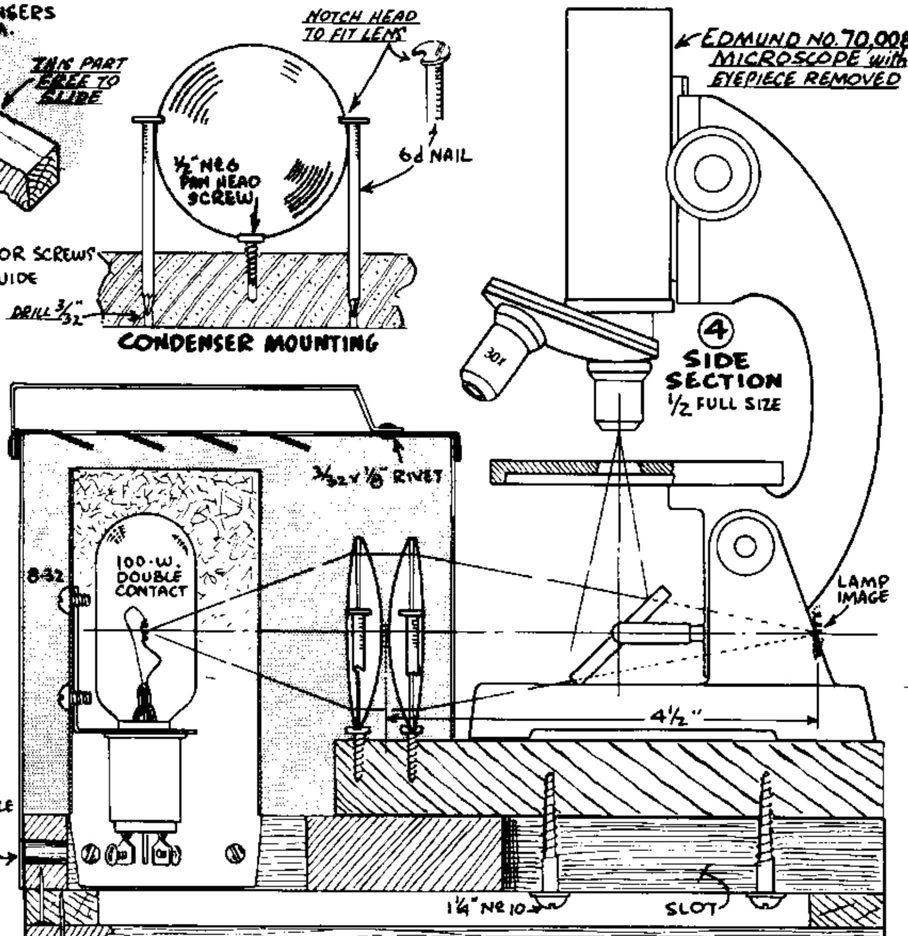

| OBJECTIVE | 3 FT. THROW | 4 FT. THROW | 5 FT. THROW |
|---|---|---|---|
| 5x | 30x | 40x | 50x |
| 15x | 90x | 120x | 150x |
| 30x | 180x | 240x | 300x |
| 50x | 300x | 400x | 500x |

MAGNIFICATION*

* APPROXIMATE MAGNIFICATION USING OBJECTIVE ONLY WITHOUT EYEPIECE

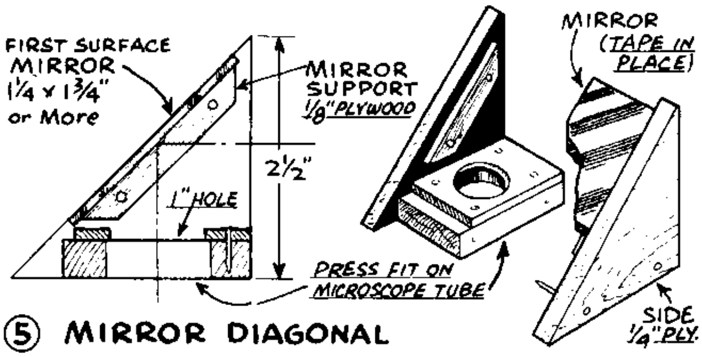



PROJECTION offers an interesting and useful method of showing your microscope slides. For wall or screen projection, you will need a right angle prism, Fig. 1, or a first surface mirror diagonal, Fig. 5. Projection can also be done on the ceiling and this setup is a straight shot with microscope alone. Best results are obtained if the objective only is used, although super high power requires the compound system of objective plus eyepiece. This takes stronger more concentrated light than the unit described.

The light unit shown is simply the lamp and condensers of a 35mm slide projector. Like a slide projector the idea is to pick up a big light cone from the lamp and put all of the light through the objective. The largest aperture you will use will probably be a 5x objective (1 in. f.l.) which is about 1/4 in. diameter. Since a small projection lamp has a filament about 1/4 in., you need only unit magnification, but a little more than this will

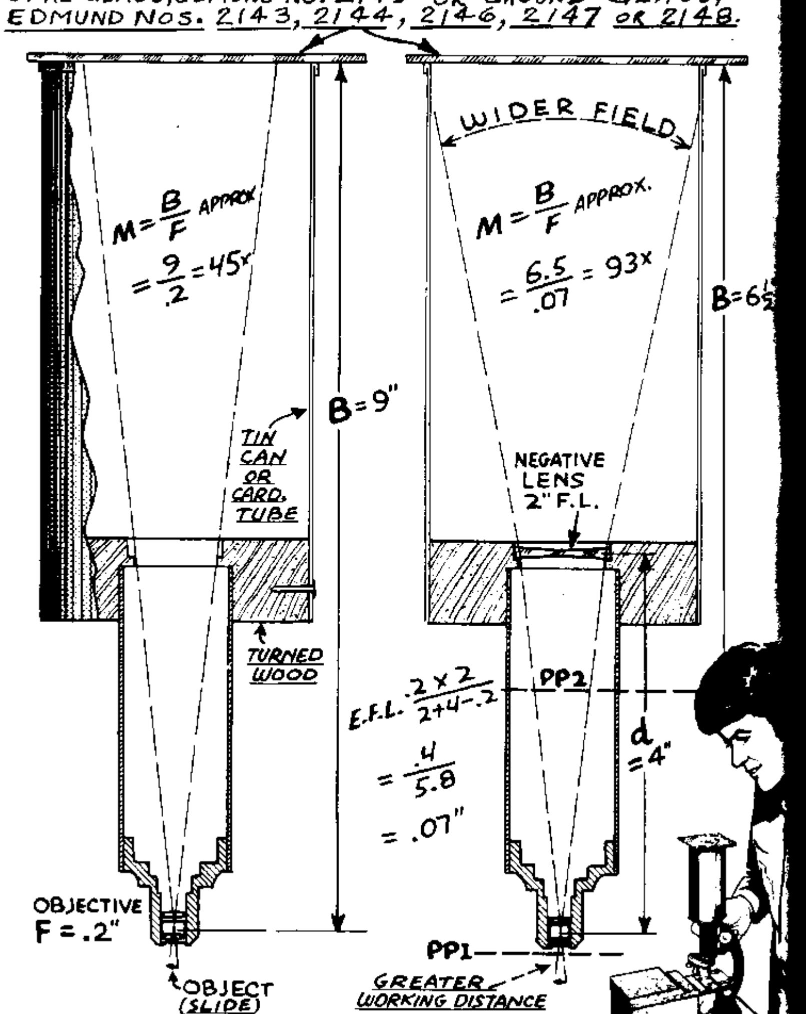



(5) MIRROR DIAGONAL

be required to cover the distance from condensers to microscope objective for the setup shown.

REAR PROJECTION. The setup for this is a simple extension tube, Fig. 6. The longer the tube, the greater the magnification. Greater field and higher M. can be obtained with a homemade reversed telephoto system, Fig. 7. The negative lens reduces the effective f.l. of the objective. Usually the price of extra magnification is reduced field, but this setup enlarges the whole field and everything in it.

HOMEMADE MICRO PROJECTOR. This departs from standard construction only in that the projection lens must be very short--not over 1 in. f.l. The commercial lens shown has a f.l. of .28 in., the design being a reversed telephoto. You can also use a short 8mm movie projector lens, or the objectives from a microscope. The condenser is also a purchased unit; it shows the deep meniscus design commonly used to minimize spherical aberration. You can of course make your own condenser, which should be about 1 in. e.f.l. for the pair or 2 in. f.l. for each lens. The slide is held in place with a metal clip, as can be seen in the drawings.

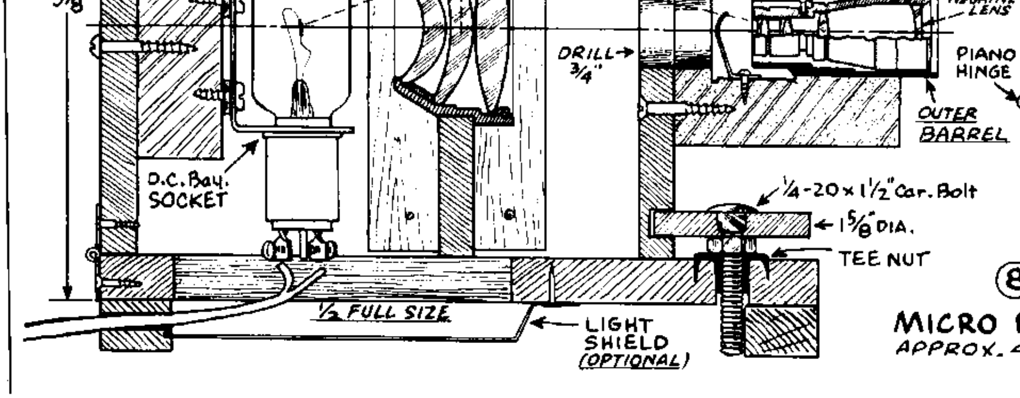


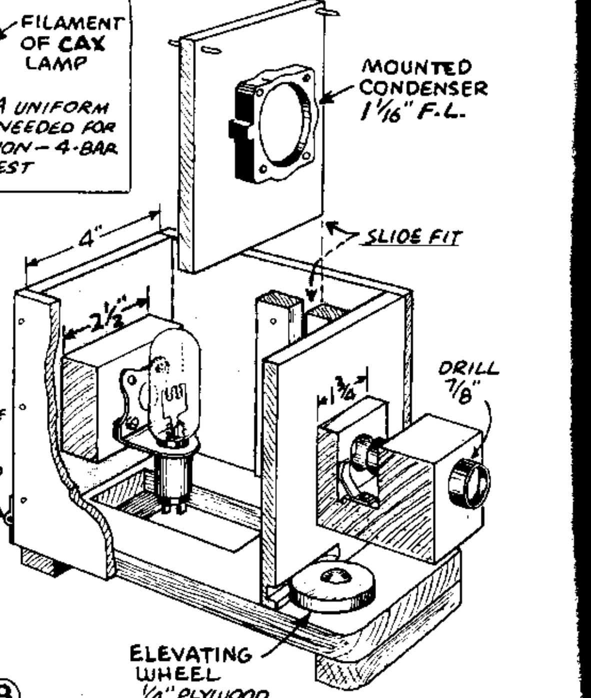

(6) REAR PROJECTION

(7) USE OF NEGATIVE LENS

5mm FILAMENT OF CAX LAMP

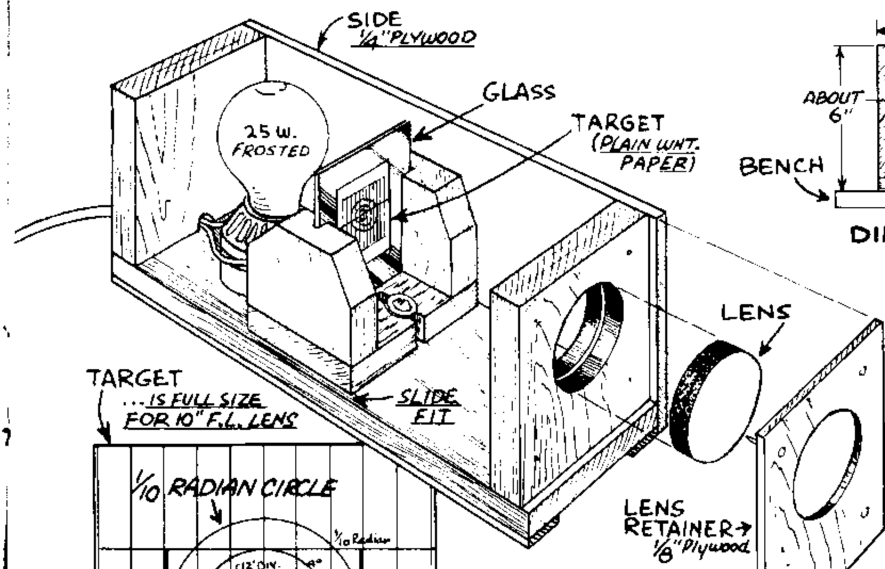
LAMP NOTE: *A UNIFORM "HOT SPOT" IS NEEDED FOR MICRO PROJECTION — 4-BAR FILAMENT IS BEST*



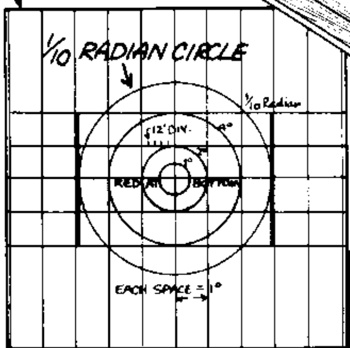




(8) MICRO PROJECTOR with 7MM LENS

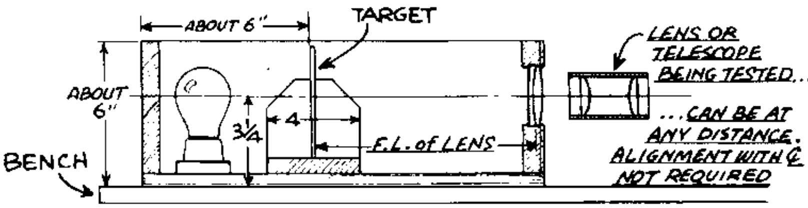
*APPROX. 4x MAGNIFICATION PER INCH OF "THROW"*



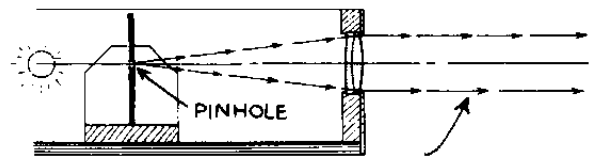

BENCH COLLIMATOR and TARGET



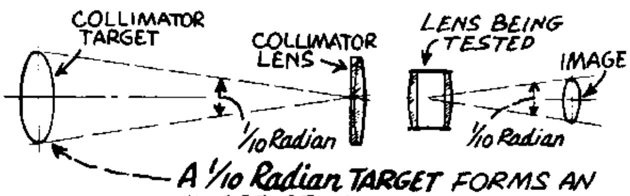

ANGULAR and 1/10 Radian COLLIMATOR TARGET for any lens




DIMENSIONS DEPEND ON F.L. OF LENS




*A PINHOLE TARGET PRODUCES PARALLEL LIGHT with LITTLE DIVERGENCE*




*A 1/10 Radian TARGET FORMS AN IMAGE OF THE TARGET AT THE SAME EXACT ANGLE OF 1/10 RADIAN*

| | You want to find | FORMULA | Ex: 20" F.L. COLLI. LENS |
|---|---|---|---|
| MAKING THE TARGET | DIA. OF 1/10 Radian CIRCLE | DIA. = F × 1/10 | $20 \times \frac{1}{10} = \frac{20}{10} = 2''$ |
| | DISTANCE EQUAL TO 1° | 1° SPACE = F × .0175 | 20 × .0175 = .35" |
| READING THE TARGET | TRUE ANGULAR FIELD OF A TELESCOPE | SIMPLY COUNT THE DEGREE SPACES — Example is ABOUT 3½° | |
| | F.L. OF ANY POSITIVE LENS OR EYEPIECE | F = DIA. OF 1/10 Radian CIRCLE [1] times 10 | Ex: 2" F.L. LENS THE IMAGE OF CIRCLE WILL READ .200" = 2" F.L. |
| | ALTERNATE: for Lenses over 10" F.L. | F = IMAGE SIZE OF 1° SPACE times 57 | Some Ex. WILL READ .035" AT IMAGE .035 × 57 = 1.995" |
| | [1] IMAGE OF TARGET CIRCLE CAN BE MEASURED EXACTLY WITH A SCALE MAGNIFIER (SCALE) | | |

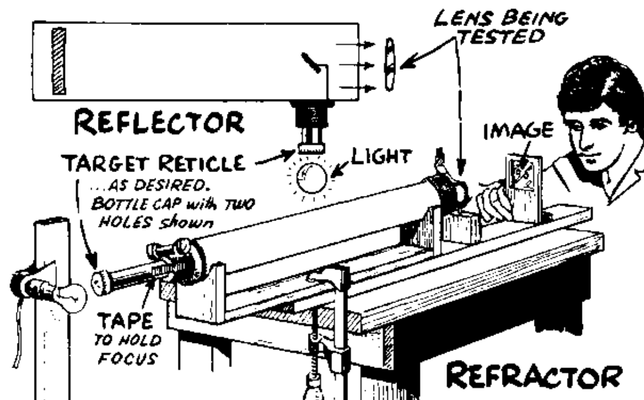
# COLLIMATORS

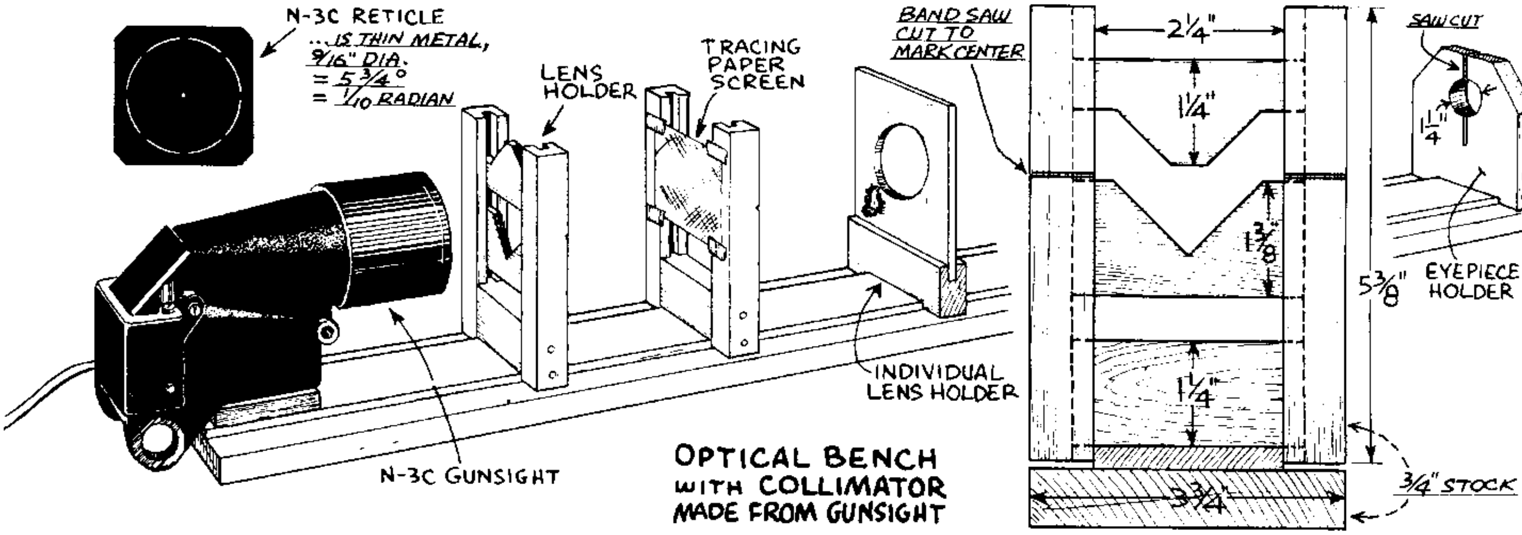
THE LIGHT emerging from a collimator is parallel light, duplicating the light from a distant object. Hence, the collimator supplies the equivalent of a distant target which you can use indoors. In addition, a collimator can tell you the angular field of a telescope or binocular; you can use it to check the focal length of any single lens or any multiple lens, such as an eyepiece or a condenser system; it may be used in various ways to determine the resolving power of a telescope.

When the collimator target is a tiny pinhole (artificial star), the emergent light will be close to the popular concept of parallel light, i.e., a

## any telescope a COLLIMATOR

Find the exact focal plane of the telescope beforehand by focusing the moon on a tracing paper screen taped to the end of the focusing tube. Secure the focusing tube with a turn or two of masking tape. Now, if you make a few random ink marks on the tracing paper screen, you have a simple reticle or target for your collimator. A 3-in. refractor is a nice size for a pinhole collimator. It is less useful as a focal collimator because the maximum target of about 1-1/8-in. at the focusing tube means a constant multiplier of 40.

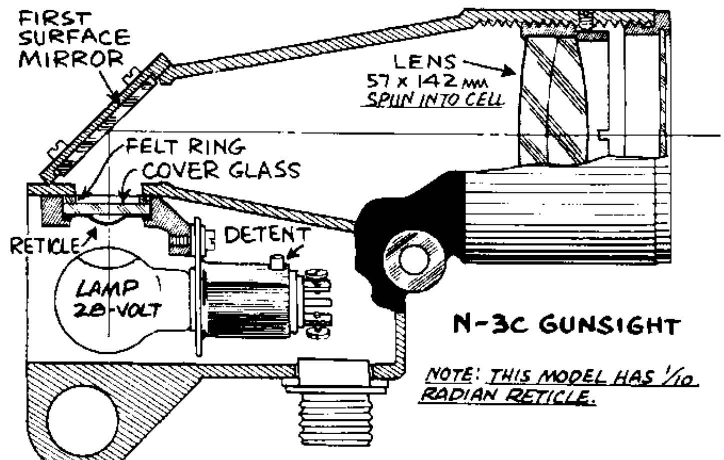


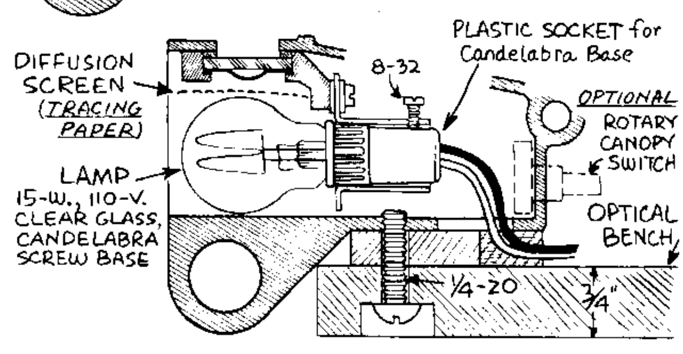



**OPTICAL BENCH WITH COLLIMATOR MADE FROM GUNSIGHT**

parallel beam right on the axis. But if the target has measurable size, the emergent light will form a diverging cone, although light from any point of the target will form a parallel bundle. Collimated light means parallel light in the sense that all rays from all points of the target will emerge in parallel bundles--it does not mean a "parallel beam" in the manner of a searchlight.

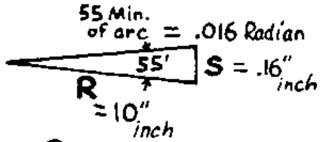
ANGULAR SCALE FOCAL COLLIMATOR. This is a general-purpose collimator with two main functions: (1) Reading the angular field of a telescope, (2) telling the focal length of a lens or eyepiece. To be most convenient, a focal collimator should have an easy-to-apply constant multiplier, of which the figure 10 is the ideal. To make a colli target with this constant, you make the target diameter 1/10 of the focal length of the collimator lens. See 20-in. f.l. example on opposite page. The whole thing is based on simple radian measure, the target being 1/10 of the base length, and so 1/10 radian. When you test any lens or eyepiece for focal length, you pick up the target image on a tracing paper screen where it can be measured--ten times the measured image diameter will be the f.l. of the lens being tested.




**CONVERSION TO 110-VOLT LIGHTING**

## Radian Formulas




Example *NOT TO SCALE*

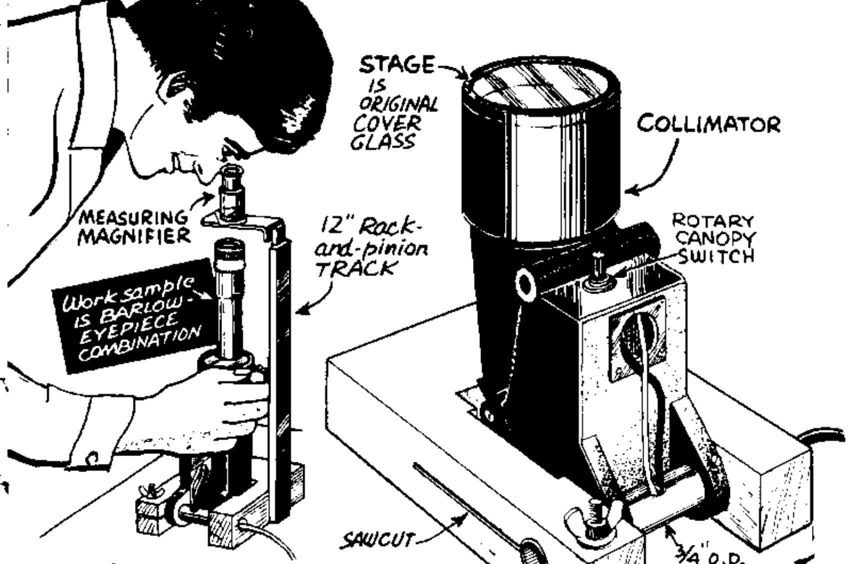
**When ANGLE IS GIVEN IN DEGREE MEASURE** — *Example*

| | | Example |
|---|---|---|
| 1 | $S = \frac{\text{ANGLE} \times R}{1 \text{ Radian}}$ (Deg., Min., or Sec.) | $\frac{55 \times 10}{3438} = \frac{550}{3438} = .16''$ inch |
| 2 | $R = \frac{S \times 1 \text{ Rad}}{\text{ANGLE}}$ (Deg., Min., Sec.) | $\frac{.16 \times 3438'}{55'} = \frac{550}{55} = 10''$ inch |
| 3 | $\text{ANGLE}_{\text{in Radians}} = \frac{S}{R}$ | $\frac{.16}{10} = .016$ Radian |

**When ANGLE IS GIVEN IN RADIANS** — *PART OF THE CALCULATION IS ALREADY DONE and FORMULAS ARE SIMPLER*

| | | Example |
|---|---|---|
| 4 | $S = \text{ANGLE}_{\text{in Radians}} \times R$ | $.016 \times 10 = .16''$ inch |
| 5 | $R = \frac{S}{\text{ANGLE}_{\text{in Radians}}}$ | $\frac{.16}{.016} = 10''$ inch |
| 6 | $\text{ANGLE}_{\text{in ANG. MEASURE}} = \text{ANGLE}_{\text{in Rad}} \times 1 \text{ Rad}$ | $.016 \times 3438 = 55'$ Min. of arc |

*1 Radian = 57.3° OR 3438' OR 206265"*




**GUNSIGHT COLLIMATOR IN VERTICAL POSITION** *HAS CONVENIENCE OF A LEVEL STAGE TO SUPPORT LENSES and EYEPIECES*

**MAX. PINHOLES for COLLIMATORS**

| ANGULAR SIZE (Radians) | APERTURE | F.L. of COLLIMATOR LENS | | | | | |
|---|---|---|---|---|---|---|---|
| | | 20" | 24" | 40" | 45" | 60" | 100" |
| .000050 | 1" | .001" | .0012" | .002" | .002" | .003" | .005" |
| .000025 | 2" | .0005 | .0006 | .001 | .001 | .0015 | .0025 |
| .000017 | 3" | .0003 | .0004 | .0007 | .0008 | .0010 | .0017 |
| .000012 | 4" | .0002 | .0003 | .0005 | .0005 | .0007 | .0012 |
| .000010 | 5" | .0002 | .0002 | .0004 | .0005 | .0006 | .0010 |
| .000008 | 6" | | .0002 | .0003 | .0004 | .0005 | .0008 |
| .000007 | 7" | | | .0003 | .0003 | .0004 | .0007 |
| .000006 | 8" | | | .0002 | .0003 | .0004 | .0006 |
| .000005 | 10" | | | | .0002 | .0003 | .0005 |

PINHOLES IN THIS TABLE ARE ABOUT SAME SIZE AS A DIFFRACTION DISK TO FIRST DARK RING for THE VARIOUS DIAMETERS and FOCAL LENGTHS LISTED
*FOR F.L. NOT LISTED, MULTIPLY ANGULAR SIZE IN LEFT COL. BY F.L. OF COLLIMATOR LENS*

If you are testing an eyepiece, the image will be small and you will need a measuring magnifier to get an accurate reading. The usual measuring magnifier has divisions of .005 inch--if you read the image as being, say, .125 inch diameter, you multiply by 10 moving the decimal point one place to the right, giving 1.25 inch as the focal length of the eyepiece. The usual measuring magnifier will read to .500 inch, which means you can measure to 5.00 in. focal length. You can also read half of the target circle diameter and then double it, increasing the working range to 10 in. f.l. Above this you can easily measure the target image with an ordinary ruler, keeping in mind you must multiply the reading by 10.

Not all focal collimators have the convenient constant of 10. Using the same example of a 20-in. f.l. lens but assuming the target 1.75 in. dia., the constant multiplier would be 20/1.75, that is, the f.l. of the lens divided by the diameter of the target. In this example, the multiplier would be 11.43, which is obviously not at all convenient to use.

The collimator lens itself should be a well-corrected achromat at least 2 in. diameter. A useful focal length is 20 inches. However, it is apparent a collimator 2 in. diameter will not test the resolution of a 4 in. telescope. Also, for most testing, a longer lens is more accurate and less likely to have optical faults of its own. In other words, the larger and longer the colli lens, the better. A long lens can be folded with a plane first surface mirror.

GUNSIGHT AS COLLIMATOR. Many artillery gunsights are essentially collimators and are easily adapted for bench use. The original lighting is usually low-voltage, requiring either a battery or a suitable transformer. Perhaps the simplest solution is to substitute a standard 110-volt lamp and use regular household current, as shown in detail drawing on previous page. This gunsight already has the 1/10 radian target; some similar models are not 1/10 radian and are poor as focal collimators although satisfactory for other work.

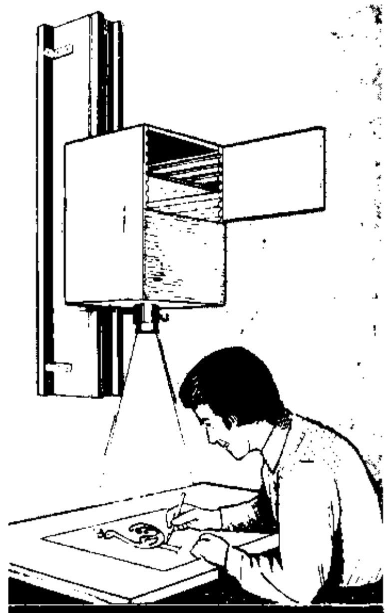
If your work runs to eyepieces and other short focal length optical systems, the gunsight collimator is most convenient in a vertical position, as shown above. This needs a 12-in. rack-and-pinion which you can make or buy from Edmund Scientific. In the vertical position, the original cover glass becomes a level stage on which you can place the lens or lenses for testing.

PINHOLE COLLIMATOR. The target for this is a tiny pinhole, measuring .002 inch or less diameter. The gunsight collimator already described has a pinhole, but its comparatively large diameter of .010 inch is too big for the job which is to make like a star. The general idea is that you are not going to see a star diffraction pattern if the pinhole you are looking at is larger than the diffraction disk of the telescope.

You can make or buy pinholes in foil or tooling metal. The homemade variety is made with a needle mounted in a dowel stick. Work over a sheet of plastic or glass and give the needle a single twirl between your fingers. First results will be about .010 in. It takes a lot of practice to make holes as small as .001 inch.

The lighting for a pinhole should be intense but not hot--a flashlight lamp working through a transformer is excellent. It can be used with a small condenser if desired.

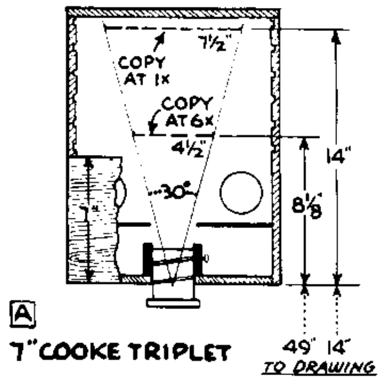
# DRAWING PROJECTORS



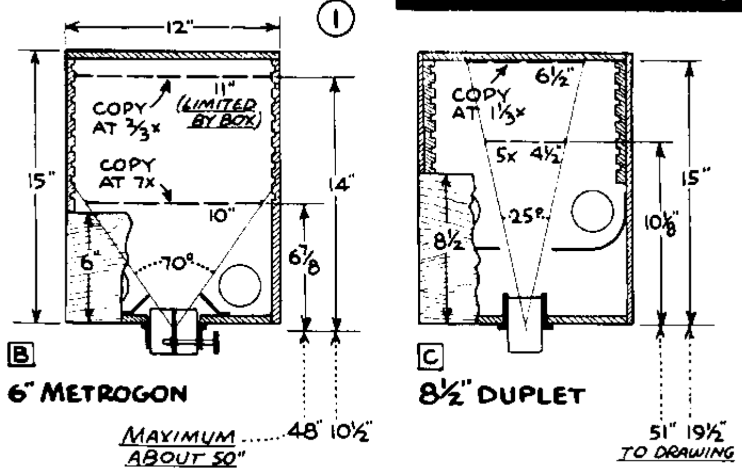

A DRAWING PROJECTOR is an opaque projector designed to enlarge opaque copy such as photographs or line drawings. The magnification range is usually low, being about 1x to 5x. The lens focal length ranges from about 6 to 12 inches. A 6-inch would be ideal except for the fact the short lens may not cover a large enough field. The Metrogon is an exception. In other lenses you usually have to go to 7 or 8 inches f.l. to get the needed field. The lens need not be fast since the usual line copy shows a bright image even at f/8. If you want to project photographs, a fast f/4.5 or wider aperture is desirable.

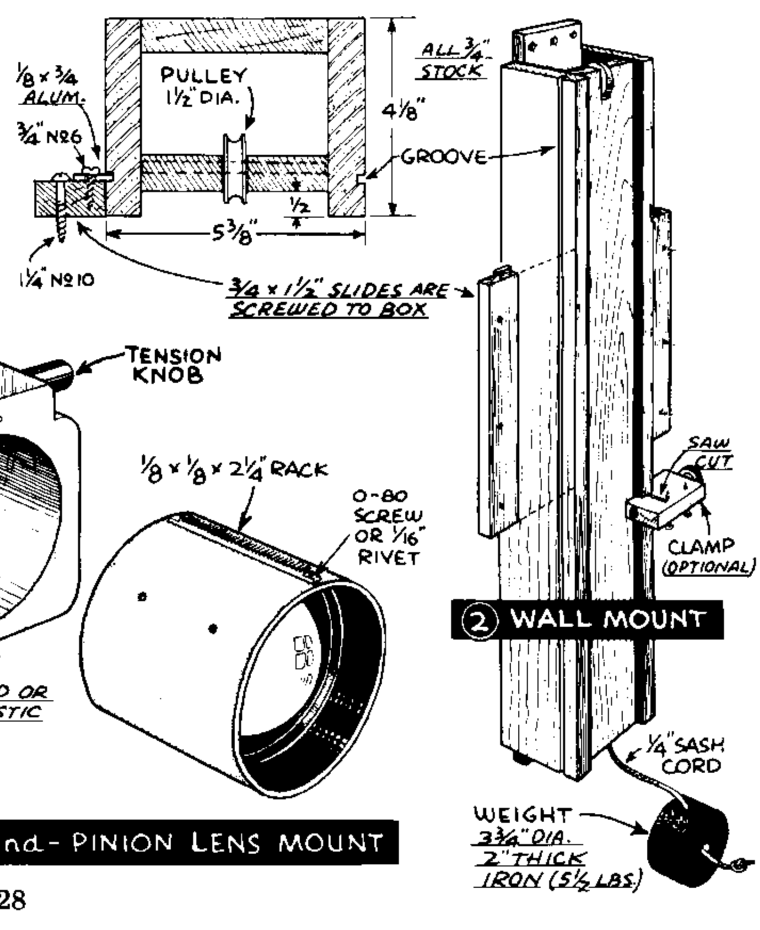
STRAIGHT-SHOT BOX. This is the simplest to build and is often satisfactory although it reverts the image left-to-right if you are using normal front projection. When rear projection is used, the image will be erect and normal left-right. Standard box dimensions for average lenses are about the size of an apple box, Fig. 1, and many builders actually use such a box. You take the box apart to dado or mould the slots in the side pieces which hold the copy board. The copy board itself should be soft pine or redwood or thicker composition board -- something that takes a thumbtack easily. The lighting is usually two 100-watt household lamps in porcelain or plastic sockets spaced no less than 8 in. center-to-center.

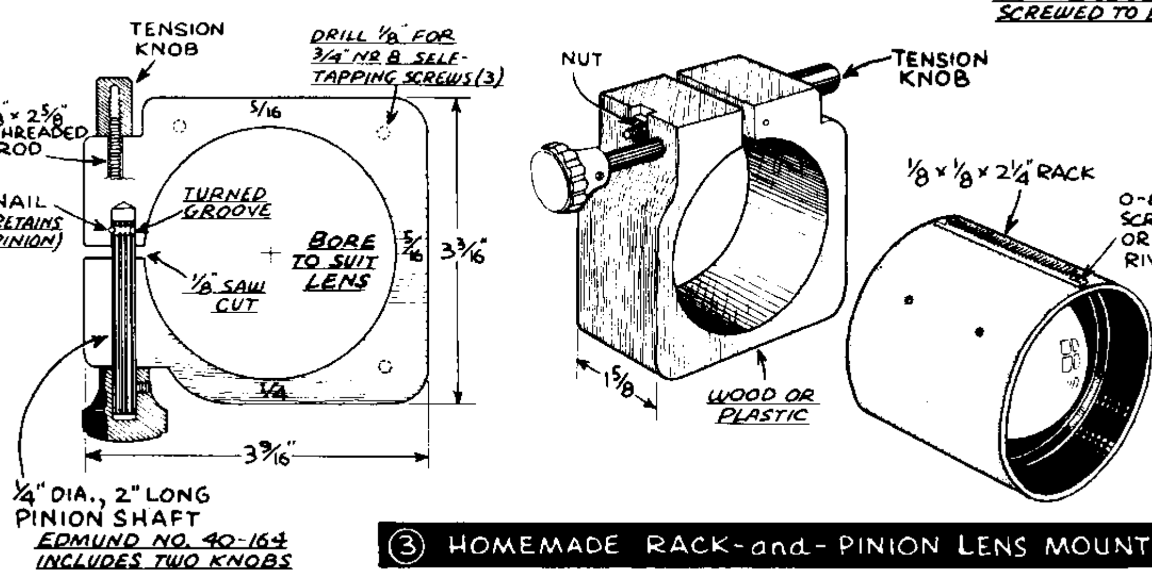
Your projector will be most satisfactory if wall-mounted over a table. Details of a simple mount are shown in Fig. 2. The counterweight



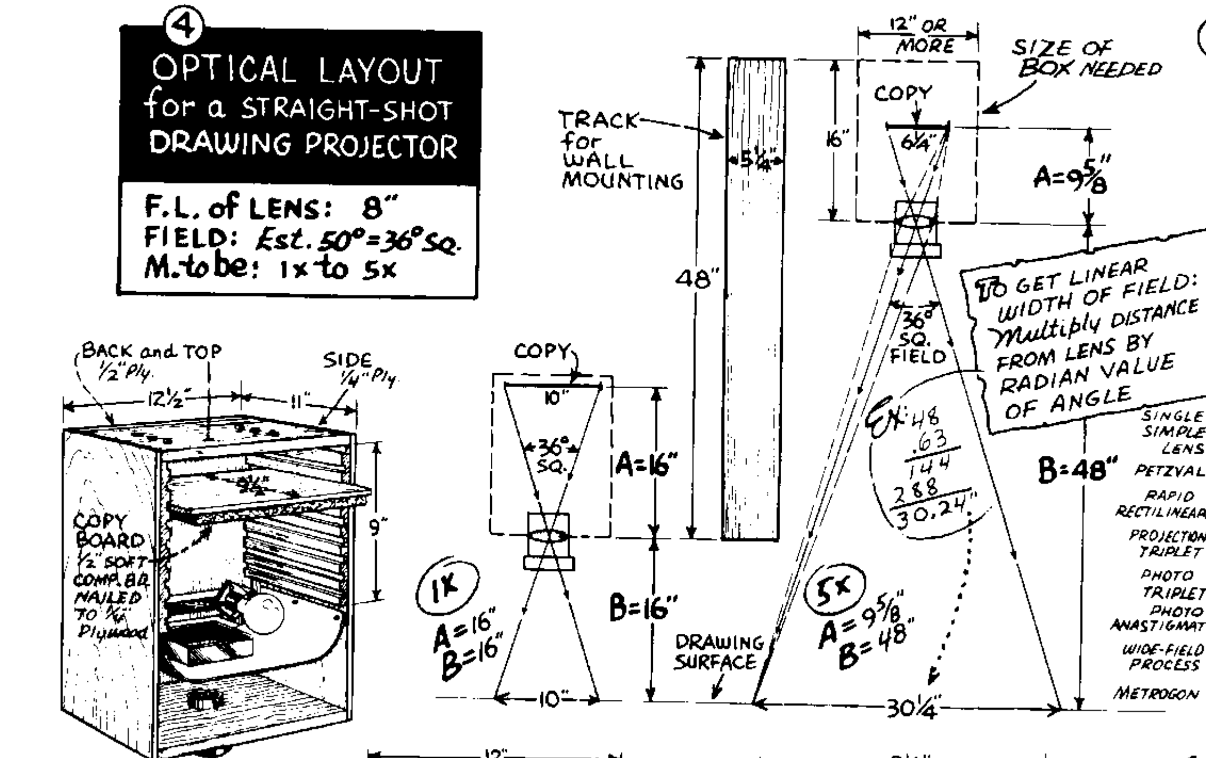

①

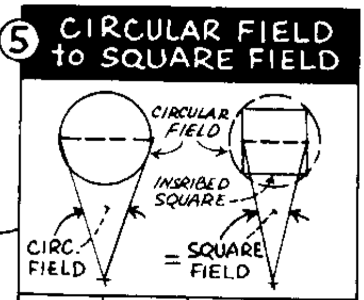


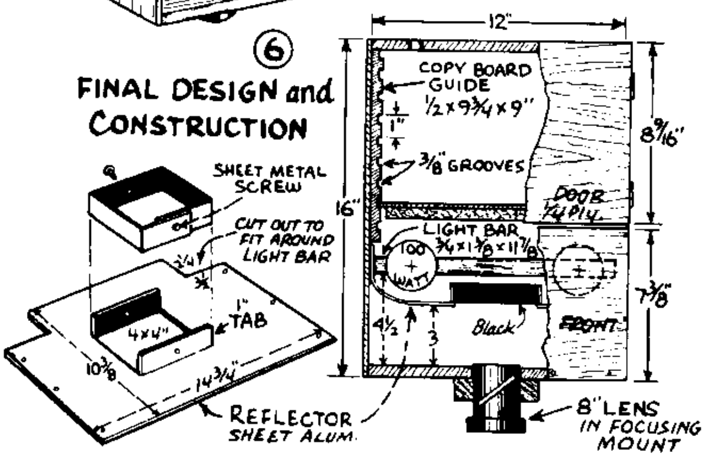




③ HOMEMADE RACK-and-PINION LENS MOUNT

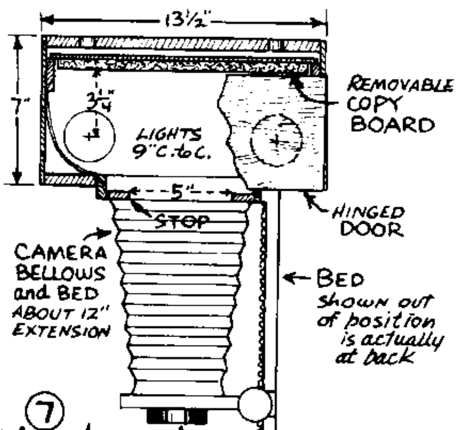


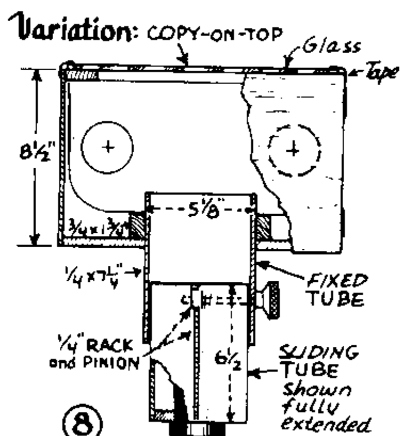

| Lens | CIRC. | Radians | SQUARE | Radians |
|---|---|---|---|---|
| | 20° | .35 | 14° | .24 |
| | 25° | .44 | 18° | .31 |
| SINGLE SIMPLE LENS | 30° | .52 | 22° | .38 |
| PETZVAL | 35° | .61 | 25° | .44 |
| RAPID RECTILINEAR | 40° | .70 | 29° | .51 |
| PROJECTION TRIPLET | 45° | .79 | 32° | .56 |
| PHOTO TRIPLET | 50° | .87 | 36° | .63 EX. |
| PHOTO ANASTIGMAT | 60° | 1.05 | 43° | .75 |
| WIDE-FIELD PROCESS | 70° | 1.22 | 50° | .87 |
| METROGON | 80° | 1.40 | 58° | 1.01 |




COARSE FOCUSING IS DONE BY MOVING THE COPY BOARD... FINE FOCUS IS AT LENS




Variation ALL FOCUSING IS DONE WITH CAMERA BELLOWS and BED



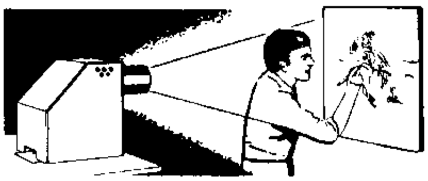

Same BUT FOCUSING WITH SLIDING PLYWOOD TUBE

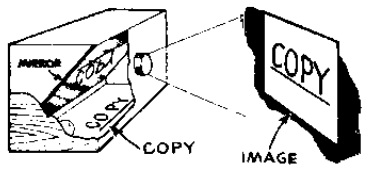
shown is from an astronomical telescope. With any vertical box, simple slide focusing of the lens should be avoided since there is always the chance the lens might drop out of the box. Rack-and-pinion focusing is best, and it is not too much work to make a homemade unit of this kind, Fig. 3. One screw or rivet will hold the rack to the barrel, and you can usually mount this single fastening outside the glass and so avoid a dis-assembly of the lens.

OPTICAL LAYOUT. If you design your own projector, the optical layout is easily made, Fig. 4, using data from the object-image table (see page 31 in this book). The field your lens will cover commonly applies to a circular field. In building a projector, it is simpler to work with a square-shape field, using the equivalent reduced angle, as given in Fig. 5.

Fig. 6 shows the final design and construction of a typical straight-shot projector with 8 in. Cooke Triplet. The lamps are 8 in. center-to-center and unavoidably will show two wide-spaced glare spots on the projected image. The glare spots are especially strong if you are working from a glossy piece of copy, such as a photograph; they are hardly seen at all if the copy is dull paper like newsprint. The square glare stop cut in the reflector will minimize general glare from the interior of the box.

ALL FOCUSING AT LENS. For 1x to 5x magnification with an 8 in. lens, you need only about 6 inches of focusing travel. All of this can be obtained with a bellows or a box to which the lens is attached, as shown in Figs. 7 and 8. When you have all of the focusing at the lens, you need only one permanent position for the copy board. This





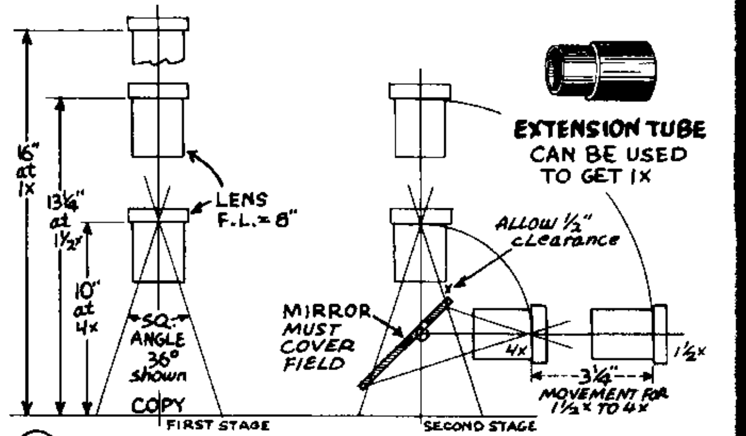

**REFLECTING PROJECTOR with FIRST SURFACE MIRROR SHOWS THE IMAGE ERECT and NORMAL LEFT-RIGHT. THE LINE OF PROJECTION CAN BE HORIZONTAL or VERTICAL**

in turn permits a fixed light-to-copy distance, as can be seen in the drawings. With one-position copy it is practical to put the copy on top of the lighthouse, Fig. 8.

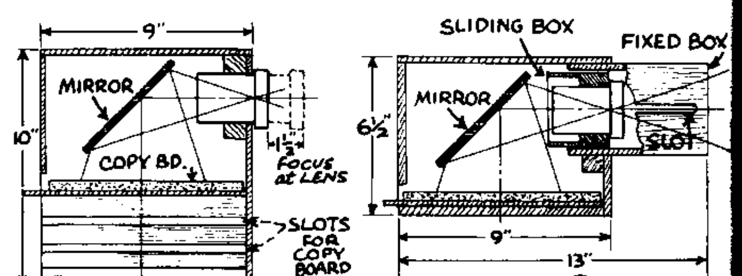
ERECT IMAGE. The image is made erect by using a first surface mirror. In designing a reflecting projector, you start by laying out the lens-to-copy distances in the same way as for a straight-shot box. The diagonal mirror is then drawn behind the lens and the lens is rotated to a horizontal plane, Fig. 9.

The simplest method of focusing is with copy board slots as already described. You also have available a short range of slide focus at the lens itself. All of the movement needed for a 1x to 4x projector can be obtained with a slide box, tube or bellows, Fig. 10.

LIGHTING SYSTEMS. A number of lighting systems are shown in Fig. 11, all being single lamp except J, which shows the familiar two-lamp system using a pair of 100-watt household lamps. Most commercial designs are one-lamp systems using either a photocopy lamp or a projection lamp. With a brighter, hotter lamp, a blower is almost a must.




**(9) OPTICAL LAYOUT** BEGINS LIKE A STRAIGHT-SHOT PROJECTOR. THE TRAVEL NEEDED FOR FOCUSING CAN BE REDUCED BY SPECIFYING 1½x INSTEAD OF 1x for Low M.

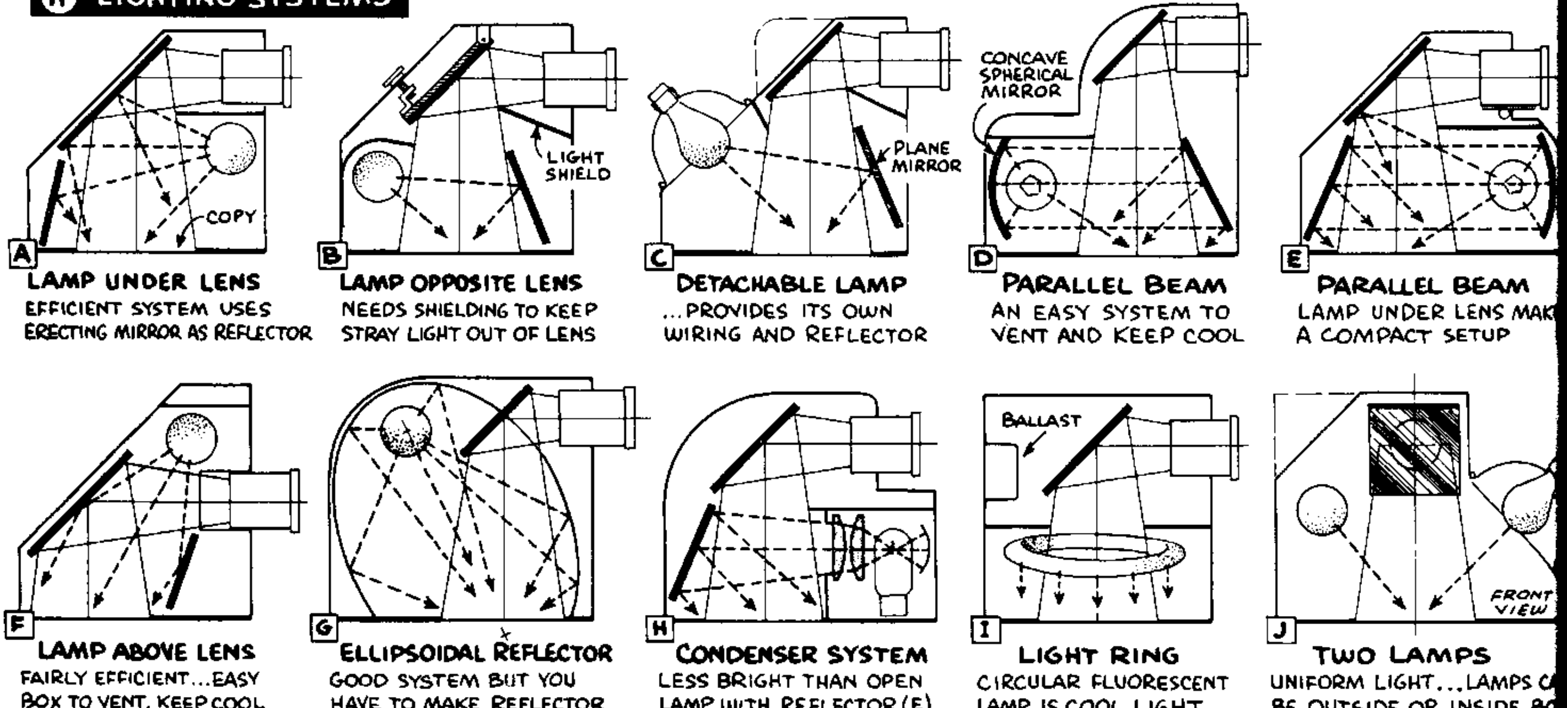



**COPY BOARD IN SLOTS**

**SLIDING BOX**

**(10) FOCUSING METHODS**

**(11) LIGHTING SYSTEMS**




**A LAMP UNDER LENS** EFFICIENT SYSTEM USES ERECTING MIRROR AS REFLECTOR

**B LAMP OPPOSITE LENS** NEEDS SHIELDING TO KEEP STRAY LIGHT OUT OF LENS

**C DETACHABLE LAMP** ...PROVIDES ITS OWN WIRING AND REFLECTOR

**D PARALLEL BEAM** AN EASY SYSTEM TO VENT AND KEEP COOL

**E PARALLEL BEAM** LAMP UNDER LENS MAKES A COMPACT SETUP

**F LAMP ABOVE LENS** FAIRLY EFFICIENT...EASY BOX TO VENT, KEEP COOL

**G ELLIPSOIDAL REFLECTOR** GOOD SYSTEM BUT YOU HAVE TO MAKE REFLECTOR

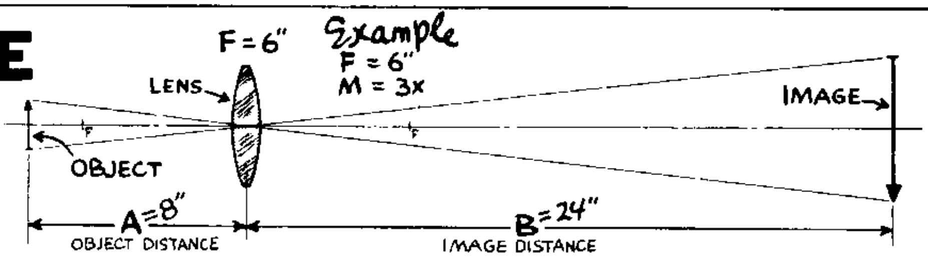
**H CONDENSER SYSTEM** LESS BRIGHT THAN OPEN LAMP WITH REFLECTOR (E)

**I LIGHT RING** CIRCULAR FLUORESCENT LAMP IS COOL LIGHT

**J TWO LAMPS** UNIFORM LIGHT...LAMPS CAN BE OUTSIDE OR INSIDE BOX

SEE EDMUND OVERHEAD PROJECTOR OPTICS KIT No. 70,966 in LATEST CATALOG

# OBJECT-IMAGE DISTANCES at Various Magnifications




| F.L. | | 1 1/4x | 1 1/2x | 1 3/4x | 2x | 2 1/2x | 3x | 4x | 5x | 6x | 7x | 8x | 9x | 10x | 12x | 15x | 20x | 25x |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1" | A → | 1 13/16" | 1 11/16" | 1 9/16" | 1 1/2" | 1 3/8" | 1 5/16" | 1 1/4" | 1 3/16" | 1 3/16" | 1 1/8" | 1 1/8" | 1 1/8" | 1 1/8" | 1 1/8" | 1 1/16" | 1 1/16" | 1 1/16" |
| | B → | 2 1/4 | 2 1/2 | 2 3/4 | 3 | 3 1/2 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 13 | 16 | 21 | 26 |
| 1 1/4" | A → | 2 1/4 | 2 1/16 | 1 15/16 | 1 7/8 | 1 3/4 | 1 11/16 | 1 9/16 | 1 1/2 | 1 7/16 | 1 7/16 | 1 3/8 | 1 3/8 | 1 3/8 | 1 3/8 | 1 5/16 | 1 5/16 | 1 5/16 |
| | B → | 2 13/16 | 3 1/8 | 3 7/16 | 3 3/4 | 4 3/8 | 5 | 6 1/4 | 7 1/2 | 8 3/4 | 10 | 11 1/4 | 12 1/2 | 13 3/4 | 16 1/4 | 20 | 26 1/4 | 32 1/2 |
| 1 1/2" | A → | 2 11/16 | 2 1/2 | 2 3/8 | 2 1/4 | 2 1/8 | 2 | 1 7/8 | 1 3/4 | 1 3/4 | 1 3/4 | 1 5/8 | 1 5/8 | 1 5/8 | 1 5/8 | 1 5/8 | 1 9/16 | 1 1/2 |
| | B → | 3 3/8 | 3 3/4 | 4 1/8 | 4 1/2 | 5 1/4 | 6 | 7 1/2 | 9 | 10 1/2 | 12 | 13 1/2 | 15 | 16 1/2 | 19 1/2 | 24 | 31 1/2 | 39 |
| 2" | A → | 3 5/8 | 3 5/16 | 3 1/8 | 3 | 2 3/4 | 2 5/8 | 2 1/2 | 2 3/8 | 2 3/8 | 2 1/4 | 2 1/4 | 2 1/4 | 2 1/4 | 2 3/16 | 2 1/8 | 2 1/8 | 2 1/8 |
| | B → | 4 1/2 | 5 | 5 1/2 | 6 | 7 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 26 | 32 | 42 | 52 |
| 2 1/2" | A → | 4 1/2 | 4 3/16 | 3 13/16 | 3 3/4 | 3 1/2 | 3 1/4 | 3 1/8 | 3 | 2 7/8 | 2 7/8 | 2 3/4 | 2 3/4 | 2 3/4 | 2 11/16 | 2 5/8 | 2 5/8 | 2 5/8 |
| | B → | 5 5/8 | 6 1/4 | 6 7/8 | 7 1/2 | 8 3/4 | 10 | 12 1/2 | 15 | 17 1/2 | 20 | 22 1/2 | 25 | 27 1/2 | 32 1/2 | 40 | 52 1/2 | 65 |
| 3" | A → | 5 3/8 | 5 | 4 11/16 | 4 1/2 | 4 3/16 | 4 | 3 3/4 | 3 5/8 | 3 1/2 | 3 1/2 | 3 3/8 | 3 1/4 | 3 1/4 | 3 1/4 | 3 1/4 | 3 1/8 | 3 1/8 |
| | B → | 6 3/4 | 7 1/2 | 8 1/4 | 9 | 10 1/2 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 39 | 48 | 63 | 78 |
| 3 1/2" | A → | 6 1/4 | 5 13/16 | 5 1/2 | 5 1/4 | 4 7/8 | 4 5/8 | 4 3/8 | 4 3/16 | 4 1/16 | 4 | 3 15/16 | 3 7/8 | 3 7/8 | 3 3/4 | 3 3/4 | 3 11/16 | 3 5/8 |
| | B → | 7 7/8 | 8 3/4 | 9 5/8 | 10 1/2 | 12 1/4 | 14 | 17 1/2 | 21 | 24 1/2 | 28 | 31 1/2 | 35 | 38 1/2 | 45 1/2 | 56 | 73 1/2 | 91 |
| 4" | A → | 7 3/16 | 6 11/16 | 6 5/16 | 6 | 5 5/8 | 5 3/8 | 5 | 4 3/4 | 4 3/4 | 4 5/8 | 4 1/2 | 4 1/2 | 4 3/8 | 4 5/16 | 4 1/4 | 4 3/16 | 4 1/8 |
| | B → | 9 | 10 | 11 | 12 | 14 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 52 | 64 | 84 | 8'-8 |
| 4 1/2" | A → | 8 1/8 | 7 1/2 | 7 1/16 | 6 3/4 | 4 1/2 | 6 | 5 5/8 | 5 3/8 | 5 1/4 | 5 1/8 | 5 1/16 | 5 | 4 15/16 | 4 7/8 | 4 13/16 | 4 3/4 | 4 11/16 |
| | B → | 10 1/8 | 11 1/4 | 12 3/8 | 13 1/2 | 11 1/4 | 18 | 22 1/2 | 27 | 31 1/2 | 36 | 40 1/2 | 45 | 49 1/2 | 58 1/2 | 72 | 94 1/2 | 9'-9 |
| 5" | A → | 9 | 8 5/16 | 7 7/8 | 7 1/2 | 7 | 6 5/8 | 6 1/4 | 6 | 5 7/8 | 5 3/4 | 5 5/8 | 5 1/2 | 5 1/2 | 5 7/16 | 5 3/8 | 5 1/4 | 5 1/4 |
| | B → | 11 1/4 | 12 1/2 | 13 3/4 | 15 | 17 1/2 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 65 | 80 | 8'-9 | 10'-10 |
| 5 1/2" | A → | 9 7/8 | 9 3/16 | 8 5/8 | 8 1/4 | 7 3/4 | 7 5/16 | 6 3/8 | 6 9/16 | 6 3/8 | 6 1/4 | 6 3/16 | 6 1/8 | 6 1/16 | 5 15/16 | 5 7/8 | 5 3/4 | 5 3/4 |
| | B → | 12 3/8 | 13 3/4 | 15 1/8 | 16 1/2 | 19 1/4 | 22 | 27 1/2 | 33 | 38 1/2 | 44 | 49 1/2 | 55 | 60 1/2 | 71 1/2 | 88 | 9'-7 1/2 | 11'-11 |
| 6" | A → | 10 13/16 | 10 | 9 7/16 | 9 | 8 3/8 | 8 | 7 1/2 | 7 1/4 | 7 | 6 7/8 | 6 3/4 | 6 5/8 | 6 5/8 | 6 1/2 | 6 3/8 | 6 5/16 | 6 1/4 |
| | B → | 13 1/2 | 15 | 16 1/2 | 18 | 21 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 78 | 96 | 10'-6 | 13'-0 |
| 6 1/2" | A → | 11 11/16 | 10 3/4 | 10 3/16 | 9 3/4 | 9 1/8 | 8 5/8 | 8 1/8 | 7 3/4 | 7 1/2 | 7 3/8 | 7 1/4 | 7 1/4 | 7 1/8 | 7 1/16 | 6 7/8 | 6 13/16 | 6 5/8 |
| | B → | 14 5/8 | 16 1/4 | 17 7/8 | 19 1/2 | 22 3/4 | 26 | 32 1/2 | 39 | 45 1/2 | 52 | 58 1/2 | 65 | 71 1/2 | 84 1/2 | 8'-8 | 11'-4 1/2 | 14'-1 |
| 7" | A → | 12 5/8 | 11 11/16 | 11 | 10 1/2 | 9 13/16 | 9 1/4 | 8 3/4 | 8 3/8 | 8 1/8 | 8 | 7 7/8 | 7 3/4 | 7 3/4 | 7 9/16 | 7 1/2 | 7 3/8 | 7 1/4 |
| | B → | 15 3/4 | 17 1/2 | 19 1/4 | 21 | 24 1/2 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 91 | 9'-4 | 12'-3 | 15'-1 |
| 7 1/2" | A → | 13 1/2 | 12 1/2 | 11 3/4 | 11 1/4 | 10 1/2 | 10 | 9 3/8 | 9 | 8 3/4 | 8 1/2 | 8 3/8 | 8 1/4 | 8 1/4 | 8 1/8 | 8 | 7 7/8 | 7 3/4 |
| | B → | 16 7/8 | 18 3/4 | 20 5/8 | 22 1/2 | 26 1/4 | 30 | 37 1/2 | 45 | 52 1/2 | 60 | 67 1/2 | 75 | 82 1/2 | 97 1/2 | 10'-0 | 13-1/2 | 16'-3 |
| 8" | A → | 14 7/16 | 13 1/4 | 12 9/16 | 12 | 11 1/4 | 10 5/8 | 10 | 9 5/8 | 9 1/4 | 9 1/8 | 9 | 8 7/8 | 8 3/4 | 8 11/16 | 8 1/2 | 8 3/8 | 8 1/4 |
| | B → | 18 | 20 | 22 | 24 | 28 | 32 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 8'-8 | 10'-8 | 14'-0 | 17'-4 |
| 8 1/2" | A → | 15 5/16 | 14 1/4 | 13 3/8 | 12 3/4 | 11 7/8 | 11 1/4 | 10 5/8 | 10 1/8 | 9 7/8 | 9 3/4 | 9 5/8 | 9 1/2 | 9 3/8 | 9 1/4 | 9 1/16 | 8 15/16 | 8 7/8 |
| | B → | 19 1/8 | 21 1/4 | 23 3/8 | 25 1/2 | 29 3/4 | 34 | 42 1/2 | 51 | 59 1/2 | 68 | 76 1/2 | 85 | 93 1/2 | 9'-2 1/2 | 11'-4 | 14'-10 | 18'-5 |
| 9" | A → | 16 5/8 | 15 | 14 1/8 | 13 1/2 | 9 | 12 | 11 1/4 | 10 3/4 | 10 1/2 | 10 1/4 | 10 1/8 | 10 | 9 7/8 | 9 3/4 | 9 5/8 | 9 7/16 | 9 3/8 |
| | B → | 20 1/4 | 22 1/2 | 24 3/4 | 27 | 22 1/2 | 36 | 45 | 54 | 63 | 72 | 81 | 90 | 99 | 9'-9 | 12'-0 | 15'-9 | 19'-6 |
| 10" | A → | 18 | 16 5/8 | 15 3/4 | 15 | 14 | 13 3/8 | 12 1/2 | 12 | 11 5/8 | 11 1/2 | 11 1/4 | 11 1/8 | 11 | 10 13/16 | 10 5/8 | 10 1/2 | 10 3/8 |
| | B → | 22 1/2 | 25 | 27 1/2 | 30 | 35 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 9'-2 | 10'-10 | 13'-4 | 17'-6 | 21'-8 |
| 11" | A → | 19 13/16 | 18 5/16 | 17 1/4 | 16 1/2 | 15 3/8 | 14 5/8 | 13 3/4 | 13 1/8 | 12 3/4 | 12 1/2 | 12 3/8 | 12 1/4 | 12 1/8 | 11 7/8 | 11 3/4 | 11 9/16 | 11 7/16 |
| | B → | 24 3/4 | 27 1/2 | 30 1/4 | 33 | 38 1/2 | 44 | 55 | 66 | 77 | 88 | 99 | 9'-2 | 10'-1 | 11'-11 | 14'-8 | 19'-3 | 23'-10 |
| 12" | A → | 21 3/4 | 20 | 18 7/8 | 18 | 16 3/4 | 16 | 15 | 14 3/8 | 14 | 13 3/4 | 13 1/2 | 13 1/4 | 13 1/8 | 13 | 12 3/4 | 12 5/8 | 12 1/2 |
| | B → | 27 | 30 | 33 | 36 | 42 | 48 | 60 | 72 | 84 | 96 | 9'-0 | 10'-0 | 11'-0 | 13'-0 | 16'-0 | 21'-0 | 26'-0 |
| 13" | A → | 23 3/8 | 21 5/8 | 20 7/16 | 19 1/2 | 18 3/16 | 17 1/4 | 16 1/4 | 15 1/2 | 15 1/8 | 14 7/8 | 14 5/8 | 14 3/8 | 14 1/4 | 16 1/16 | 13 7/8 | 13 5/8 | 13 1/2 |
| | B → | 29 1/4 | 32 1/2 | 35 3/4 | 39 | 45 1/2 | 52 | 65 | 78 | 91 | 8'-8 | 9'-9 | 10'-10 | 11'-11 | 14'-1 | 17'-4 | 22'-9 | 28'-2 |
| 14" | A → | 25 3/16 | 23 5/16 | 22 | 21 | 19 5/8 | 18 1/2 | 17 1/2 | 16 3/4 | 16 1/4 | 16 | 15 3/4 | 15 1/2 | 15 3/8 | 15 3/16 | 15 | 14 11/16 | 14 1/2 |
| | B → | 31 1/2 | 35 | 38 1/2 | 42 | 49 | 56 | 70 | 84 | 98 | 9'-4 | 10'-6 | 11'-8 | 12'-10 | 15'-2 | 18'-8 | 24'-6 | 30'-2 |
| RECIPROCAL M. → | | 4/5x 80% | 2/3x 67% | 4/7x 57% | 1/2x 50% | 2/5x 40% | 1/3x 33% | 1/4x 25% | 1/5x 20% | 1/6x 17% | 1/7x 14% | 1/8x 12 1/2% | 1/9x 11% | 1/10x 10 | 1/12x 8% | 1/15x 6 1/2% | 1/20x 5% | 1/25x 4% |

*THE RECIPROCAL OF M. GIVES MAGNIFICATIONS LESS THAN 1. USE SAME FIGURES BUT INTERCHANGE A and B*

# Parts Used in Designs

TOGGLE SWITCH
Stock No. 75

CONCAVE REFLECTORS
Use these in back of projection bulbs to increase screen light.

METAL CONCAVE REFLECTOR 35MM DIAMETER
Placed 32mm from lamp filament.
Stock No. 566

TUNGSTEN HALOGEN LAMPS
500-watt 10,000 lumens 3-5/8" x 1/2"
Stock No. 40,779
250-watt 5,000 lumens 3" x 1/2"
Stock No. 40,780
Screw Socket for either lamp. No. 40,781

GROUND GLASS
Use this in Enlargers, Viewers, Projectors, etc.

| Stock No. | Size | Thickness |
|---|---|---|
| 2143 | 2-1/4"x3-1/4" | 1/16" |
| 2144 | 3-1/4"x4-1/4" | 1/16" |
| 2146 | 5"x7" | 1/16" |
| 2147 | 8"x10" | 1/16" |
| 2148 | 4"x5" | 1/16" |

TEMPERED HEAT ABSORBING GLASS
Use with bulbs up to 500 watts. Not mounted.

OPAL GLASS
Size 4" x 5", thickness 1/8", Stock No.2149

SMALL MOTOR WITH 3½" FAN BLADE
Ideal for cooling your projector, less damage to slides, longer bulb life, allows you to use brighter light, runs on 115 volt current found in most homes, can be used vertically or horizontally. Size approx. 3-1/4" x 2-1/4" without fan on it. Runs quietly. Stock No. 101

MOTOR AND 6" FAN FOR COOLING PROJECTORS
Prolongs life of projector bulbs and allows you to use brighter light. This 3,600 RPM, 120v AC motor with 4-blade aluminum fan is the same one we recommend for our Overhead Projector Optics Kit ( No. 70,966). Rotates counterclockwise. Includes instructions for quick conversion to clockwise rotation. Stock No. 60,689

HEAT ABSORBING PLATE GLASS
Unmounted. Not to be used with bulbs over 150 watts without using a blower.

| Stock No. | Size | Thickness |
|---|---|---|
| 4009 | 4" x 5"(102 x 127mm) | 1/4"(6.4mm) |
| 4010 | 2" x 2"(51 x 51mm) | 1/4"(6.4mm) |

ROUND HEAT ABSORBING GLASS

| Stock No. | Size | Thickness |
|---|---|---|
| 30, 791 | 38 mm dia. | 3 mm |

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