classes and to measure their crown diameters.

Quantitative studies of several forest types will be necessary before a definite opinion on the value of this type of photography can be expressed; however, it is clear that the encouraging results of these initial studies justify further more detailed investigations into the subject of low-elevation photography from helicopters.

REFERENCES

1. Avery, Gene, "Helicopter Stereo-Photography of Forest Plots," PHOTOGRAMMETRIC ENGINEERING, 24: 617–625 (1958) Illus.
2. Avery, Gene, "Photographing Forests from Helicopters," *Jour. Forestry,* 57: 339–342 (1959) Illus.
3. Colwell, R. N., "The Taking of Helicopter Photography for Use in Photogrammetric Research and Training," PHOTOGRAMMETRIC ENGINEERING, 22: 613–621 (1956) Illus.

*A Reflecting Projector You Can Build**

DAN MEYER†

ABSTRACT: *Reflecting projectors provide efficient means for transferring photographic detail from annotated contact prints to base maps, particularly where an enlargement or reduction is desired. This paper describes an inexpensive, "build-it-yourself" reflecting projector that compares favorably with commercially-manufactured models.*

REFLECTING projectors are used primarily for transferring detail from existing planimetric and topographic maps, aerial photos and technical drawings to more convenient scales. They are faster and less laborious to use than the pantograph, and generally cheaper than photographic enlargement or reduction. The ability to make scale changes rapidly is one of the principal advantages of such machines, especially when compiling controlled maps from aerial photographs. A projector is superior to a sketchmaster in speed and clarity, but like the sketchmaster it permits viewing only a single photograph and commonly requires stereoscopic annotation of detail before transferring to the base map.

Commercial reflecting projectors are expensive, selling for $1,000 and more, and often difficult to justify economically. A simple projector that will enlarge or reduce opaque copy can be constructed for less than $100. The homemade model described in this paper is not as refined, but it does an adequate and efficient job at a tenth the cost of commercial models.

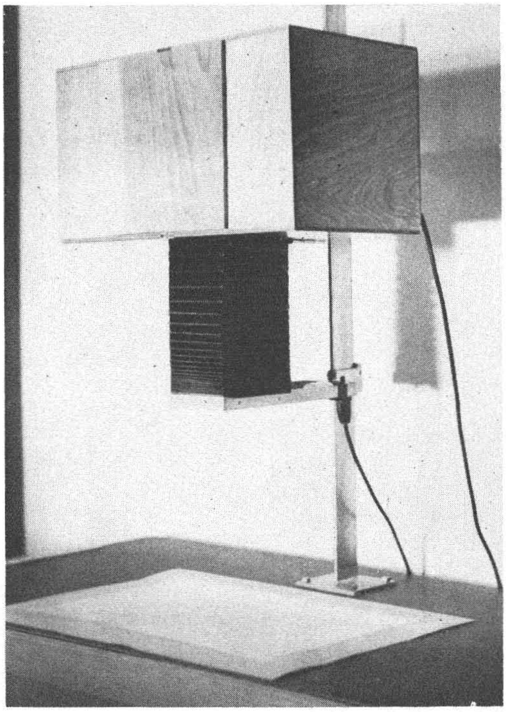

FIG. 1. Photo of the Yakima projector.

Basically, all reflecting projectors work on the same principle, and are similar to photographic enlargers. They differ from photographic enlargers in that instead of passing light through a transparent negative to project the image, light is used only to illuminate the copy, and the image is reflected by a mirror through the lens. Hence, the name reflecting projector has been applied. Enlarge-

* Publication approved by Sup't of Yakima Agency and Portland Area Director of Bureau of Indian Affairs.

† Forester, Yakima Indian Agency, Toppenish, Washington.

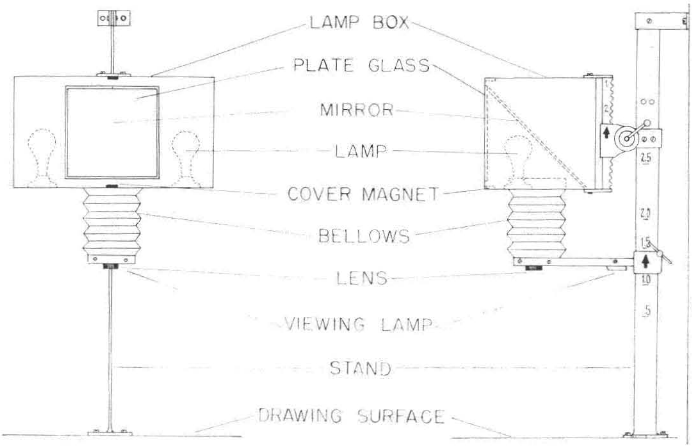

FIG. 2. Sketch of a homemade reflecting projector.

ment and reduction are effected by changing the distances between object and lens, and between lens and projected image. Commercial models incorporate elaborate systems which control these two distinct movements in one operation so that the resulting image is always in focus.

The projector shown in Figure 1 was developed by the author at the Yakima Indian Agency. The projector was assembled in one week at a cost of $76, excluding personal labor. It will project an 8″×8″ area of opaque copy through a range of .33× to 3×. The basic difference between it and the commercial models is that it is not self-focusing throughout its range of enlargement and reduction. Actually, the time spent in focusing is but a fraction of that spent in tracing, and unless the machine is intended solely for radial-line mapping, the excess in time expenditure is not a great drawback. The machine has a calibrated index which permits quickly setting to the desired enlargement or reduction. In compiling controlled maps from aerial photos, the calibrations serve as guides and provide approximate setting; exact positioning is then determined by trial and error.

The following is a brief description of the component parts illustrated in Figure 2.

Lens: A 7-inch-focal-length anastigmatic projection lens is recommended. (Any good projection lens with a focal-length of between 6 and 8 inches will also work.) This type of lens is used in the better 35 mm. slide projectors, and may be purchased from camera supply houses, manufacturers, or through companies specializing in surplus optical equipment.

Bellows: The bellows is 4″×4″, inside diameter, and 22″ long. The length will depend on the focal-length of the lens used. To compute the minimum length required, use the formula: $f+f/M-H$; where f=focal-length (say 7″), M=lowest magnification (say .33), and H=height dimension of the lamp box (say 10″). It is advisable when ordering to add 3 or 4 inches to permit fastening the bellows to the machine. The bellows must be specially ordered from a manufacturer, or camera supply house.

Lamp Box: The lamp box is $\frac{1}{4}$″ birch plywood, and measures 10″×10″×18″ outside dimensions. It is lined with aluminum foil to aid reflection and cooling. A network of holes in the top panel provides ventilation. The holes are small, closely spaced, and drilled at an angle to permit the warm air to escape with a minimum of light loss. A small fan inside the box is recommended if the projector is to be subjected to long hours of constant operation. Otherwise, the air vents will be adequate. Two 75 watt lamps will provide enough illumination if the projector is used in total darkness. The projector may be modified to operate in a semi-darkened room by the addition of more powerful lamps and a cooling fan. The lamp box is fitted with an 8″×$\frac{1}{4}$″×12$\frac{1}{2}$″ plate mirror set at a 45 degree angle. First surface mirrors are superior because they are distortion free, but these are more expensive. Either $\frac{1}{4}$ or $\frac{1}{8}$ inch plate-glass will work, the latter being preferred. An 8$\frac{1}{2}$×8$\frac{1}{2}$ inch piece of $\frac{1}{4}$ inch plate-glass fits flush with the front of the lamp box. The glass is held in place with tape, and is easily removed to permit replacement of bulbs and

TABLE 1. COST OF PROJECTOR COMPONENTS

Item	*Possible Source*†	*Approximate Cost*†
Lens	Edmund Scientific Co., Barrington, New Jersey	$12.00
First Surface Mirror*	Edmund Scientific Co., Barrington, New Jersey	11.50
Cooling Fan*	Edmund Scientific Co., Barrington, New Jersey	3.25
Bellows	Western Bellows Co., 5234 East Valley Blvd., Los Angeles, California	24.00
Rack and Pinion	Automotive Supply Houses	15.00
Stand and Lens Clamp	Local Machine Shops	10.00
Plywood, plate glass, electrical fixtures, magnets, and shellac	Local Hardware and Lumber dealers	15.00
	Total	$90.75

* Optional.
† It should not be inferred that there are not other sources that will be fully satisfactory. Also the cost may vary considerably from the amounts given in the tabulation.—*Editor*

general servicing. A 10″×10″ cover holds the copy flush against the glass. The cover is fastened to the lamp box by means of permanent magnets which permit insertion of large copy between the cover and the glass. These magnets are those used in magnetic cabinet catches and may be purchased at local hardware or lumber dealers.

Stand and Attachments: The reduction and enlargement of copy necessitates movement of both the lamp box and the lens. The lens is lightweight and may be attached to the stand by means of a simple clamp. The lamp box, on the other hand, is fairly heavy and fine adjustments with a clamp would be extremely cumbersome. The machine is equipped with a 10″ rack-and-pinion which provides sufficient movement of the box while maintaining positive control. This size of rack is very convenient for mounting to the lamp box, but necessitates a movement to the alternate higher position on the stand ($30\frac{1}{2}$″) in order to permit the .33× and 3× projections. (The lower position will permit a range of .5× to 2.5× and is suitable for most work.) Such a device can often be found on surplus machinery. (Automobile valve-spring lifters are equipped with such rack-and-pinion gears, for example.) The rack will undoubtedly have to be modified to fit the box. This work, and that of making the lens bracket and clamp, can be performed by most machine shops.

The stand is made of steel, 2″ wide, $\frac{1}{4}$″ thick and 38″ long. A 4″×4″ steel base is welded to the bottom, and has four $\frac{5}{16}$″ holes for mounting to table or drawing board. A single hole is centered 1″ from the top of the stand to enable bolting to stabilizing wall bracket.

Once the machine is assembled, the stand and rack may be calibrated to permit quick setting. The exact position of the box and the lens at .33× is scribed in the metal. Their position at other magnifications is similarly marked. In this way, the operator may adjust the lens and box to a desired magnification easily and quickly.

A small lamp is attached to the lens bracket to provide illumination of the base map during tracing. A night light is most suitable and is easily attached to the bracket. Such lights may be purchased at drug and department stores.

The above recommendations concerning methods and materials of course may be changed to suit the builder's needs and skills. The cost will also depend on how much the the builder himself can do, and how fortunate he is in finding the necessary materials in surplus stores. An itemized list of materials is presented in Table 1.

The following formulas can be used to determine projector dimensions for any focal length lens: $Do=f+f/M$; $Di=f+fM$; where Do and Di are the distances between object and lens, and image and lens respectively; f is the focal-length of the lens; and M is the magnification.