UCRL-4781

UNIVERSITY OF CALIFORNIA
Radiation Laboratory, Livermore Site
Livermore, California
Contract No. W-7405-eng-48

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February 1, 1957

Printed for the U. S. Atomic Energy Commission

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ABSTRACT

A simple method is described for producing parabolic mirrors by revolving a horizontal pan of liquid plastic and allowing it to harden into the parabolic shape which has been assumed by the liquid plastic. This surface can be plated without further polishing into a mirror of a quality suited to various laboratory and industrial applications.

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Among the most interesting surfaces of solid geometry is the paraboloid. This surface, generated by revolving a parabola about its axis, is widely used for reflectors in telescopes, searchlights, automobile headlights, and solar furnaces. The well-known characteristic of the paraboloid that accounts for its use in such devices is its ability to reflect all light parallel to the principal axis onto a common focal point.

The current method of forming a paraboloid surface presents certain problems requiring extensive and specialized equipment and a very large amount of labor in the final polishing operation. This article describes the manufacture of paraboloids from a synthetic resin by a process that requires no extensive machinery and completely eliminates the polishing operation.

The principle utilized is that a liquid in a revolving horizontal pan takes the shape of a paraboloid, and that a liquid resin suitably catalyzed to harden after this form is taken will retain the shape. The possible reason why this simple method has not been developed in the past may have been the unavailability of a suitable resin.

With the development of the epoxy resins, which has occurred on a commercial scale only within the last several years, a satisfactory material has been made available. These resins are characterized by high strength, low shrinkage, and, of special interest, an extremely smooth glass-like surface when set. This surface may be plated to produce a mirror without polishing.

The focal length is controlled by the speed of rotation of the pan. The density and the viscosity of the resin have no effect on the focal length of the paraboloid. The formula for the focal length may be simplified to $\sqrt{f} = 38.4/\text{rpm}$, where f is the focal length in feet. Thus a paraboloid of the general appearance of an automobile headlight is formed at 180 rpm while a 36-inch focal length requires a speed of only 22.7 rpm.

While various epoxy resin-catalyst systems might be employed, a suitable resin Epon 828 catalyzed with 5% piperidine and cured at 80 to 90°C has been found to give satisfactory results. The principal problem has been to devise a suitable turntable which would be free of harmful vibrations.

In 1900 R. W. Wood, an American inventor, investigated the use of a revolving pan of mercury as a parabolic astronomical mirror. Further development of this idea was handicapped by the lack of a vibration-free turntable. Very fortunately, insofar as vibration is concerned, the requirements for producing a plastic or resin mirror are much less severe than those for producing a smooth surface on a revolving pan of mercury. Thus, good resin surfaces up to ten inches in diameter were produced from a turntable mounted directly onto the slow-speed shaft of a gear-reduction motor. The production of 36-inch mirrors, which is currently under way, has been attended by some difficulty, the problem being aggravated somewhat by the easy success of the smaller turntables. These difficulties centered on the proper selection of bearings, reduction gears, motor, etc.

The actual production of a mirror is a relatively quick and simple process. The resin (warmed) and catalyst are mixed together and poured into a pan on the rotating turntable. A lid is placed over the pan to prevent entrance of dust and the resin allowed to cure for a period of from 5 to 6 hours. Additional resin may be poured onto this surface after it has set. In general, superior surfaces are obtained on the second or third pour. Inasmuch as the quantity of resin required on these additional pours is much less than on the first pour, a considerable saving in resin is possible. This also serves as a means for introducing reinforcing material into the resin without affecting the mirror surface.

Mirrors up to 36 inches in diameter with a 36-inch focal length have been produced with the techniques described. The first mirror of this size cracked after cooling. Several layers of fiberglass cloth were placed on the surface and a new surface poured. This reinforced mirror appears to be much less subject to thermal shock. Subsequent f1, 36-inch mirrors have been produced with a foamed-in-place plastic backing and a fiberglass reinforcement. This reduced the weight of the mirror to 25% of the solid one of the same size. These mirrors have been successfully plated with vaporized aluminum under high vacuum (see Fig. 1).

The possibility of producing a thin mirror by pouring resin onto a spinning pan of mercury was also investigated. A primary form was first cast from plastic to minimize the amount of mercury required to cover the surface and then liquid resin was added and allowed to set. This produced a thin-walled paraboloid with a mirror surface on both sides (see Fig. 2). The use of fiberglass reinforcement with this system would appear to present no great difficulty.

While epoxy resins are characterized by a relatively low shrinkage of 3-4% compared to 10-12% for the polyester resins, the actual shrinkage does not apparently cause the surface to depart from its parabolic shape. Surface tension causes a slight meniscus to form near the edges, however, the effect of surface tension on the rest of the surface appears to be negligible. In any event, mathematical analysis indicates that surface tension would tend to form a paraboloid which added to the one already present would serve only to shift the focal point.

At the present stage of development, the process described would appear to be well suited for producing mirrors of short focal length for use in solar furnaces and other light-gathering devices. At the present time, no apparent size limit for this process is evident except that of producing large vibration-free turntables.

The quality of the mirrors produced to date is better than anything now available without the use of grinding and polishing techniques. Whether astronomical-quality mirrors can be made by this process awaits further refinements in the technique.

This work was performed under the auspices of the U. S. Atomic Energy Commission.

FIGURE LEGENDS

Fig. 1. F 1, 36-inch epoxy mirror with vacuum-plated aluminum surface.

Fig. 2. Paraboloid shape of epoxy resin cast on rotating surface of mercury at 180 rpm.

Fig. 1

Fig. 2