HONEYCOMB MIRRORS OF BOROSILICATE GLASS; CURRENT RESULTS AND PLANS FOR 7-8m DIAMETER

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The case for making large mirrors for astronomy with borosilicate glass honeycomb structure has been made in an earlier paper (Angel and Hill, 1981). Honeycomb structure gives rigidity in a lightweight mirror as well as low thermal inertia. Mirrors which are in thermal equilibrium with the air hold the promise of better images, since convection at the mirror is eliminated. Thermal expansion of borosilicate glass is problematical in thick mirrors which are likely to be out of thermal equilibrium and hence distorted. This will not be a problem in honeycomb mirrors with thermal time constants of only a few minutes. We believe a single casting technique holds the greatest promise of making borosilicate honeycomb mirror blanks up to 7 meters in diameter. Our work to develop the technique now involves casting test blanks 60cm in diameter but which have the full thickness (33cm), cell size (15cm) and faceplate thickness (2.5cm) needed for a 1.8m mirror.

METHOD FOR CASTING HONEYCOMB MIRRORS IN ONE PIECE

The idea is to fill most of the mirror mold with square blocks on stalks, as shown in Figure 1. Cold glass is placed in the mold, on top of the blocks, and the mold is heated in the oven. On melting, glass runs down between the blocks to form the ribs and back plate, and the top continuous surface that will later be ground to form the front reflecting surface of the mirror. When the cast glass is cold the blocks and stalks are removed by sand blasting.

The furnace for the 60cm test blanks, built with the same techniques and materials as are planned for much larger furnaces, is shown in Figure 1. A layer of insulating firebrick is built on a steel base. On the top surface, in grooves 10cm apart, are electric heating elements wound from the iron chromium aluminum wire used in pottery and ceramic kilns. These elements have been used for all our tests to date, and are capable of bringing furnaces to 1250°C without difficulty. Even the low expansion Pyrex, Corning 7160, requiring the highest temperature can be cast at about 1200°C. The advantages of electric over gas heating are

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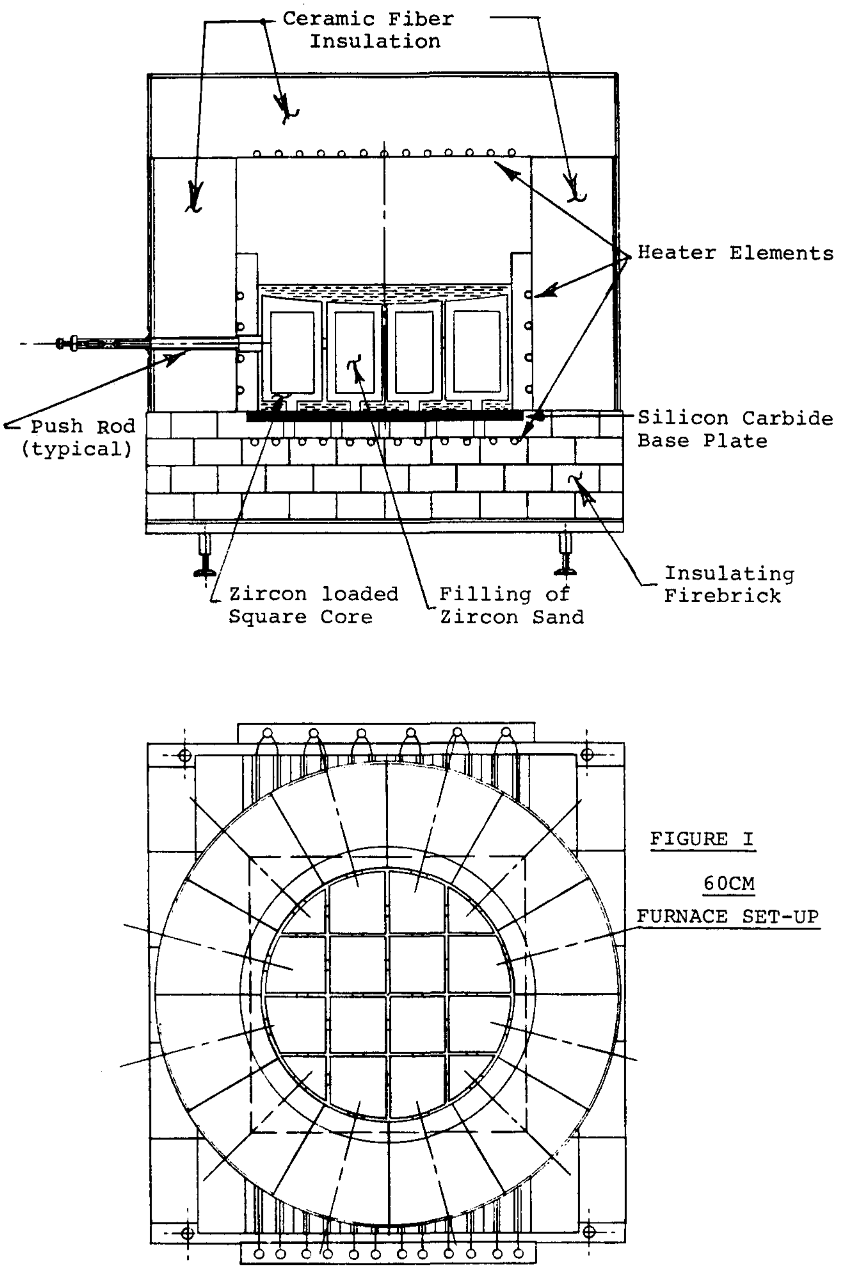

Figure 1. Diagram of the furnace used to make a 60 cm honeycomb mirror in a single casting. On firing for 4 hours at 1200°C glass runs down between the square towers to form ribs, backplate and front face.

that it is completely clean and easy to distribute and control, allowing annealing to be carried out in the same furnace as casting.

When the 200" Palomar blank was made, very high temperature electric elements were not available. It had to be transported while hot (~700°C) from a casting furnace (gas heated) to a separate electrically heated annealing oven.

Spaced slightly above the base heaters is the mold base, made from plates of silicon carbide. These have good thermal conductivity and low expansion coefficient, about $5 \times 10^{-6}/^{\circ}C$ compared to 3×10^{-6} for the glass. The walls of the mold are cast from high temperature concrete, with four circular grooves to carry heating elements. Surrounding the walls is a compressed circle of ceramic fiber insulation 20cm thick, backed with steel plates. This is made in twelve radial segments. Compression is applied by spring pushers acting between the steel plates and two steel hoops surrounding the walls, to resist the pressure of liquid glass in the mold. The furnace lid is made by Ceramic Fiber Fabrication Inc., again of 20cm thick silica-alumina fiber, but now with spiral heating elements mounted directly in the hot face. The large number of elements in the floor, sides and roof of the furnace is required for annealing, so as to be able to maintain the whole mold at nearly constant temperature.

The square mold towers are cast from zircon loaded insulating concrete, to give the right combination of high density and friability. The pure zircon sand filling has density 3.0, substantially larger than the glass density of 2.23. The towers are spaced by, and supported on, discs of insulating firebrick, which leave ventilation holes in the back and honeycomb core of the cast piece. To keep all the towers snugged together during firing we have installed ceramic push rods that act through the fiber walls against all the outside towers.

We have determined the thermal conductivity of all the materials involved, and computed the temperature lag of the core centers during cooling. A casting 33cm thick (both the 60cm and 1.8m diameter blanks) requires an annealing schedule of about two weeks for a safe anneal. Thermocouples are located in the square cores as well as the furnace walls, to monitor the cooling.

RESULTS AND PLANS

A 60cm mirror blank which completed annealing in Tucson during this conference is shown in Figure 2. It is structually sound except for some small cracks in the ribs caused either by chemical contamination of the glass by the mold or possibly by thermal shock when a radiation shield was installed during cooling. New mold surface materials are being explored to eliminate this problem. The present blank will be ground and polished so that mechanical and thermal characteristics can be investigated by interferometry.

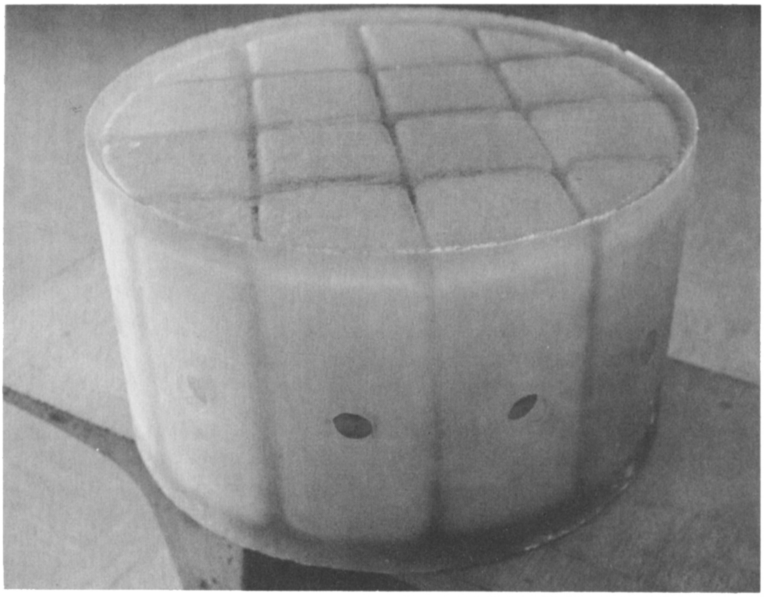

Figure 2. Cast honeycomb blank of 60cm diameter, made of borosilicate glass (Schott's Tempax).

A furnace to cast blanks up to 2m diameter is under construction, and we hope to make the first castings before the end of the year. A 1.8m mirror will be figured to very high precision (1/4 arc-second images) and tested at the MMT in 1983. Larger furnaces and mirrors up to 8m are planned, contingent on financial support.

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REFERENCE

Angel, J.R.P. and Hill, J. 1981, Proceedings of the ESO Conference on Scientific Importance of High Angular Resolution at Infrared and Optical Wavelengths, Garching, 24-27 March 1981.