LARGE TELESCOPES, LOW PRICES

Astronomers do it with mirrors—by leaving out most of the glass

By DIETRICK E. THOMSEN

Fateful things have happened under the stands of football fields. The nuclear age and all that goes with it began 40 years ago under the stands of the University of Chicago's Stagg Field. The University of Chicago no longer plays football.

The University of Arizona still plays football. Its giant stadium stands out like nothing else in aerial views of Tucson. Under those stands a building is now rising that promises a more peaceful revolution than the one that began in Chicago—a revolution in the casting of large telescope mirrors. The building will house an oven capable of casting mirrors up to 8 meters in diameter, and a "generator," a grinding machine capable of shaping surfaces that large.

Mirrors of that size do not exist, and most experts would say they are impractical if not impossible by conventional casting methods. The largest conventionally cast mirror in the United States is the 5-meter (200-inch) Hale Telescope on Palomar Mountain in California; the largest in the world is the 6-meter mirror of the Crimean Astrophysical Observatory in the Soviet Union.

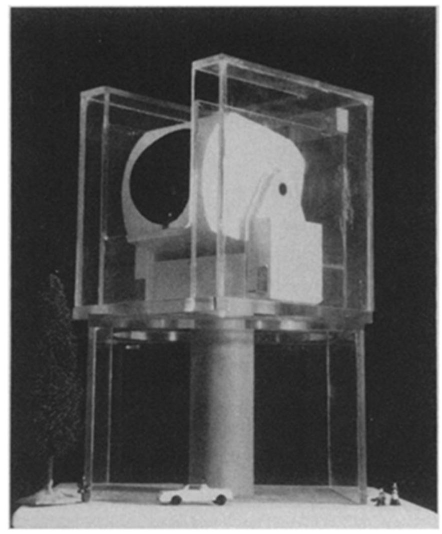
Conventional mirrors are cast as monolithic slabs of glass. The catch 22 — or perhaps it should be the 6-meter catch — in this procedure is that the mirror must be rigid enough to keep its figure, that is, the shape of its reflecting surface. Rigidity requires thickness of glass, but thickness means weight, and too much weight results in slumping and corresponding degradation of the figure. Gossip has it that the Crimean telescope has had problems of this kind.

The new casting facility will use a new method devised by Roger Angel of the University of Arizona, which has already been used satisfactorily for smaller mirrors. With it the U. of A. hopes to cast a mirror for a new telescope it would like to place on the summit of Mt. Graham, an 11,000-foot (3,267-meter) peak near Willcox, Ariz. The University of Texas, which plans a telescope of similar size for its McDonald Observatory in Ft. Davis, is interested in Angel's procedure. So are the planners of the National New Technology Telescope, which is projected to be a multiple-mirror arrangement with a light-gathering power equivalent to a 15-meter single mirror.

In Angel's method the way to get the necessary rigidity but keep the weight down is to leave out most of the glass. The idea seems simple but it took a lot of effort to get it to work. Hexagonal plugs made of refractory material are anchored to the bottom of the mold. The molten glass flows over the plugs and between them. Although the refractory material stands up to the heat of molten glass, it breaks down under a stream of pressured water. Thus, it is easily flushed out. The result is a mirror with a thin surface backed by a glass honeycomb. The walls of the honeycomb provide sufficient rigidity.

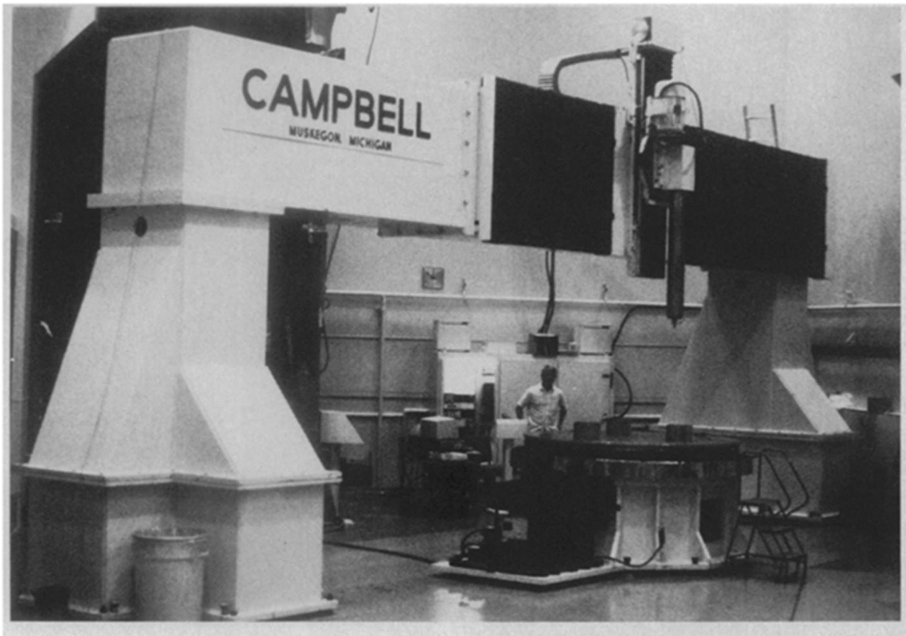
Angel says an 8-meter mirror made by this method should keep its figure well enough to give images accurate to a quarter of a second of arc. According to Richard Sumner of the U. of A.'s Optical Sciences Center, a 1.8-meter honeycomb mirror (made by somewhat different technique) weighs 1,200 pounds, whereas a solid 1.8-meter mirror would weigh 4,400 pounds.

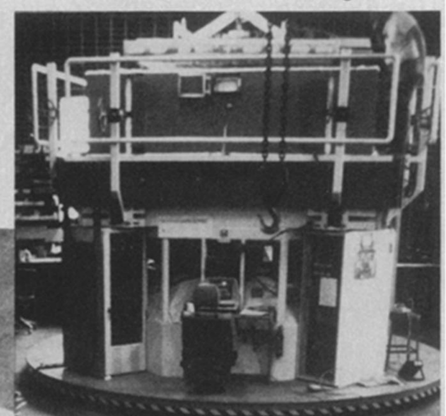
Another advantage of using less glass is quicker cooling of the cast. Angel estimates for this process "a cooling period... [of] six weeks. [The Hale mirror on] Palomar took a year to anneal." He expects to be able to turn out castings at six-month intervals.

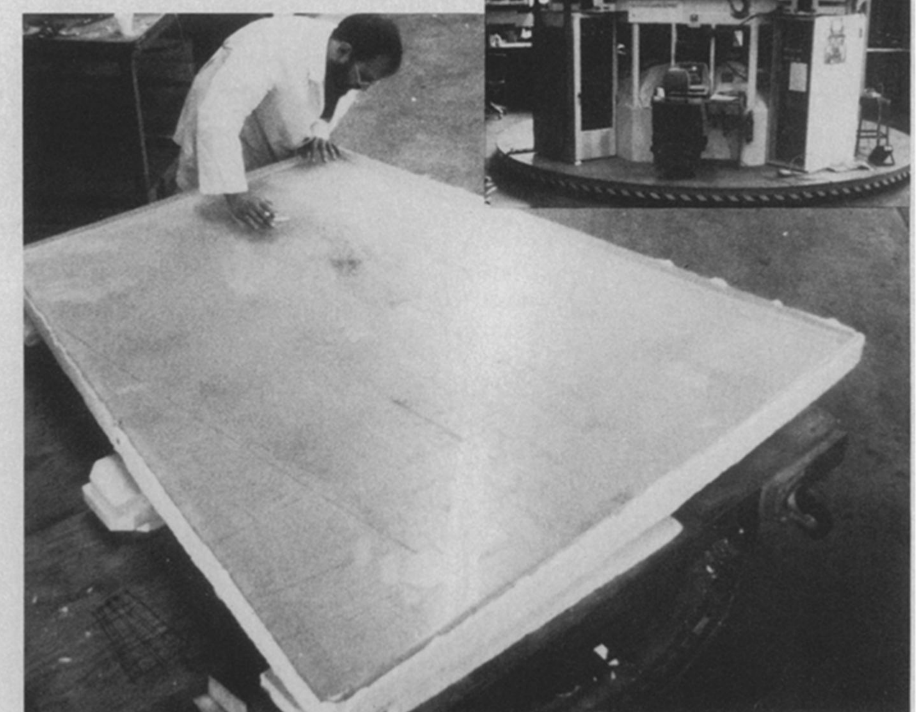


The University of Arizona would like to build the 8-meter f/1 telescope modeled above. Its mirror would be cast by the same honeycomb procedure as in the 6-foot mirror shown below with Roger Angel. The "generator" or grinding machine shapes surfaces (above on p. 107). Mirror blank sits on turntable. Pencil-shaped object grinds surface, moving back and forth on overhead beam. Rectangular glass casting (below on p. 107) is examined in the "temple," which houses the 2-meter rotating furnace (inset).

Photos: University of Arizona







The second major innovation in Angel's technique is to use a rotating oven. Conventionally telescope mirrors have been cast in stationary molds, and they come out with flat surfaces. Then they must be ground to the desired curved shape (usually a paraboloid of revolution or a piece of a sphere). According to Robert Parks of the Optical Sciences Center, the Hale mirror took train car loads of abrasive and years of time to shape. In a rotating oven the liquid glass climbs the walls of the mold to form naturally a paraboloidal surface. For the large telescope that the U. of A. plans, the curve produced by the rotation is accurate to 1 millimeter. Then it will have to be ground and polished to 1 micrometer accuracy. If they were to start with a flat blank, Angel says, they would have to dig out about 20 tons of material. Nevertheless, the 8-meter generator will be a giant of its kind and will have to use shaping guides that change their shapes from place to place to correspond to the changing curvature of the paraboloid.

The U. of A.'s 8-meter mirror will require a steeper curvature than most telescope mirrors. It is designed to have a focal length equal to its diameter. In terms familiar to people who use cameras and similar optical equipment, this is an *f*/1 system. Up to now, telescope mirrors have generally had focal lengths much longer than their diameters. The Hale telescope, Parks says, is *f*/5.3. The short ratio means that the U. of A. telescope can have a stubbier barrel and so save money, but it also means more difficulty of fabrication. "An *f*/1 mirror is almost an order of magnitude [10 times] more difficult to make than *f*/2," Angel says.

To make the 8-meter, *f*/1 mirror the oven will have to rotate at 8 revolutions per minute (rpm), or slightly faster than an amusement park carousel. At present a smaller rotating oven, about 2 meters across, stands in a building on the edge of the campus that the workers call "the temple." It gets its name not because telescope builders worship at the rotating furnace—come to think of it, that would be a rather Canaanite thing to do — but because it was once a synagogue, which the university bought and remodeled when the congregation moved elsewhere. The smaller oven must rotate faster than 8 rpm to make smaller mirrors. Although it has a control console that rotates with it, not everybody can sit at the console while it is moving. It makes some people dizzy.

Another cost reduction factor with this technique is that ordinary Pyrex—rather than glasses of special composition—can be used for large mirrors. Pyrex went out of favor because it has too much thermal inertia. In large slabs it does not come to thermal equilibrium with the surrounding air quickly enough, and differences in temperature through its bulk can distort the shape of the surface. With the honeycomb construction, even Pyrex comes to thermal equilibrium quickly enough.

The building that is rising under the football stadium will contain the 8-meter rotating oven and the 8-meter grinding machine that is now being designed. Meanwhile the U. of A. is looking for funds for the proposed telescope. The combination of stubby optics and a somewhat unusual building to house the telescope, which will be based on what has been learned from the building of the Multiple Mirror Telescope on Mt. Hopkins near Amado, Ariz., will mean "a big breakthrough in the cost versus aperture equation," says Peter Strittmatter, director of the U. of A.'s Steward Observatory. He estimates the cost of the optics at $6 million and that of the building at $15 million.

There is no conventional project of similar size with which this could be compared. The planned California Institute of Technology-University of California 10-meter telescope is the nearest thing in size, but it will be built by a radically different method. Its mirror will be made up of hexagonal segments and its figure will be controlled by mechanisms in its supports. Its estimated cost is more than $70 million. □