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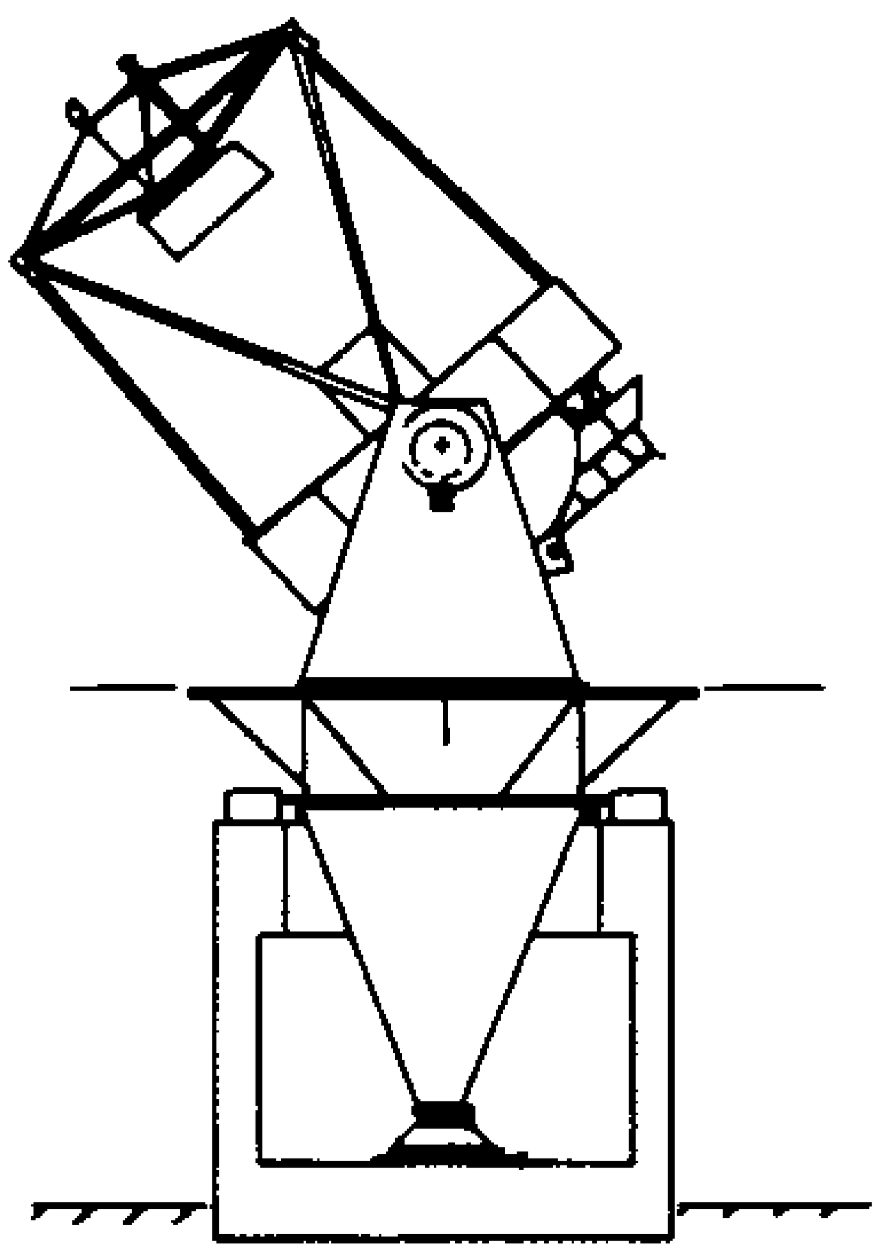

3.5 Meter Telescope

Calculation of Possible Heat-Induced Stress in the 3.5-meter Mirror

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WODC 03-06-01

8/29/91

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Calculation of Possible Heat-induced Stress in the 3.5-meter Mirror

Larry Stepp, 8/29/91

A crack developed in one of the ribs of the WIYN 3.5-meter mirror blank some time last fall. Roger Angel suggested the crack might have been caused by thermal conditions inside the mirror handling container, which sat outside in direct sunshine on the summit of Kitt Peak for several days.

At my request, Dr. Myung Cho of NOAO modeled the thermally-induced stress in the mirror blank. In general, it is impossible to predict the thermal conditions that existed in the mirror blank, but to get an order of magnitude calculation we developed a simple assumed temperature pattern. This pattern was based on the following factors:

1. The shipping box is not thermally insulated.
2. The inside and outside of the box are painted white.
3. The mirror sat on 2 inches of foam rubber, on a platform suspended inside the container.
4. The mirror was encircled by its handling band. The handling band contacts the mirror with thick rubber pads at the top and bottom edges. In the middle of the handling band there is a gap between the rubber pads, allowing air to flow between the steel band and the side of the mirror.
5. The mirror surface was not coated, and therefore had a very high emissivity.

With the container sitting in direct sunlight, the front surface of the mirror would heat up fairly quickly, both from contact with heated air and by radiation coupling with the lid of the container. The bottom surface would be insulated, and would hardly change temperature at all. The edge of the mirror is somewhat insulated, but would have some contact with heated air and could couple radiatively with the steel handling band. Therefore, we assumed the top surface of the mirror would heat up 10° C relative to the bottom of the mirror, with a linear gradient from 10° to 0° in the top half of the ribs. We assumed the outer diameter would heat up 5° C, with a gradient in the ribs from 5° to 0° over the outer few inches of mirror radius.

A half-mirror finite-element model was used to analyze this thermal loading condition. This model has about 1000 nodes, in three levels, and is shown on the next page. Myung's analysis showed a maximum tensile stress in the ribs in the approximate vicinity of the crack of about 200 psi.

This global mirror model does not show the effects of stress concentration around the holes in the mirror. This could raise the stress by approximately a factor of 2. Also, if the thermal conditions were more extreme than those assumed, the stress would be proportionately larger.

It appears the assumed thermal conditions could produce tensile stresses of a few hundred psi. If these stresses added to existing tensile stresses in the ribs (as described by Roger Angel) the total stress might have been enough to cause a crack to elongate.

Therefore, this does seem to be a plausible explanation for the formation of the crack in the rib.