MULTIPLE MIRROR TELESCOPE OBSERVATORY

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MEMORANDUM : MMTO Technical Memorandum No. 81-1

FROM: J. M. Beckers and B. L. Ulich

RE: Radiation Cooling of MMT Optical Support Structure and Building, Possible Solutions

DATE: March 30, 1981

(1) From thermographic experiments done at the MMT in December 1980 (see MMTO Technical Report Nr. 10), it became clear that radiation cooling of the MMT building and Optical Support Structure (OSS) is a major factor in establishing the temperature of these structures at night. For the building this causes the shutter temperature to be 5-10°C colder than the air temperature. Since this implies cooling of the air above and in front of the shutters, this is a cause for astronomical seeing. "Shutter-generated seeing effects" have indeed been noted in knife edge and out of focus seeing tests. The cooling of the OSS members is less than that of the shutters but is still significant (2°C). Cooling is less because only a part of the OSS members are exposed to the cold sky and because even those parts see less of the sky than the shutter does. The OSS cooling occurs predominately at the top of the OSS. We suspect that the thermal gradients resulting from it are the cause of the changes in the MMT coalignment ($\sim$ 5 arcsec) experienced in the early evening and under rapidly changing radiation environments.

(2) Both the shutters and the OSS are painted with a titanium dioxide paint. This paint is widely used at astronomical observatories because of its good thermal properties when exposed to sunlight. Since it is white in the optical, it absorbs little sunlight; since it is black (high emissivity) in the IR (10μm), it radiates efficiently there thus easily losing any excess heat. Surfaces and buildings painted with TiO_2 paint therefore stay cool in the daytime. It is used for astronomical domes for that reason, since it does not heat up the inside of the dome as aluminum domes with insufficient insulation do. At night, however, the high emissivity IR property of TiO_2 causes it to cool well below air temperature, thus introducing seeing and thermal deformation problems. We have experimented with other surface coverings to see if these cooling problems can be reduced or eliminated. The following results are based on measurements made at the MMT site at day and at night in March 1981 during clear skies. The day temperatures were 40-55°F and the night temperatures were 30-45°F.

(3) To test the OSS behavior, we used a number of 3 1/8 inch O.D. steel tubes with wall thickness of 1/8 inch and length about 3 feet. These tubes were placed horizontally at a location at the MMT site where they were exposed to sun and night sky. They were covered with

(a) TiO_2 paint, (b) a heavily pigmented aluminum paint provided by Pioneer Paint Company in Tucson, (c) an aluminum, reflecting foil made by the 3M Company. This foil has a sticky back which makes it easy to install, (d) a material called MAXORB produced by Ergenics for solar collectors and hot water heaters. It is exactly the opposite of TiO_2, being black in the visible (absorptance 0.97) and light in the IR (emittance 0.10). It is also a foil with a sticky back. No IR emittance values were available for the Al paint and foil used, but typical values for these materials are 0.3 and 0.05 respectively.

Table 1 below shows the temperature rise above air temperature for the top of these four tubes under different circumstances:

Table 1: TEMPERATURE DIFFERENCE ($T_{tube} - T_{air}$) (^{o}F)

Tube Covering	Noon (Wind ≈ 10 mph)	Night (Wind ≈10 mph)	Night (Wind ≈ 20 mph)
TiO_2 paint	+ 5	- 3	- 1.5
Al paint	+ 14	- 2	- 1
Al foil	+ 8	0	0
MAXORB	+ 35	- 0.5	0

In addition, we measured the difference in temperature between the top part of the tube (exposed to sun and cold sky) and bottom part of the tube (exposed to ground). The results are:

Table 2: TEMPERATURE DIFFERENCE ($T_{top} - T_{bottom}$) (^{o}F)

Tube Covering	Noon (≈ 10 mph)	Night (≈ 10 mph)	Night (≈ 20 mph)
TiO_2 paint	+ 3	- 1.0	- 0.7
Al paint	+ 3	- 1.0	- 0.7
Al foil	+ 2.5	- 0.5	- 0.1
MAXORB	+ 12	- 0.3	- 0.3

We conclude the following from these measurements:

(A) Aluminum foil and MAXORB substantially reduce the radiation cooling effect in the OSS members at night. As a result, any bending of the members due to the top-bottom temperature difference will be reduced. Al-paint is disappointing although it reduces the cooling effects at night somewhat.

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(B) The radiation cooling is wind-velocity dependent. This is no surprise since the convective coupling to the air increases with increasing wind velocity. For zero wind velocity, the temperature differences in Table 1 would probably be higher by perhaps a factor of 2-3. For the OSS this wind-velocity-related effect may cause substantial thermal gradients since the wind velocities often vary substantially across the MMT chamber. Again, reducing the radiation coupling causes wind-related effects to be diminished.

(C) MAXORB and Al foil coverings behave similarly as far as nighttime radiation coupling goes. In the optical they are very different, of course. MAXORB covering will give us a black telescope with a reduced scattering from OSS illumination. If exposed to direct or diffuse sunlight during daylight observations, it will heat up substantially, however. Al foil does not react anywhere as badly to sun illumination. If the MMT is not properly baffled it may cause, however, some scattered light if exposed e.g. to moonlight. The use of either material will, however, much improve the thermal stability of the OSS at night and hence the coalignment accuracy of the MMT.

(D) From the temporal change of the values in Table 1 while the sun was setting, we conclude that the thermal time constant of the OSS members is short enough to cause no significant $T_{tube} - T_{air}$ effects in this period of rapid change. The $T_{tube} - T_{air}$ settled to a constant value immediately after sunset.

(4) To test the shutter behavior, we used a number of segments of the same insulation panels as were used for the shutters. We repeated the same tests as for the OSS, except that we did not use MAXORB and we only covered the top of the panel leaving the bottom as it was. The results are:

Table 3: TEMPERATURE DIFFERENCE ($T_{panel\ top} - T_{air}$) (^{o}F)

Panel Covering	Noon (≈ 10 mph)	Night (≈ 10 mph)	Night (≈ 20 mph)
TiO_2	+ 15	- 11	- 2.5
Al paint	+ 32	- 6	- 2
Al foil	+ 21	- 0.5	- 0.2

Table 4: TEMPERATURE DIFFERENCE ($T_{bottom} - T_{air}$) (^{o}F)

Panel Covering	Noon (≈ 10 mph)	Night (≈ 10 mph)	Night (≈ 20 mph)
TiO_2	+ 4	0	0
Al paint	+ 5.5	0	0
Al foil	+ 7	0	0

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We conclude the following from these measurements:

(A) Aluminum foil vastly reduces the radiation cooling of the shutters. Installation of the foil on the front of the shutter doors might not be acceptable to the U. S. Forest Service unless the building is rotated so that it will never reflect sunlight to the valley (e.g. stow facing North). There appears to be, however, no reason not to cover the top of the doors.

(B) Al paint is again disappointingly poor.

(C) For all surfaces daytime heating on the reverse (bottom) side is significant. The numbers in the second table ($T_{bottom} - T_{air}$) are inaccurate (± few degrees) so one should be careful in comparing them. There is no doubt, however, that there is a few degrees temperature rise on the interior chamber side due to solar heating.

(5) In addition to the tests above on OSS tubes and on shutter panels, we also tested a 1½ inch thick panel of polyurethane with Al foil covering on both sides used at KPNO to thermally stabilize the grating lab to a few millidegrees. This material had better properties than any of the panels tested. It had a smaller T rise in daytime on top, a bottom temperature close to air temperature even during the day and radiation cooling effects at night identical to the Al foil. This material is available in 4 x 8 foot panels and should be considered as possible additional insulation for the chamber walls which are currently hotter than the chamber air, as well as for the chamber doors.

(6) The measurements described above use new Al and MAXORB foil. After some time the radiation properties of these materials may deteriorate (oxidation of the aluminum). The same Al foil has been used at the NRAO 36 foot dish where it has been exposed for 3 years both to outside air and to sunlight without significant visual deterioration.