MMTO 6.5-m Conversion

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Single Axis Actuator Overhead Forces
and Pressure Relief Valves

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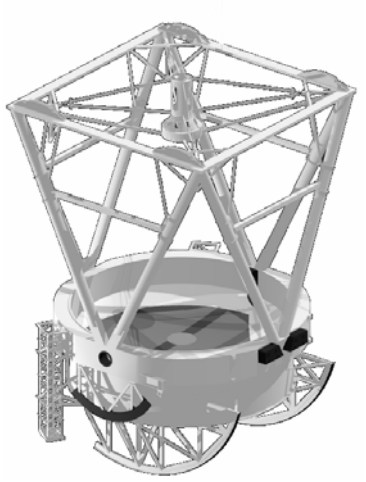
Multiple Mirror Telescope Observatory



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This report describes the required overhead correction forces, control valve regulation, and the effects of bias pressures and pressure safety relief valves on mirror stress for single axis actuators.

Overhead force calculations

At the 7/23/97 mirror support safety meeting, John Hill stated that the mirror support must provide a 30% overhead force above the BCV finite element support forces. This 30% overhead is in addition to the optimized axial forces required to support the mirror weight at all elevation angles. All actuators with loadspreaders of the same type require an overhead force of 30% of the highest applied force applied to an actuator of that type.

The maximum axial finite element forces for each of the 50 single axis actuators is calculated from BCV report #7 Rev 0, December 1994. Mirror 6.5m F/1.25: Axial and Lateral Supports Optimization. The resultant force for any actuator (k) at any elevation angle (θ) is:

$$\text{Resultant\_Force}_{\text{Axial}}(\theta,k) = V_{A_k} \cos(\theta) + V_{L_k} \sin(\theta)$$

V_A is the axial force at $\theta = 0$ (zenith pointing) and V_L is the axial correction force required to balance the overturning moment of the mirror at $\theta = 90$.

The following table shows the maximum finite element force, the overhead force, and the maximum force plus overhead force for each type of loadspreader.

Loadspreader type / Actuator No.	Max BCV force (lbf)	30% overhead (lbf)	Max + overhead (lbf)
1-puck (actuator # 3)	94.9	28.3	123.4
2-puck (actuator # 24)	215.3	64.6	279.9
3-puck (actuator # 19)	274.7	82.4	357.1

Pneumatic cylinder operation

The mirror support actuators use double acting pneumatic cylinders to develop the required support forces. Each double acting pneumatic cylinder consists of two chambers. A solenoid control valve regulates the pressure in each chamber. The force generated by the actuator is the pressure differential between each chamber times the cross-sectional area of the cylinder (6 square inches).

The control system regulates force by commanding half the required differential pressure to one chamber and subtracting an equal amount from the opposing chamber.

For zero output force, each chamber is set at a common pressure. This common pressure, referred to as the "bias pressure", plus or minus half the required differential pressure in the cylinder determines the amplitude of the chamber pressures. Scott DeRigne and Ken Duffek have recently determined that they could easily adjust the bias pressure with the actuator electronics to as low as 40 psig without adversely affecting the performance of the actuator.

In case of an electrical or mechanical failure, the maximum possible pressure in a chamber determines the maximum possible force applied to the mirror. For example, disconnecting the load cell drives the differential pressure to the control valve limits.

Bias Pressure and Mirror stress

According to Giancarlo Parodi's fax of November 30, 1995, 100-lbf axially applied to a single puck cause 40 -psi stress in the mirror. The mirror support design requirements, as stated in J.M. Hill's Mirror Support System for Large Honeycomb Mirrors II/R UA-95-02, require that for brief periods (less than a 5 minutes) the mirror stress never exceeds 150-psi. The axial force per puck must then be limited to 375-lbf or 63-psi.

The table below shows one acceptable configuration of bias pressures, maximum cylinder chamber pressures, and resulting mirror stress.

Loadspreader type	Max Bias pressure (psig)	Maximum Chamber Pressure (psig)	Mirror stress at Maximum pressure. (psi)
1-puck	40	50	121
2-puck	60	83	100
3-puck	60	90	72

Pressure safety relief valves

Since the control valves require 120-psig input pressures, pressure safety relief valves will be installed on each control valve to protect against unacceptable output pressures. These valves will be set to release at pressures near the maximum chamber pressures required during operation.

Factory calibrated pressure safety relief valves are available in 5-psi increments. The following table shows the closest relief valve setting to meet our demands and the resulting mirror stress at this pressure.

Loadspreader type	Pressure relief setting (psig)	Max mirror stress. (psi)
1-puck	50	121
2-puck	85	102
3-puck	No valve required. (Stress based on 120)	96

Experiments show that pressure relief valves set at 60-psi maintain a pressure of 30-psi immediately after release. The corresponding mirror stress is well below the 100-psi operational stress for all types of loadspreaders.

Conclusion:

Pressure relief valves and adjustment of the bias pressure safely protects the 6.5m mirror from electrical and mechanical failures. For brief periods, the maximum mirror stress can be as high as 121 psi. After the pressure relief valve releases, the stress in the mirror is below the 100-psi operational stress.