




## MULTIPLE MIRROR TELESCOPE OBSERVATORY

Smithsonian Astrophysical Observatory and Steward Observatory, University of Arizona

MMT Technical Memorandum 84-15

From: <sup>DW</sup> D. Blanco and J.T. Williams 

Subject: Tertiary Mirror Mounts

May 4, 1984

### Summary

Optimum performance criteria for tertiary mirror mounts are listed. Problems with the current mounts are listed and their sources identified. Methods for improving the mounts are discussed. New tertiary mounts are recommended for the MMT. Design features, cost estimates, and logistics for implementing these mounts are given.

### Optimum Performance Criteria

Optimum performance criteria for the MMT tertiary mirror mounts were specified by J. Beckers in 1980. These are:

- 1) Angular adjustment accuracy of 15 arc sec or better over  $1^\circ$  full range.  
(15 arc sec tertiary rotation corresponds to  $\sim 1$  arc sec image movement at the focal plane.)
- 2) Coarse optical path length adjustment accuracy of 0.1 mm over 10 mm full range.
- 3) Optional fine optical path length adjustment accuracy of 0.5 micron over 0.1 mm full range.

In addition the mounts should allow for easy and safe interchange of tertiary mirrors.

### Present Mounts

The present tertiary mounts fall far short of these specifications. Angular adjustments are "sticky" and do not repeat. No optical path length adjustment is provided. Moreover, assembly is both difficult and dangerous.

The problems with the present tertiary mounts stem from two sources:

- 1) The angular adjustment mechanism is inherently sticky. The present tilt mechanism consists of two orthogonal cylindrical surfaces held together with tension springs. These springs must be installed ~ 2 inches from the primary mirror face under ~ 20 lbs tension - a nerve wracking and dangerous procedure. This non-kinematic design depends on friction between the surfaces for stability; however this friction makes adjustment unpredictable and unrepeatable.
- 2) Compliance of the support. Presently the tilt mechanism is supported above the primary mirror on four steel tubes bolted to a 1/4 inch thick end plate at the tertiary and to the 1/4 inch thick back plate of the primary mirror cell. The thin compliant material of the end plates, and the compliance of the tubes add together to make the total assembly compliant. This total was measured to the nearest  $10^{-5}$  inch in telescope D. Loads were applied normal to the tubes just above the surface of the primary, and the deflection was recorded using the MMT's Hewlett Packard laser interferometer. The measured compliance was  $4.4 \times 10^{-5}$  in/lb with no measurable hysteresis (see figure 2).

#### Improving the Mounts

There are clearly three ways in which the mounts can be improved: 1) the support can be made more rigid, 2) the tilt mechanism can be optimized for minimum friction and maximum stability (the essence of kinematic design!). In addition, 3) we should consider the addition of a counterweight.

- 1) Support. Maximum rigidity would be realized by supporting the tertiary on a single large diameter tube (an 8" tube would be ~ 10 times stiffer). However, since this would require drilling large holes in the primaries, it is not recommended.

Maximum rigidity of a four post design would be realized by: adding a thick end plate at the tertiary and a reinforcing plate at the primary cell, using welded construction wherever possible, and choosing tube diameters for optimum strength to weight.

The deflection equation for an ideal four post design is

$$\delta = \frac{WL^3}{12EI} \left(\frac{1}{4}\right) + \frac{qL^4}{24EI}$$

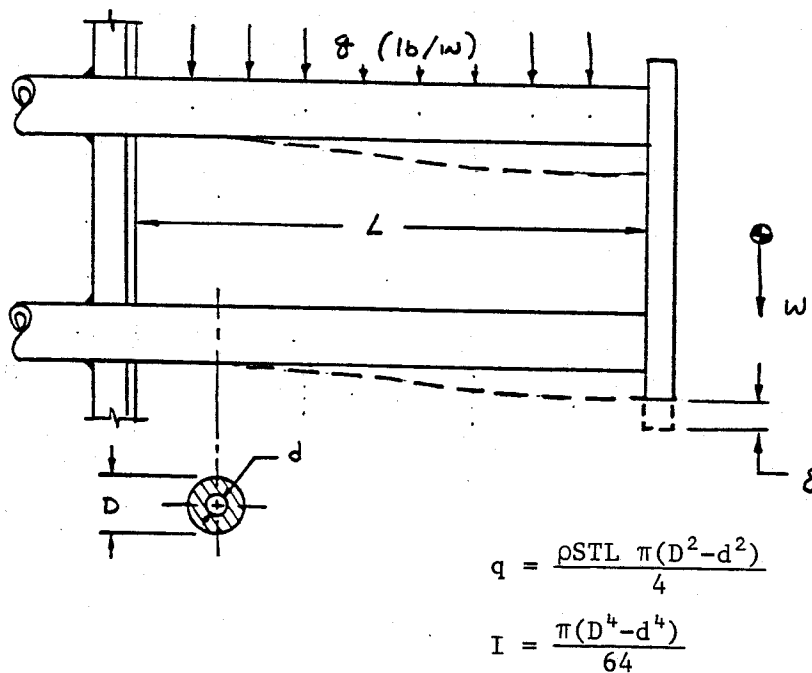


Figure 1: Ideal Four Post Design

By taking the derivative with respect to the inside diameter and solving the expression for minimum  $\delta$  we find an optimum tube geometry where

$$d = .3369 D$$

(with  $W = 20$  lb,  $L = 13$ ",  $E = 30 \times 10^6$  lb/in<sup>2</sup>)

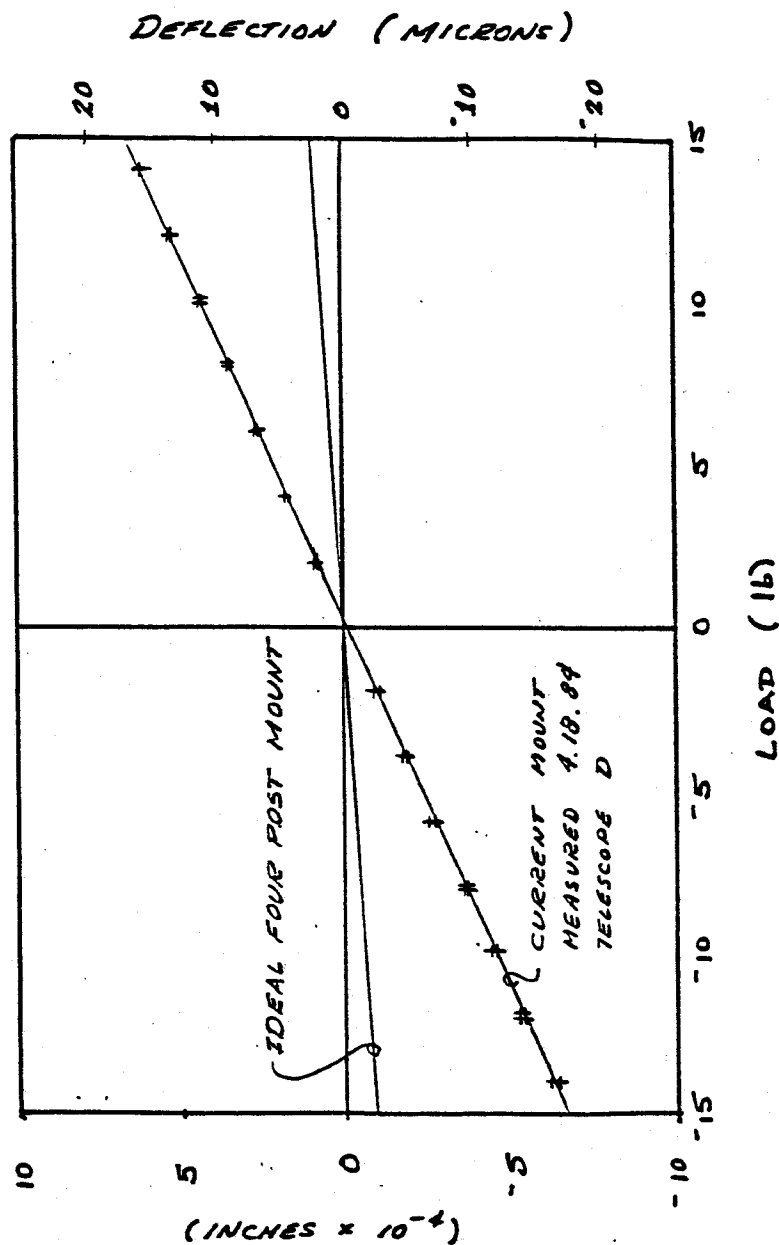
The present supports are made with 1.5" OD, 1.0" ID tubing ( $d = .667 D$ ).

Tubing with 1.5" OD and .5" ID ( $d = .333 D$ ) is readily available.

With the above improvements, new supports could be made which approach

the  $6.22 \times 10^{-6}$  in/lb compliance of an ideal four post design. Such a support could be up to seven times more rigid than the present support. The load deflection curves for an ideal support and the present real supports are shown in figure 2.

Figure 2: Deflection Under Load of the Present Support and an Ideal Tertiary Support

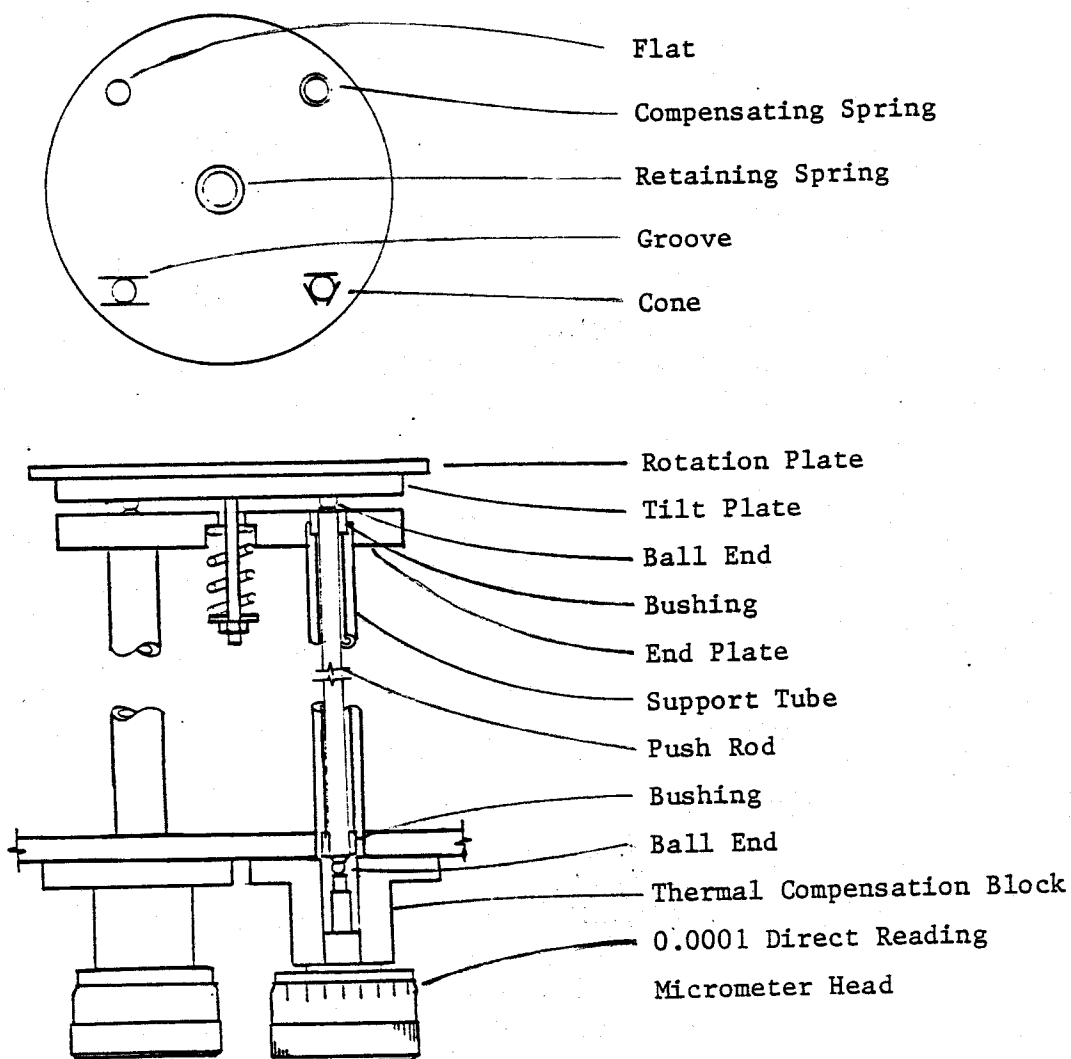


2) The Tilt Mechanism. The semi-kinematic design of the MMT active secondaries has proven very successful. We recommend a classic kinematic design for the tertiaries based on three moveable contact points in the well-known combination of a cone, groove and flat. The contact points would be moved together to provide optical path length adjustment, and singly to provide tilt. Using micrometer heads with large 0.0001" direct reading drum and thimble, one 0.0001" increment would result in 2.54 micron path length adjustment (moved together), or ~ 3.5 arc sec angular adjustment (moved singly). With heavy-duty 3/8-40 pitch lead screws, positioning to this fine increment is easy even under the 10-15 lb loading required to safely retain the tertiary against each contact point. The kinematic design will give this mount excellent stability and repeatability. The proposed mount is shown in figure 3.

There are two disadvantages to this kinematic design: A) it will not achieve the desired 0.5 micron fine optical path length adjustment, and B) tilt adjustments will change the optical path length.

- A) Fine optical path length adjustment could be implemented later by adding planetary or harmonic type gear reducers to drive the micrometer heads (differential screws were considered, but do not work well under the 10-15 lb required load, and do not provide the needed 0.5 inch travel). Gear reducers would add significantly to the cost and complexity of the mounts, and are not here recommended. Certainly a 2.54 micron adjustment ability is better than none at all.
- B) In a kinematic mount, moving one of the three point contacts revolves the mirror around the axis defined by the other two. This swings the tertiary mirror away from the telescope axis ~ .09" per degree of rotation. There is also an optical path length change of ~ 0.5 micron

Figure 3: The Proposed Kinematic Mount



in a 3.5 arc second increment (corresponding to 0.0001" at the micrometer head). In practice, one would adjust the mirror in tilt, and then correct for phasing by moving all three micrometers together. We feel that the benefits of the kinematic design outweigh these drawbacks.

3) Adding Counterweights. The idea of adding a counterweight to the tertiary mirror mount has been kicking around since before the MMT was built. In the light of recent progress in phasing the MMT, the idea bears a new look. Beckers and Hege, in successfully phasing the MMT, measured the optical path length change in each telescope over a  $40^\circ$  change in elevation (see MMTO Technical Memo 84-9). Their results indicate the OSS is a remarkably good stiff spring, with a repeatable path length change of only  $\sim 50$  to  $\sim 300$  microns (depending on the telescope), and a hysteresis of only  $\sim 5$  microns. This was further verified in an as yet unpublished experimental run in which the telescopes were passively phased to an accuracy of  $\sim \lambda/4$  over  $30^\circ$  elevation at 800 micron wavelengths. After initial phasing, the MMT remained phased for more than a week!

By adding tuneable counterweights to the tertiary mounts, we could, in theory, tune out the repeatable optical path length changes in each telescope, thus correcting for the flexure of the entire OSS. This would allow us to phase the MMT for wavelengths as short as  $\sim 40$  microns without adding any new optics. Shorter wavelengths would require computer-driven, articulated optics to correct for path length hysteresis. Counterweights have the obvious virtue of being totally passive - they do not require computer memory, CPU time, nor a program. Moreover, the tertiary mirror is the only place where this can be done in the present MMT.

A counterweight would make use of the spring compliance of the tertiary support. For a reasonably sized counterweight to work, we would have to

make the support even more compliant than it is now. We have to admit that the idea of intentionally introducing compliance into any part of the OSS makes us somewhat uneasy. There is a certain appeal, however, in turning the inherently nonrigid four post design into serendipity.

#### Implementing New Tertiary Mounts

In the fall of 1984, we will begin cycling primary mirrors in and out of the MMT. R. Angel's experimental honeycomb pyrex mirror is scheduled to go into telescope E, and a seventh MMT primary and cell are now under construction to allow regular exchange of primaries for refiguring and re-aluminizing. As a consequence, the tertiary mounts and supports will be regularly disassembled and reinstalled.

We therefore have a strong motivation to make mounts which are safe and quick to install, and easy to adjust. We also have the opportunity to upgrade each tertiary mount as the primaries are cycled.

Many of the ideas presented in this memo will be of interest in the development of future MMT's. We therefore suggest that the prototype and testing of these new features should be incorporated into R. Angel's honeycomb mirror support system which is being built under the National New Technology Telescope (NNTT) program. MMTO will provide a design based on our familiarity and unique experience with tertiary mirrors.

#### Time and Cost

We estimate the time and cost to build one prototype to be:

- 1) Engineer's time: 1 man month (this memo represents 1/2 of this time).
- 2) Machinist's time: 2 man weeks
- 3) Materials: About \$3,000

## Recommendations

There are clearly several ways in which the tertiary mirror mounts can be improved. We feel the biggest single benefit will come from replacing the present tilt mechanism with a simple classic kinematic design. We also recommend replacing the present four post support with one which is easier to service. The addition of a counterweight influences the design of the support, so this option needs to be discussed and a decision made. We recommend that new tertiary mounts be included in the MMT Operating Plan.