Technical Report #32

F/9 SECONDARY SUPPORT

SYSTEM DESIGN, REV. 1

B. Cuerden

August 1997

The University of
ARIZONA®
Tucson Arizona

STEWARD OBSERVATORY
TUCSON, ARIZONA 85721

August 19, 1997

MEMORANDUM

To: Steve West

FROM: Brian Cuerden /home/bcuerden/f9sec/text/perf.wpd
Technical Services

SUBJECT: F9 Secondary Support System Design, Rev. 1

Reference 1. Fabricant, D. McLeod, B. and West, S., "Optical Specifications for the MMT Conversion", Version 6a, 7-Jan-97.

SUMMARY

The support performance of the F9 secondary mirror cell is predicted and compared to specifications. Rms WF distortion is 0.0264 waves (at 0.633 microns) at zenith and 0.0536 waves (at 0.633 microns) in going from zenith to 60 degrees from zenith. Rms surface slope is 0.0114 arc-seconds at zenith and 0.1246 arc-seconds in going from zenith to 60 degrees from zenith as compared to a requirement of 0.14 arc-sec rms at zenith and 0.22 arc-sec at 60 degrees from zenith. Structure functions at zenith and 30, 45 and 60 degrees from zenith have been calculated and are below the specification structure function limit allocated to the support system.

INTRODUCTION

The secondary support system consists of 10 lateral supports and 18 axial supports, three fixed axial positioners and three fixed tangential positioners. Loads are sensed at the fixed positioners and are held to a low value (0.25 lbs) by adjusting the pressures in three zones of axial and one zone of lateral supports. At each of the 34 locations on the mirror where a force or position constraint is

applied, there is the possibility of inadvertently applying 5 force and moment components in addition to the intended force, and the intended force may vary from its ideal value. For example, at an axial support we wish only to apply a force parallel to the optical axis, Fz, but because of small misalignments, offsets, friction or stiffness in the axial support system, we can expect to obtain in addition Fx, Fy, Mx, My and Mz components. Much of the design of the supports is involved in minimizing the magnitude of these extraneous forces and in making the intended force (Fz in the example) sufficiently accurate to maintain good surface figure.

The magnitude of these error forces can be estimated and the effect of each individual component can be predicted. Since there are 6*34=204 such components, and since most of them can be considered to be statistically independent of the others, the net effect of all these components can be obtained by RSS'ing the effects of each force.

Some of the error forces are not statistically independent. If the axial supports have stiffness, cell bending will result in a support force distribution that induces astigmatic bending of the mirror. With the finite number of axial supports we have, the probability of obtaining a random distribution of error forces having an astigmatic component is too high to ignore (astigmatic bending is the softest mode of deformation of the mirror and we must be particularly careful to keep force error small enough to prevent this deformation mode). The effects of systematic force sets are calculated by FEM analysis and RSS'd into the statistically independent results described above.

Gravity deflections are also included in the "support" term of the secondary error budget. Gravity deflections are calculated by FEM. Since the mirror is figured to meet its polishing budget when supported by axial supports at the same locations as those used in the telescope cell, the zenith pointing gravity sag attributable to the mirror support is zero (already included in the polishing). As the line of sight (LOS) moves away from zenith, the mirror distorts due to the change in gravity and the shift in support forces from the axial supports to the laterals. This is modeled by applying the gravity and support force changes that occur in moving from zenith to some elevation angle to the finite element model. These results are RSS'd in with the other sources of distortion to arrive at a net result for a particular telescope orientation.

Surface figure can be expressed as rms or P-V surface or wavefront distortion, FWHM, encircled energy or as a structure function. All these can be combined using the RSS operation although the details of combining structure functions may not be obvious and are described in Appendix A.

The calculations outlined above were performed on the MMT F9 Secondary Mirror using an initial set of estimated error forces. The initial results exceeded the distortion requirements and the component force effects were searched to find damaging terms. Once a particular component was identified as a major contributor to distortion, the design was changed to reduce the magnitude of that force component. The results of this operation are a performance prediction that meets the requirements for the support system and a large number of design constraints on the secondary support system components. Much of these design constraints are in the form of positional and alignment tolerances. These are identified in Appendix B.

This report describes the results of evaluating and combining a large number of finite element solution sets in accordance with the general procedures outlined above. Due to the large volume of data being processed, the compilations are performed by a computer program using data files generated by other computer programs. Details of this procedure and of the results obtained are described in this report and its Appendices.

DISCUSSION

Secondary Support System Requirements

The F9 secondary support requirements are defined in Reference 1 section 6.2.1. The table lists a support allocation r_o of 89 cm for the F9 secondary. The encircled energy requirement is 0.113 arc-sec FWHM. These requirements apply for zenith pointing. At angles, θ, from zenith, the allowable structure function is $89^*\cos(\theta)^{0.6}$ cm and the required encircled energy requirement is $0.145/\cos(\theta)^{0.6}$ arc-sec rms ($0.113/\cos(\theta)^{0.6}$ FWHM).

Table 1 Summary of f9 Secondary Support Requirements

Requirement	Value	Specification
Rms Surface Slope	$0.145/\cos(\theta_{el})^{3/5}$ arc-sec	Ref 1, Sections 6.2.1, 4.1 and 4.2
Structure Function, r_o, cm	$89^*\cos(\theta_{el})^{3/5}$ cm	Ref 1, Section 6.2.1

The encircled energy requirement for the secondary support is $0.017^*6.69^*1.28\cos(\theta)^{0.6}$

Appendix C

Cell Configuration

The cell configuration is shown in Appendix F. There are 18 axial supports and 10 lateral supports (with an option for 12 lateral supports). The 12 lateral support option has become possible due to a redesign of the lateral support assembly. The new assembly is small enough to permit the addition of the supports at the East and West positions (lateral gravity acts in the North-South direction).

Analysis Procedure

An ANSYS finite element model of the f9 secondary was used as shown in Figure 1. This model is estimated to be accurate to better than 20% so the mass has been adjusted upward 20% to ensure conservatism in the gravity sag results. ANSYS displacement results were processed to remove translation tilt and power after which the rms and P-V deviations, the maximum slope deviation and the structure function was computed. Load cases considered are summarized in Table 2.

Table 2 Summary of Mirror Support Load Cases

Gravity	1 g, Zenith to 60° el, Zenith to 45°, zenith to 30° el and horizon pointing.
Unit Load	Fx, Fy, ...Mz loads were applied to representative support locations. One location on the inner and outer axial support locations and one location on the OD (tangent supports/ lateral force actuator location). These results were used to compute the effects of random mounting force errors. Error forces are estimated in Appendix B. Effects of error forces are obtained by RSS'ing individual effects (see Appendix A, section 2.2.2).
Other	The effects of non-random force distributions (see Appendix A, section 2.2.3 and Appendix B section B.7) were also investigated. Of primary concern is the effect of a $\sin(2\theta)$ axial force distributions which generate more deflection than randomly distributed forces of the same magnitude.

A detailed description of the methods employed to evaluate and combine these load cases may be found in Appendix A. The magnitude of error forces are calculated in Appendix B.

RESULTS

In Table 3, the total effect of gravity loading and spurious error forces is obtained by RSS'ing all effects. The random error effects are based on the error forces estimated in Appendix B. These error force estimates are in part based on the dimensional tolerances specified in Appendix B. Additional Tables may be found in Appendix C. Structure function plots are provided as Figures 2 to 5. In Appendix D structure function plots are provided that define the contribution to the total error of selected groups of error sources.

Table 3 MMT F/9 Secondary Support Performance, Various Orientations

Orientation	WF Distortion, Waves at 0.632 μ-m	RMS Surface Slope arc-seconds rms	Reference Figure for Structure Function
Zenith Pointing	.0264	.0114	Figure 2
30° From Zenith	.0319	.0718	Figure 3
45° From Zenith	.0405	.1013	Figure 4
60° From Zenith	.0536	.1246	Figure 5