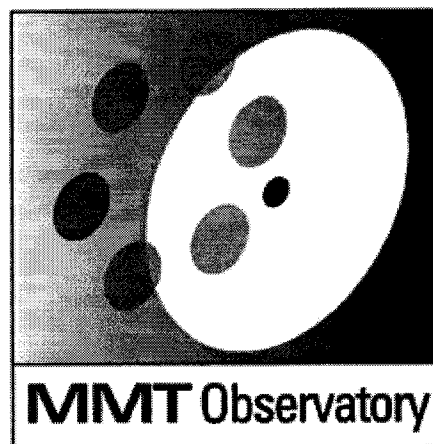


MMTO Conversion Technical Memorandum #98-1



Smithsonian Institution &
The University of Arizona®

Wind Distortion of the MMT Primary and f/9 Secondary Mirrors, Rev 1

Brian Cuerden

July 24, 1998

The University of
ARIZONA[®]
Tucson Arizona

STEWART OBSERVATORY
TUCSON, ARIZONA 85721

July 24, 1998

MEMORANDUM

/home/bcuerden/mmt/text/windload

To: S. West

cc: J. Hill

FROM: Brian Cuerden
Technical Services

SUBJECT: Wind Distortion of the MMT Primary and f/9 Secondary Mirrors, Rev 1

Summary:

The effect of wind load on the MMT primary and f/9 secondary mirrors has been estimated. Wind induced deformations are shown to be less than half the allowable structure function at wind speeds of 6.7 m/sec.

Introduction:

The MMT telescope is required to meet performance requirements in wind speeds up to 6.7 m/sec, and to operate with graceful degradation in winds up to 22 m/sec. West, S.C and Martin, H.M in "Approximate Wind Disturbance of the MMT 6.6 M Primary Mirror on Its Supports", MMT Technical Report #28 define the wind velocity spectra and methods of determining wind pressure and force power spectra. Fabricant, D., McLeod, B. and West, S in "Optical Specifications for the MMT Conversion, Version 6a", January 6, 1996 define budgets for wind induced distortion ($x_0 = 122$ cm for the primary and 135 cm for the f/9 secondary) and primary hardpoint reactions for a five Hertz hardpoint/actuator outer loop. The hardpoint reactions have been updated for the actual 1 Hz loop. The hardpoint reactions are given in Table 1.

Table 1 RMS Piston Load Reacted by the Six Primary Hardpoints

Mean Wind Speed m/sec	RMS Dynamic Force, Newtons	
	5 Hz Loop	1 Hz Loop
6.7	40	75*
22	570	1130*

* Wind velocity de-correlation effects are neglected.

Much of the wind loading is reacted by the pneumatic actuators which are controlled to minimize the net loads on the hardpoints. This is true for both the primary and secondary systems. Most of the wind pressure is at DC or very low frequencies so the control systems are effective at keeping hard point forces low.

The wind velocity varies from point to point tending to be similar at nearby points and to exhibit larger variations for remote points. Over the face of the secondary there is little variation in wind pressure but the effect is significant over the surface of the primary (see West and Martin, Part II). S. West has proposed that the decorrelation effect be neglected in calculating hardpoint reaction forces for the purpose of calculating mirror distortion because the load on a given hardpoint is mainly related to pressures acting on that part of the mirror near the hardpoint connection. This proposal represents a reasonable way of accounting for the non-uniform pressure distributions and has been used in this memo. The portion of the wind loading reacted by the pneumatic actuators will induce deflections comparable to a gravity loading of the same magnitude. Since the mean wind pressure is comparable to 0.8% of gravity at 6.7 m/sec, this portion of the wind effect can be neglected.

Secondaries wind loads have been calculated using the methods described in West and Martin.

Discussion:

Wind Loads:

The primary wind loads have been calculated by West and Martin and are summarized in Table 1. These loads are characterized by the hardpoint force required to react them. A similar computation has been performed for the f/9 secondary mirror. The force loop on the f/9 secondary will have a bandwidth of at least three Hz. The control system force rejection will be:

$$\text{Rejection} = \text{frequency/bandwidth}$$

The calculated fixed point reactions for the f/9 secondary for control bandwidths of from 1 to 5 Hz are as follows:

Table 2 f/9 Secondary Reaction Force Verses Force Loop Bandwidth

Control System Bandwidth	Net Reaction Force, Newtons					
	No Control No De-Correlation		Control No De-Correlation		Control And De-Correlation	
Wind V =	6.7 m/sec	22 m/sec	6.7 m/sec	22 m/sec	6.7 m/sec	22 m/sec
1 Hz	2.5	38.5	1.0	15.6	0.6	12.6*
3 Hz	2.5	38.5	0.7	10.8	0.3	7.2
4 Hz	2.5	38.5	0.6	9.8	0.2	6.0
5 Hz	2.5	38.5	0.6	9.2	0.2	5.2

* Corrected from 22.5 in Rev 1

The 3 Hz bandwidth forces with no decorrelation were applied to the f/9 secondary model resulting in the structure functions shown in Figure 1 for wind speeds of 6.7 and 22 m/sec. The allowable value in these figures is an r_0 of 135 cm (given in the MMT optical spec. for f/9 wind loading). Figure 2 gives the wind loading structure function if six fixed supports are used. Since the three point support is acceptable at 22 m/sec, the six support design is not needed.

The primary load cases were generated from 1 g load cases (Ref. Appendix A) with the primary supported by the hardpoints. These were scaled down to the rms force level for the wind loading, the same procedure as was used for the f/9 results. The structure functions are plotted and compared to the $r_0 = 122$ cm primary wind allowable in Figure 3. Adequate performance is obtained at 6.7 m/sec with degradation proceeding proportional to V^2 at higher wind speeds.

Conclusions:

The primary and the f/9 secondary meet performance requirements at wind speeds of 6.7 m/sec as required. The f/9 secondary meets the 6.7 m/sec requirements at wind speeds up to 22 m/sec with three fixed axial locators on the back of the mirror. The primary uses up the primary wind distortion budget at about 13 m/sec (acceptable since performance degradation is allowed above 6.7 m/sec). At 6.7 m/sec, most of the wind budget is available for rigid body motions of optical elements (not evaluated here).

Figure 1 f/9 Secondary Wind Distortion
 Structure Function, 3 Support Points

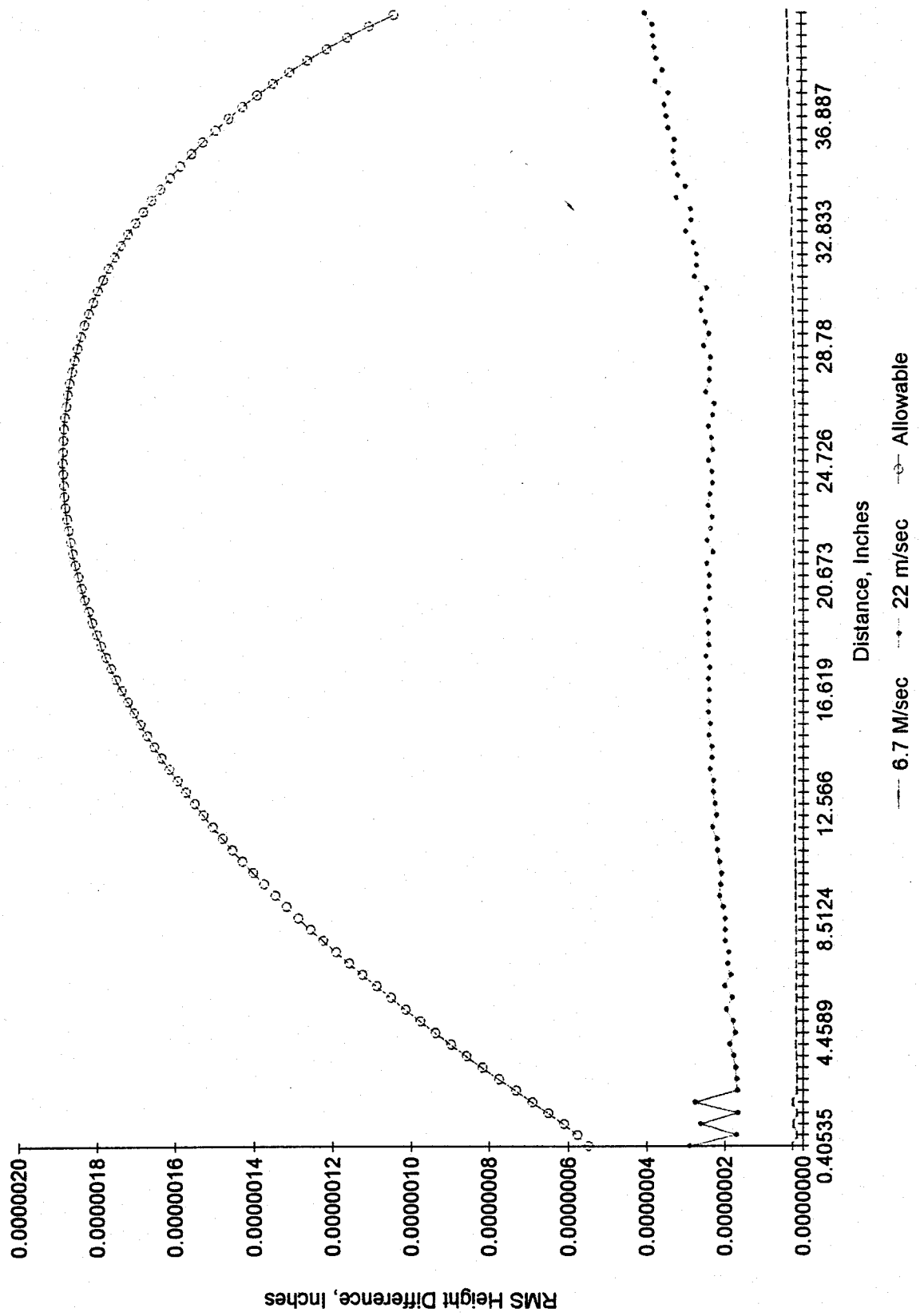


Figure 2 f/9 Secondary Wind Distortion
 Structure Function, 6 Fixed Supports

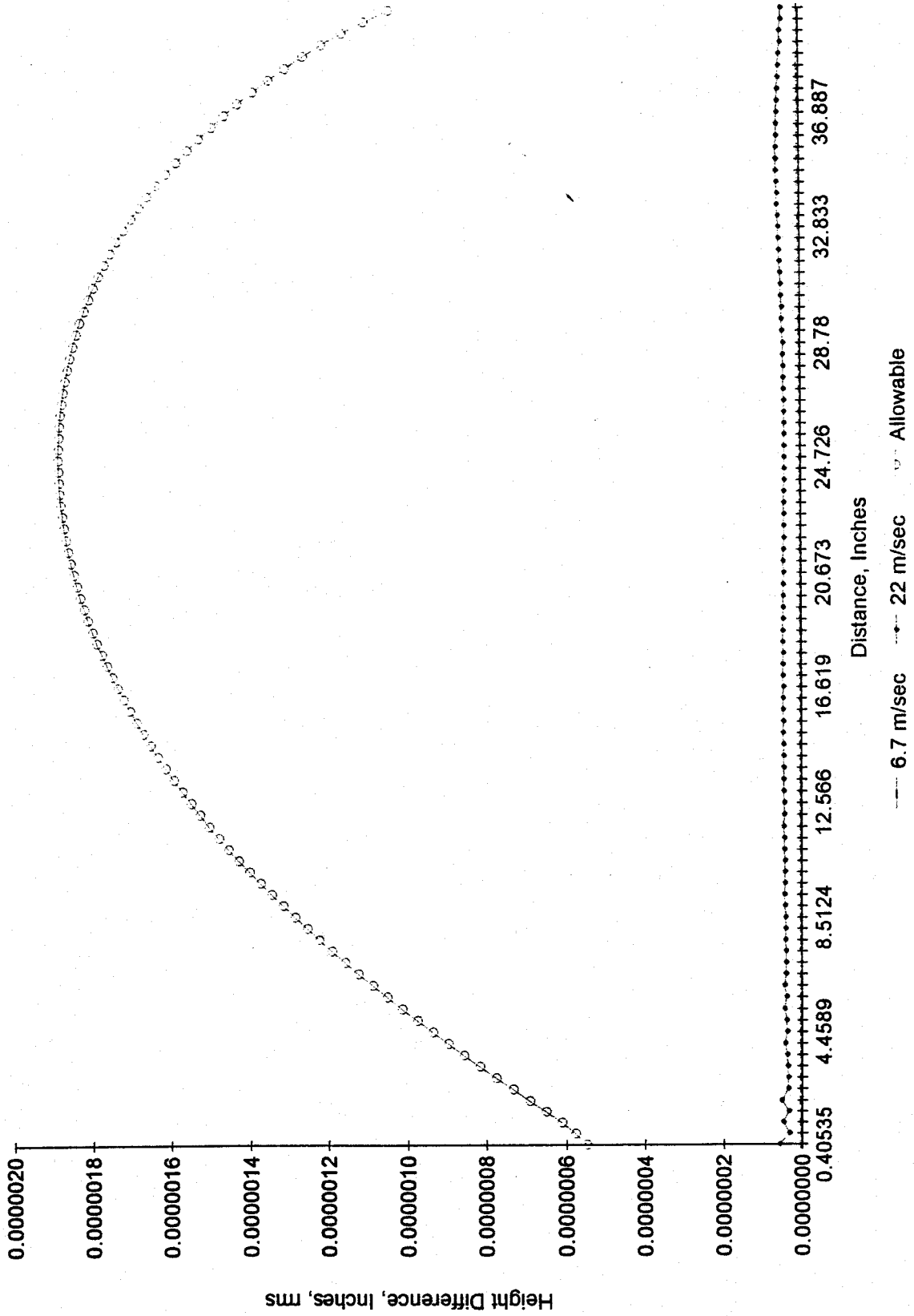
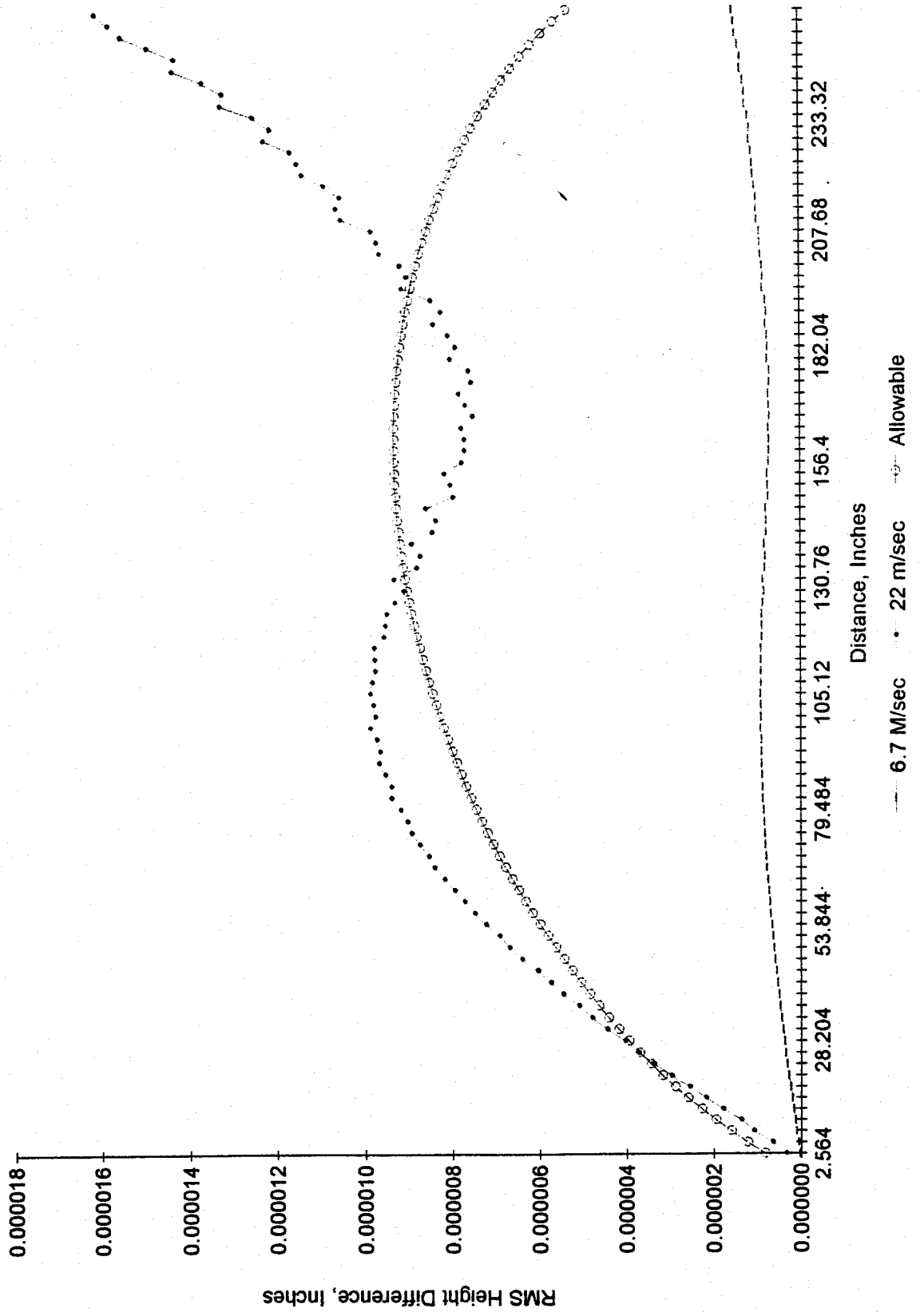


Figure 3 6.5 M Wind Distortion
Structure Function



APPENDIX A Finite Element Analysis Results

Gravity load cases were used to approximate wind pressure effects. The f/9 and primary results were based on existing models. The primary was supported on six spar elements aligned with the haerdpoint axes. The f/9 was supported by three axial and three tangential supports (the six point case was obtained by applying axial forces of 1/6 the weight between the three fixed axial supports. Model weights were 30,500 lbs for the primary and 200 lbs for the f/9 secondary. The primary weight is high because the material density used was 1.41 times the actual. The elastic modulus used for the primary was also high by a factor of 1.2 . The effect of the higher modulus has been accounted for in the wind response results.

Mass properties of the 6.5 M primary are as follows:

Weight	=	30,504 lbs
CG	=	0,0,-3.2068 inches

Mass Moments of Inertia

Ixx	=	371,600	370,800	in-lb-sec ²
Iyy	=	371,400	370,760	in-lb-sec ²
Izz	=	730,500	730,500	in-lb-sec ²

APPENDIX B LBT 8.4 M Wind Response Results

A model of the LBT 8.4 M primary has been used to obtain 1 g normal gravity results (other load cases consisting of 1 g gravity, unit angular acceleration and force sensitivity cases near the ID and OD and at an intermediate point are available). The model is shown in the attached figures. Mass properties are as follows:

Weight = 46,047 lbs (density input at 1:2 times)

CG = 0,0,-2.167

Mass Moments of Inertia:

I _{xx}	=	928,900	928,300	in-lb-sec ²
I _{yy}	=	927,700	927,100	in-lb-sec ²
I _{zz}	=	1,832,000	1,828,000	in-lb-sec ²

The wind force was calculated for a 1 Hz outer loop bandwidth and a projected area of 597 ft². This gave net axial loadings as follows:

8.4 M Primary Net Wind Loads:

	No Decorrelation	With Decorrelation
6.7 M/sec wind	472.4 lbs	188.8 lbs
22 M/sec wind	29.63 lbs	6.15 lbs

Results may be found in the attached structure function plots.