

## **MMT Azimuth Axis Test Plan**

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Below are the inspections, measurements, and tests for beginning to upgrade and improve the MMT azimuth axis servo system.

### **I. Inspections**

#### **A. Pintle and azimuth bearings**

All bearings should be inspected for contamination and proper lubrication. Where possible, samples should be taken and tested for wear indicators (e.g. metal chips/flakes).

#### **B. Motor assemblies**

Each motor assembly (4 total) should have the following items checked:

1. Gearbox lubricant; sample and test if possible.
2. Mounting bolts for tightness.
3. Alignment adjustment blocks.
4. Pinion gear mesh and runout.
5. Motor shaft flex coupling tightness.
6. Gear tooth quality (chips, marks, cracks).
7. Motor shaft runout at output side (if possible).

#### **C. Bull gear**

The bull gear should be inspected for wear, cracks, lubricant issues, or other problems.

#### **D. Motors**

Each motor should be visually inspected for brush wear, contaminated or dry bearing lubrication, excessive shaft play, proper mounting bolt tightness, wire insulation quality; the two motors with historically inoperative tachometers should be tagged and the other two marked accordingly.

#### **E. Encoders**

The motor shaft and absolute encoders should be checked for proper mounting, loose hardware, solid electrical connections, and signal quality problems to confirm the encoders are in good working order.

#### **F. Amplifiers**

Each motor drive amplifier should be checked for proper adjustments, wiring, and output to ensure no amplifier has some unnoticed issue.

#### **G. Wiring**

All cables and wiring in the azimuth drive system should be visually inspected; unmarked cables, if any, will be identified and marked where needed. Any wires with ozone or other damage will be replaced.

## **IIa. Mechanical Measurements**

### **A. Azimuth runout**

The radial runout has not been measured since after the installation of the pintle bearing; the radial runout should be measured and coherent data with the azimuth angle should be collected and stored in the MMT0 MySQL database.

### **B. Friction torque**

The static and running friction torque referred to the motor shaft torque should be measured at several azimuth positions.

### **C. Elevation mechanical cross-coupling**

“Nodding” motions in elevation should be measured via precision measurement of bearing tilt in the azimuth bearings, which has direct relation to the overall stiffness of the azimuth mechanical system; this value should be known.

### **D. Building cross-coupling**

Similar to elevation cross-coupling, this is a measurement of the effect of building/utility connections to the telescope and their magnitude.

### **E. Gearbox runout**

Any runout or tilt in the azimuth motor gearboxes or pinion gears should be measured to verify proper alignment of all the gears in the drive train.

### **F. Absolute encoder shaft runout**

Runout on the absolute encoder should be measured, in part to support addition of an incremental encoder on top of the existing absolute encoder housing.

### **G. Motor shaft runout and end play**

The motor shafts should be measured for runout and end play. In case of excessive values, the motor should be scheduled for removal and rebuilding.

### **H. Gear backlash**

Gear backlash for both individual, unbiased motor shafts and biased-torque motors should be measured and recorded to ensure that the current simple offset anti-backlash approach is in fact working.

### **I. Drive position hysteresis**

The hysteresis curve for drive velocity reversals w.r.t. the absolute azimuth position should be measured and recorded.

### **Iib. Electrical Measurements**

- A. The motor resistance and inductance for each drive motor should be measured and recorded. The motor resistance should be measured at several shaft positions to detect any possible brush-resistance problems.
- B. Each motor assembly with an operating tachometer should have its tachometer output measured, including with an oscilloscope trace to document any commutation spikes, if any.
- C. Each drive amplifier shall have its gain and offset measured and adjusted, if necessary, to bring all outputs to within 2% of each other.
- D. The drive amplifier output bandwidth shall be measured into a dummy load and recorded for later use in drive system modeling.
- E. The lead resistance in the amplifier output cables shall be measured and recorded.
- F. The encoder signal quality for both the motor shaft incremental encoder and the on-axis absolute encoder should be measured and verified to be within operational specifications.
- G. The incremental encoder scaling should be measured and recorded; changes in scaling over motor revolutions should be measured in possible (gear reduction eccentricity).
- H. The correct coarse/fine meshing offsets for the absolute encoder to form the correct 25-bit result from the raw Inductosyn and resolver 16-bit values should be found.
- I. Cyclical error from gear meshing should be measured and recorded (e.g. differential measurements between shaft and absolute encoders that result in cyclical residuals).
- J. The total torque on the telescope should be measured and recorded for tracking, accelerating, and decelerating to record the torque required in the drive system, in part to support a long-term “stiff azimuth drives” project.

### **III. Drive System and Servo Controller Tests**

- A. To document the operation of the existing LM628-based control system, the closed-loop disturbance response should be measured with the HP35670A DSA, repeating the measurements reported in 2003.
- B. The operational signals in the LM628-based systems should be measured and recorded, and FFTs performed to verify output signal frequency content (e.g. 1.5Hz gain peaking, 3.8Hz modal frequencies).
- C. Total differential torque applied to the azimuth drive system for several common tracking and slew profiles should be measured and recorded (see section Iib, item J above).
- D. The open-loop response of the drive system at different azimuths and elevation angles should be measured and recorded for model development for step, noise, and chirp-signal inputs.
- E. Candidate controllers should have their operation measured and compared to predicted performance, and iterated until the controller performs as desired.

