WIYN Project

Wisconsin Indiana Yale NOAO

MEMORANDUM

TO: Distribution
FROM: D. Blanco & J. Little
SUBJECT: Secondary actuator tests
DATE: May 4, 1993

Interim Report on the WIYN Secondary mirror Focus/Tilt Actuators

Introduction

This interim report describes tests done on a prototype actuator for the WIYN secondary mirror.

The WIYN secondary actuators will reside on the cage at the center of the upper spider truss and provide the anchor points for mounting the secondary mirror cell. Three actuator units will be used to control the position of the secondary mirror in focus and tilt. A single actuator consists of a 200 step per revolution stepping motor, a Harmonic Drive gear reducer with an 80:1 reduction ratio and an integral Kaydon type X bearing, and a 2mm pitch Transroll recirculating roller screw. These components were selected to give a nominal linear advance of 0.125 microns per step of the motor. When moving only one actuator to tilt the secondary mirror, one step is equal to a lateral image motion of 1.81 microns or 0.017 arcseconds at the focal plane.

All components were selected for high capacity, good repeatability, and low hysteresis. In addition to the actuator components, a rigid and rather massive test stand was also fabricated. This stand simulates the spider cage and the secondary mirror cell, and provides a stable frame for measuring the very fine resolution of the actuator. A compression spring was included to simulate the variable loading the actuator will see in use.

Parts for three actuators were purchased or fabricated in the NOAO machine shops. One unit was assembled and mated with step a motor controller and driver board developed at NOAO for use with the primary mirror actuators. This board has several features which make it attractive for use with the secondary actuators - low power consumption, the ability to power down when not in use, as well as providing both the indexing (ie step generation) and power amplifiers on one board. The board also has a 12 bit analog to digital converter which could be used to read an LVDT position feedback.

Phase I Test Setup

For testing the assembled actuator a PC using the LabWindows hard- and soft-ware package was loaded with the proper drivers to communicate with the NOAO board via an RS485 link. The actuator, test stand, driver, and PC were assembled to test the system performance.

The actuator position was measured with an electromike non-contacting gage head. This device returns a voltage proportional to the distance of a metallic object (the target) from the gage head. This signal was fed to a 12 bit AD board in the PC. LabWindows was used to acquire the electromike voltage reading. This signal turned out to be rather noisy, so a C routine was added to the control software to introduce a digital filter which returns the median of 100 data samples.

Procedure & Observations

After calibrating the electromike, two basic tests were performed; the spring rate of the actuator was measured by adjusting the spring load and recording the position. The second test recorded the positional hysteresis of the actuator both loaded and unloaded. Two significant discoveries were made in the course of these tests:

1) The actuator spring rate was measured to be about 120,000 lbs/inch. This is only 44% of the value predicted from an analysis of the components - 316,000 lbs/inch. Some impromptu probing and "charismatic" engineering traced the cause of this unexpected compliance to the anti-rotation constraint for the nut. The nut was constrained by a simple strap flexure which allowed the nut to float in any direction save rotation about the lead screw axis. For reasons which are still unclear this method of mounting the nut reduced the overall stiffness by about a factor two.

   The strap flexure was replaced by a jury rigged parallel leaf spring flexure which constrains the nut in all directions except for translation along the screw. With this jury rigged arrangement, the device compliance was measured to be 308,000 lbs/inch, which is within 3% of the predicted value.

2) Three limitations in the NOAO driver board became apparent. These boards were specifically designed for use with the primary mirror active supports where control of the motors to a single step accuracy is not necessary. As presently configured the board issues two motor steps for every single "step" command.

   Second, the control board by design loses a step whenever the direction is changed. On the board a change in direction is accomplished by inverting two of the phases. This necessarily entails the position change of one motor detent. This step loss is not accumulative and it is repeatable.

A third more fundamental limitation is found in the board's behavior on power up. We are using four phase stepper motors with 200 detent positions per revolution. The control board moves the motor to each detent by energizing the four phases in a quadrature sequence. When the driver is powered down it does not retain memory of its last phase. On power up the board energizes the motor in a default phase. If the motor happened to be positioned at some arbitrary detent it will snap to the nearest default phase position with no record of the step loss or gain. Thus there are only 50 valid detent positions where the motor can be "parked" while the board is powered down. This has the effect of reducing the system resolution by a factor four.

For the system tests the actuators were moved in four detent increments (two commanded "steps" that were doubled on the driver board). This was done to avoid any step loss when the board was powered down and up again. Several traverses forward and backward were made and the position measured with the electromikes. This was repeated with the system loaded to 300 pounds compressive load.

Results

The positional hysteresis curves under a 300 pound load are shown in the attached sheets (when unloaded the performance was similar but with slightly less hysteresis). Because of the hysteresis, the actuator showed a bi-directional repeatability of 1.34 microns rms, or 0.18 arcseconds rms at the focal plane. Approaching a position from one direction only gives considerably better results - 0.036 microns rms (0.005 arcseconds rms).

There was some indication that there may be a time dependent change in position under load (creep), however this was not measured.

The actuator has been disassembled, and revisions to the parts will be done to incorporate a parallel leaf spring flexure for the nut restraint. Other modifications will be done to make assembling the actuator easier.

Interim Conclusions

The actuator appears to work acceptably.

The present system resolution appears to be limited by the NOAO driver board.

Phase II Tests

After modifications are complete the actuator will be reassembled. We are currently planning to use a commercial stepper motor controller consisting of a single board computer, an indexer card, and a drive amplifier for the Phase II tests.

Two amplifiers have been purchased, one of which is capable of micro-stepping, which may allow higher speed traverses than whole- or half-stepping drivers. Initial estimates indicate the power dissipation of these boards is comparable to that of the NOAO drive boards.

It is our intention to evaluate the use of the commercial driver for the secondary actuators. Further tests of the mechanism will also be done, including a measure of creep, and a verification of performance at low temperatures.

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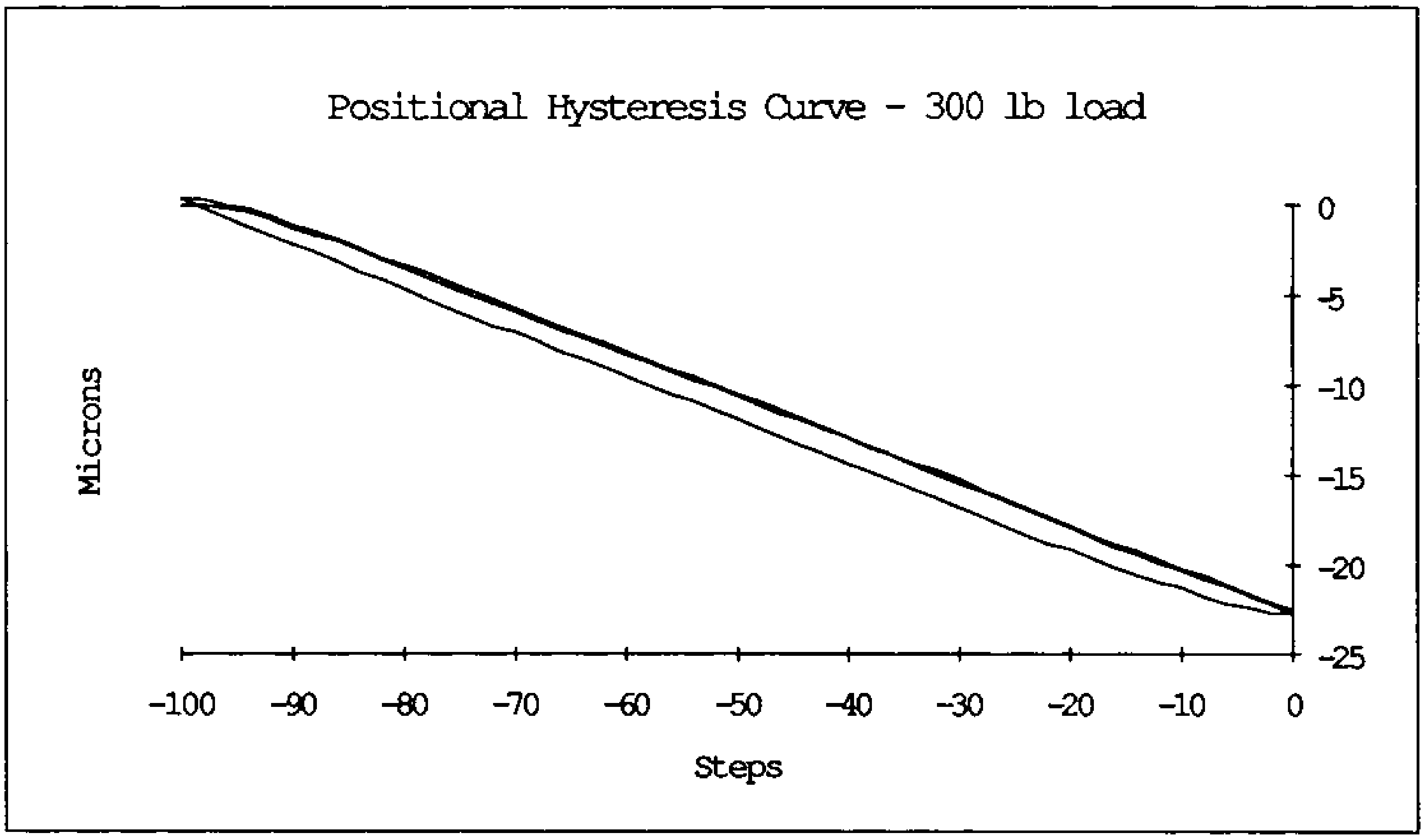
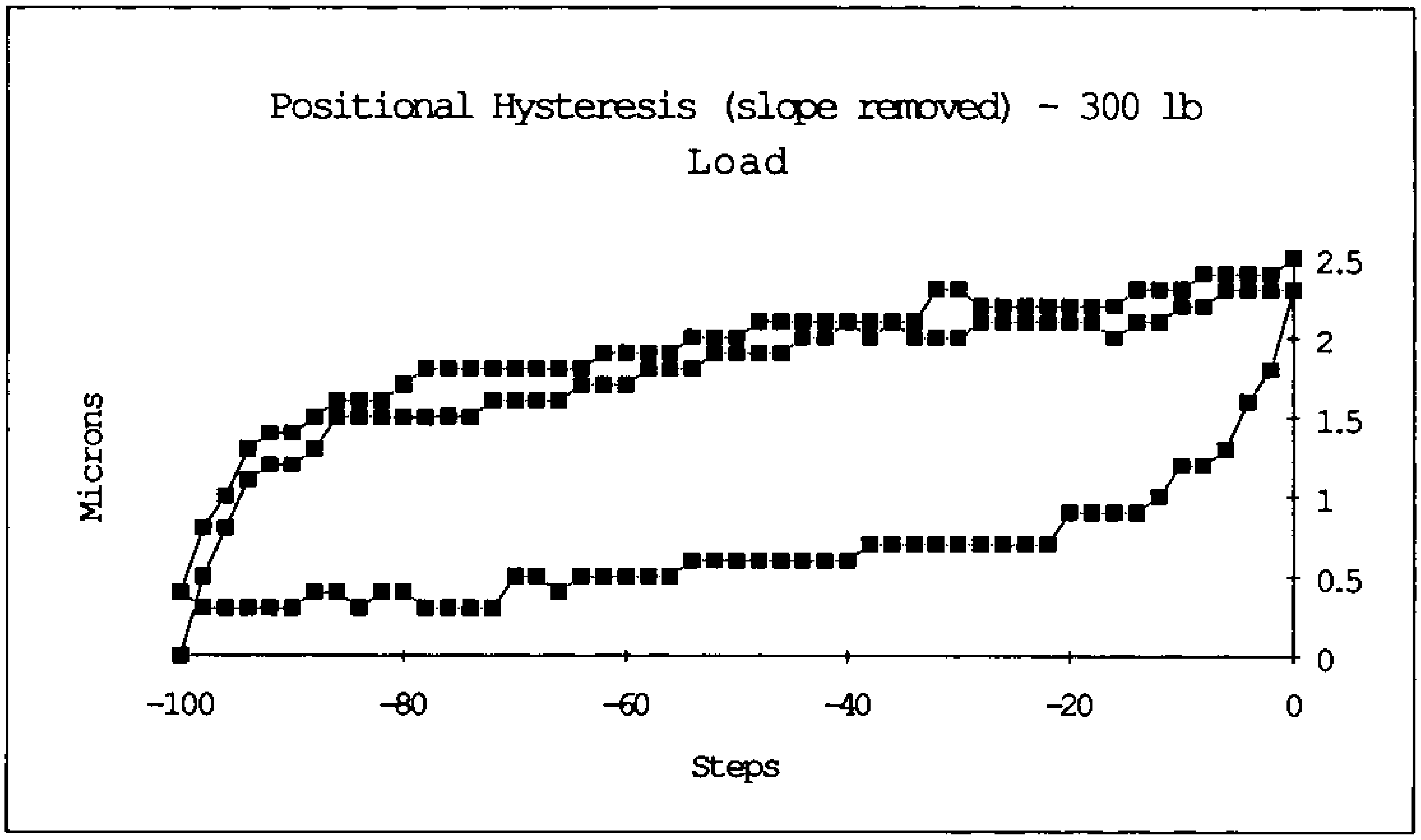
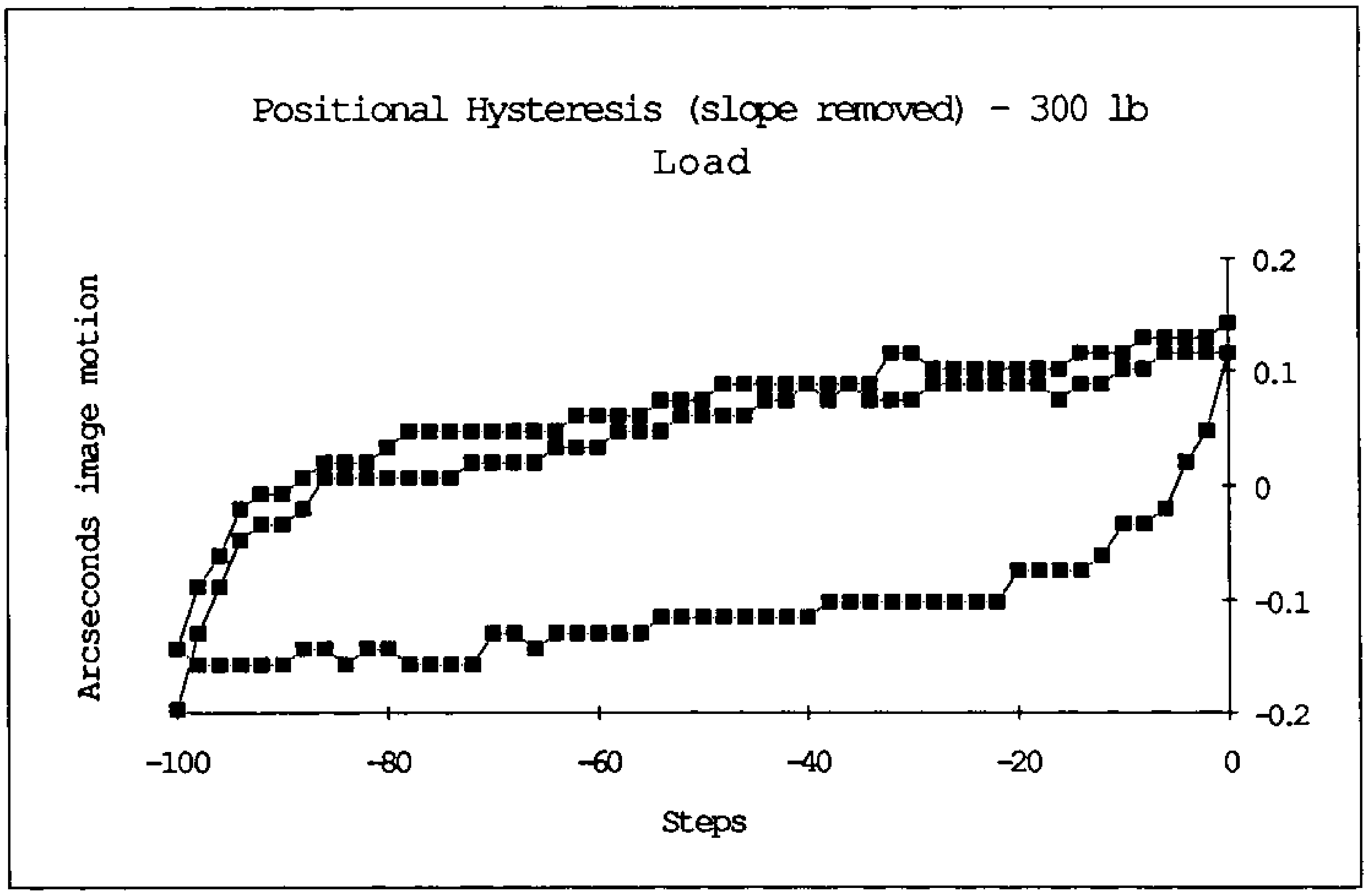
WIYN Secondary Actuator Phase I Test
Hysteresis curve under 300 lb compression load
data taken 3/19/93

Note: One "step" = 2 motor detents





-0.25 Microns per step slope removed



Bidirectional Repeatability is 1.34 Microns rms
0.18 Arcseconds rms

Unidirectional repeatability is 0.035604 Microns rms
0.004842 Arcseconds rms

(Based on two traverses - 82 samples)