Interoffice

NATIONAL RADIO ASTRONOMY OBSERVATORY

TUCSON, ARIZONA

September 21, 1978

Engineering Memo #126

To: M. A. Gordon

From: B. L. Ulich

Subject: Progress report on telescope pointing

I want to report in some detail on my efforts to understand and to improve the telescope pointing accuracy.

I. COMPUTATIONAL ACCURACY

At my suggestion, Mike Hollis investigated the accuracy of the corrections calculated by the on-line software. He found significant errors (several arc seconds) particularly in the northern part of the sky. He has changed the program to use double precision arithmetic, and the computational errors are now less than ± 0.2 arc seconds peak-to-peak.

II. SYSTEMATIC RESIDUALS

When fitting several sets of data taken at different times, there are large (~40 arc second) systematic offsets between runs. In addition, the azimuth RMS pointing accuracy seems to degrade with time faster than the elevation accuracy. When fitting a single data set, smaller systematic residuals are apparent in both azimuth and elevation offsets as a function of telescope azimuth (see Figures 1 and 2). Their similar shape suggests a common origin, perhaps the azimuth bearing. To check out this idea I measured the tilt of a bracket welded on the pedestal just below the azimuth bearing. As shown in Figure 3, the pedestal deforms with a double period in azimuth, but the peaks are slightly shifted in phase from the pointing glitches. I have also measured the bearing and cable wrap torque versus azimuth (see Figure 4). Again one can see a pronounced double period in the bearing friction. This may mean that the bearing is not flat, but rather is astigmatic. As it turns, it flexes and wobbles the yoke arms, particularly near 60° AZ and 260° AZ. While I don't understand the phase difference, I do believe the pointing glitches are related to the azimuth bearing. Of course, if these glitches are stable with time, we can (and should) correct for them empirically.

III. ADDITIONAL TERMS

It is difficult to determine the functional form of significant terms which have not been included in the least-squares data fit because of the incomplete sky coverage. Therefore, Bob MacDowall and I undertook to look for them using an electronic level and laser/quadrant detector. In several cases our measurements showed that the telescope mount behaved in the predicted manner. In others, however, it did not. In particular, the elevation encoder case is not fixed with respect to the earth. It rotates as a function of elevation and azimuth, as shown in Figures 5 and 6.

IV. REFRACTION

The encoder case rotation has previously been compensated for by biased fits of refraction and bending. I plan to remove the linear elevation term and refit my old data to see if the agreement between the observed and calculated refraction improves. If the agreement is good, we will constrain the refraction to the calculated value, which can now be entered into the on-line program. We have an HP-65 program and a graph which give the refraction coefficient as a function of ambient temperature, relative humidity, and barometric pressure. My pointing data during shutdown were taken with variable refraction and the fit was significantly improved.

V. FEED LEG INSULATION

During shutdown I covered the feed legs with styrofoam and aluminum tape to reduce the pointing errors caused by sunlight. A direct comparison of solar heating showed that an insulated leg rose in temperature about a factor of 10 less than an uninsulated leg. The similar improvement in pointing stability has been noted by Bill Wilson who compared his observations of Venus before and after the legs were insulated.

VI. VERTICAL AXIS TILT

Bob and I measured the tilt of the vertical axis of the telescope mount on several occasions (an example is Figure 7). The amplitude and azimuth of the tilt change significantly with time but there does not seem to be a simple relationship with temperature. Much more data are needed to search for correlations that can be used to predict this term. In addition, the curves clearly deviate from a sinusoid (due to bearing wobble), and these deviations contribute to the systematic residuals.

VII. AZIMUTH ENCODER OFFSET

The azimuth encoder has not been replaced or adjusted in about two years, and I now have enough data to see a remarkable trend. As shown in Figure 8, the encoder offset varies with temperature by a large amount ($\sim$3 arc seconds/^{o}C). It seems very unlikely that the encoder case (which is bolted to the pedestal floor) can rotate. To search for some odd effect in the pedestal, I heated the air to change the temperature of everything inside by 15^{o}C. The encoder changed only 1 arc second. Thus it seems that the reflector (i.e. elevation axle) is rotating with respect to the encoder shaft (torque tube). I believe this rotation occurs because the yoke arms twist. Are the aluminum reflector and steel mount still behaving like a bimetallic thermostat? While the data in Figure 8 are certainly suggestive, I believe we should try to directly measure this movement during a diurnal temperature cycle using a laser and remote detector.

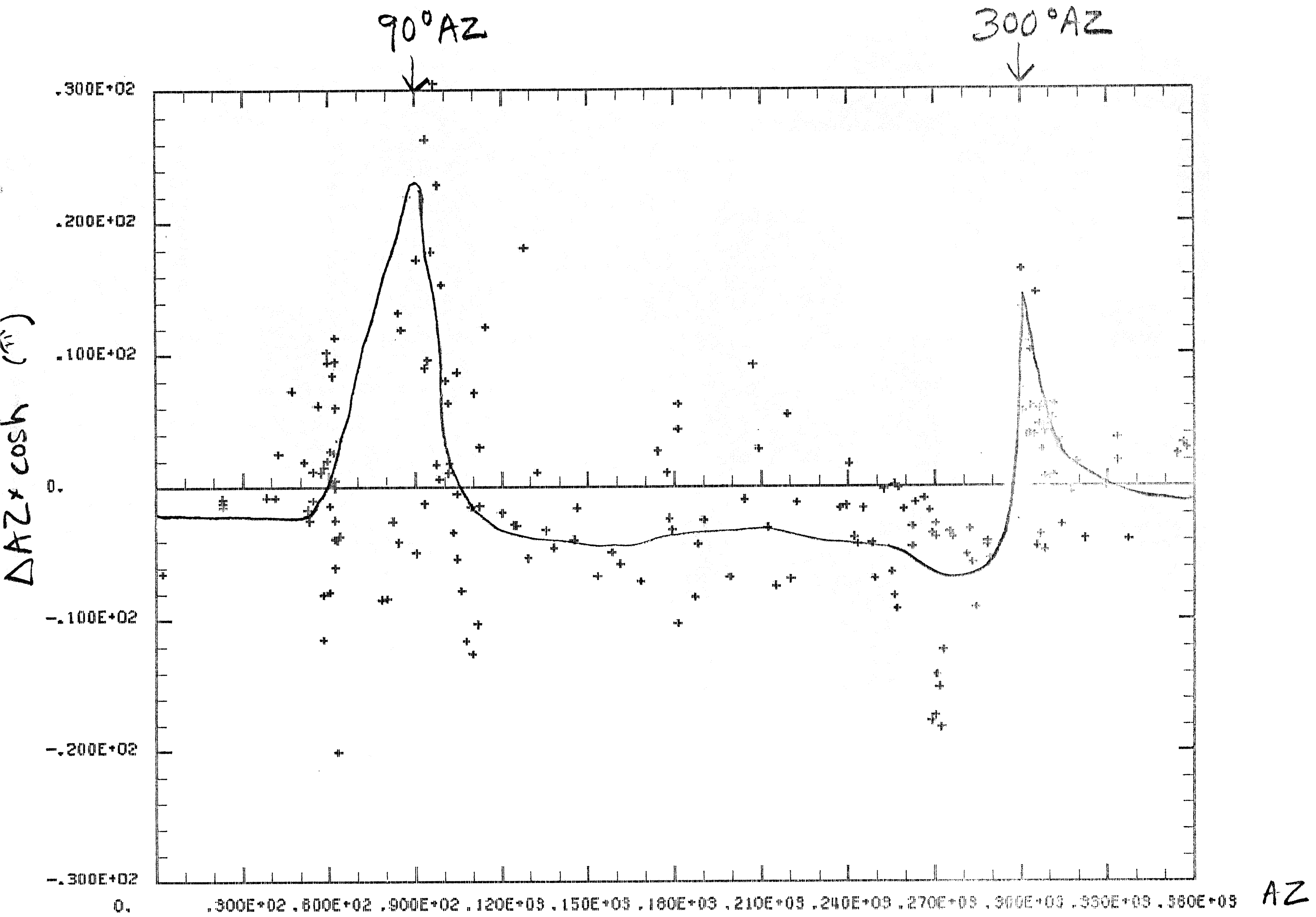
I request that for a year's time an additional 24-hour period be scheduled adjacent to the normal 24-hour pointing runs in order to determine correlations of telescope mount movements with temperature.

c: J. Hollis
L. King
R. MacDowall
J. Payne
G. Peery
S. von Hoerner

FIGURE 1

PROJ. AZIMUTH RESIDUALS (F SEC) VS.AZIMUTH

ALLDATA



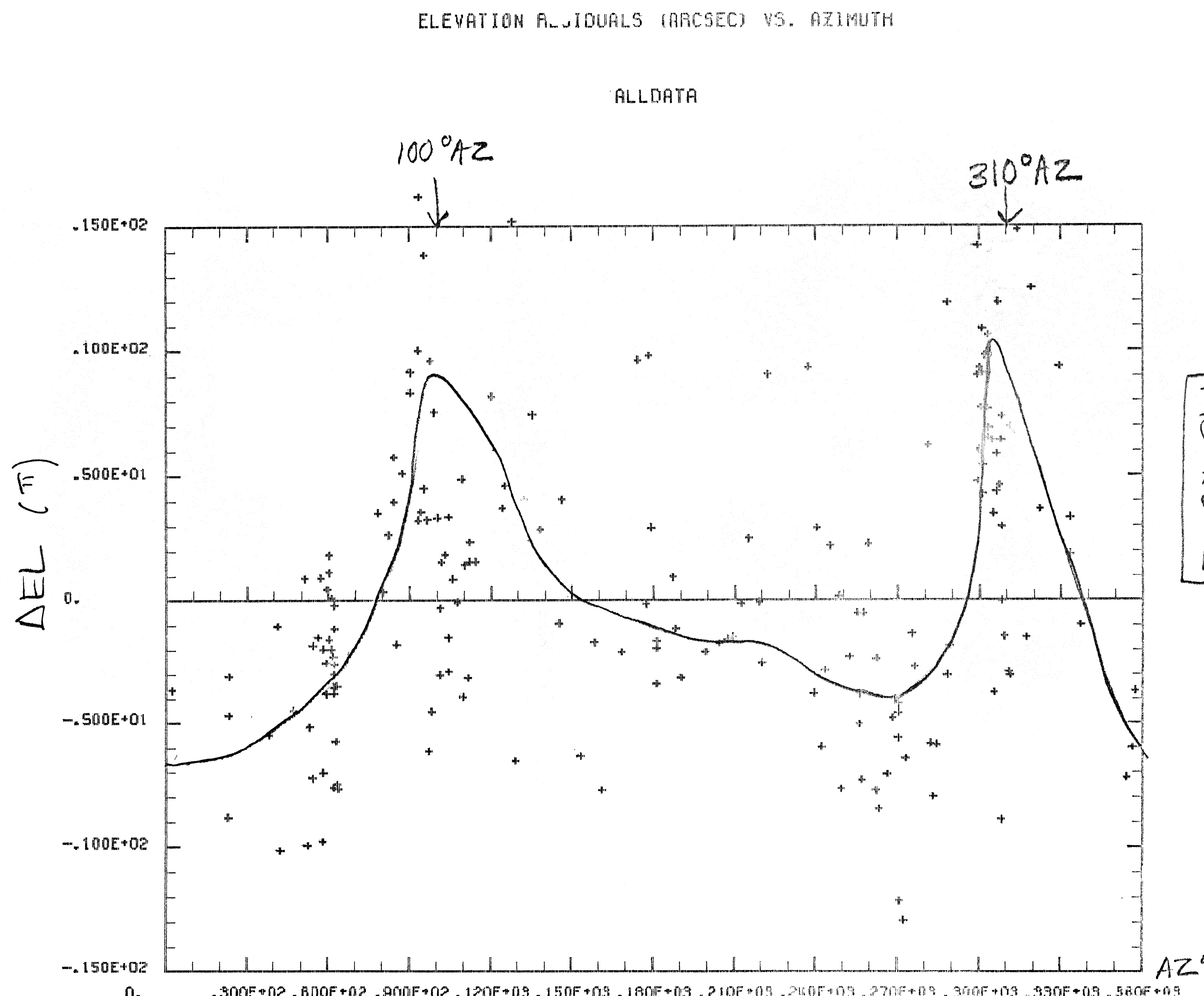
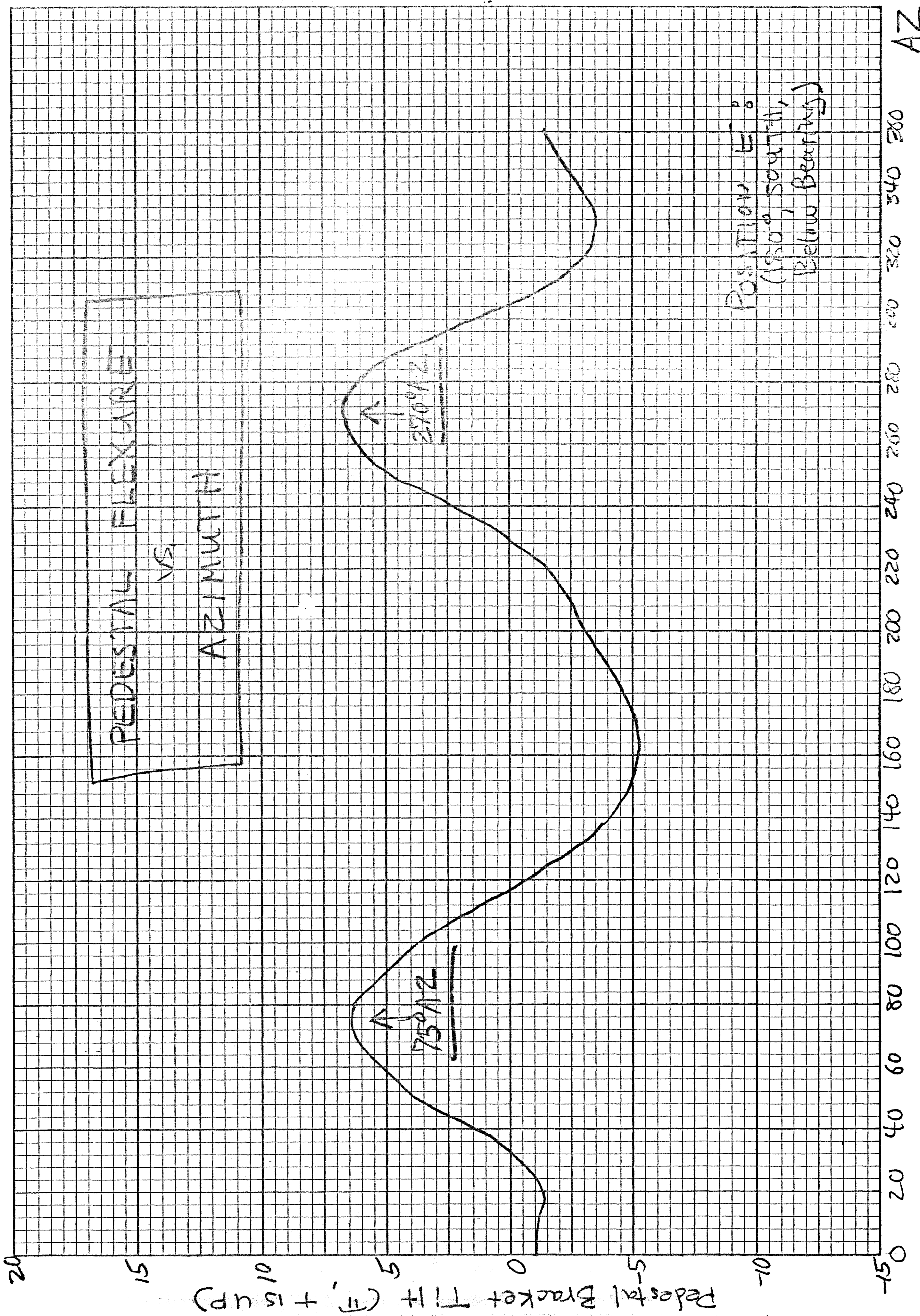

ELEVATION R..IDUALS (ARCSEC) VS. AZIMUTH
ALLDATA
100°AZ
310°AZ
.150E+02
.100E+02
.500E+01
0.
-.500E+01
-.100E+02
-.150E+02
ΔEL (″)
0.
.300E+02
.600E+02
.900E+02
.120E+03
.150E+03
.180E+03
.210E+03
.240E+03
.270E+03
.300E+03
.330E+03
.360E+03
AZ°

FIGURE 2

FIGURE 3



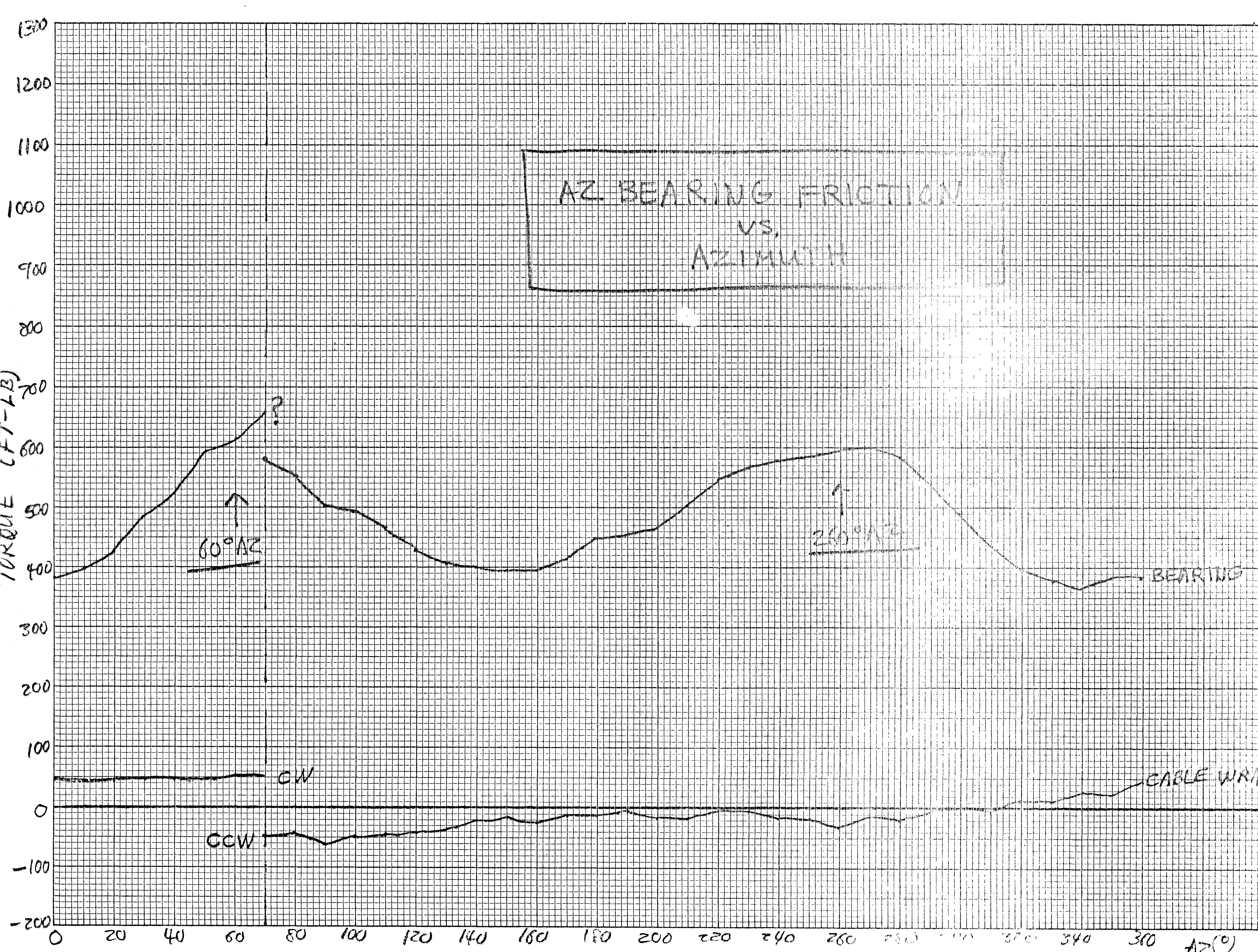
PEDESTAL FLEXURE
vs.
AZIMUTH
Position
(180° South,
Below Bearings)
AZ°
75° AZ
270° AZ
Pedestal Bracket Tilt
20
15
10
5
0
-5
-10
-15
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380

S.L. ULICH

FIGURE 4

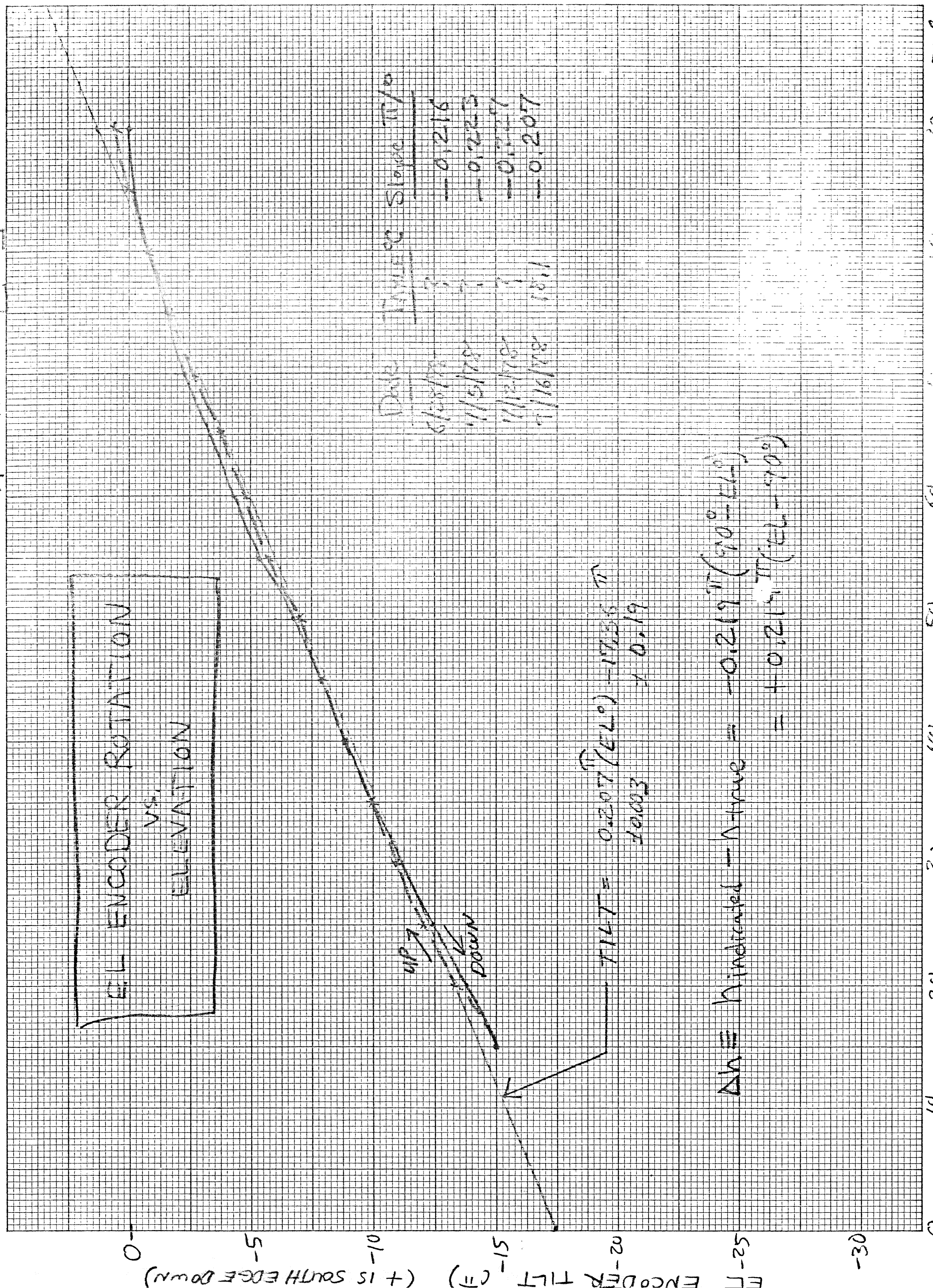
4/16/78
~1230 AM HST

$T_{EL\ AXLE} = 18.05°C$ · $T_{AMB} = 14.96°C$



E.L. ULICH

[FIGURE 5]



9/6/78

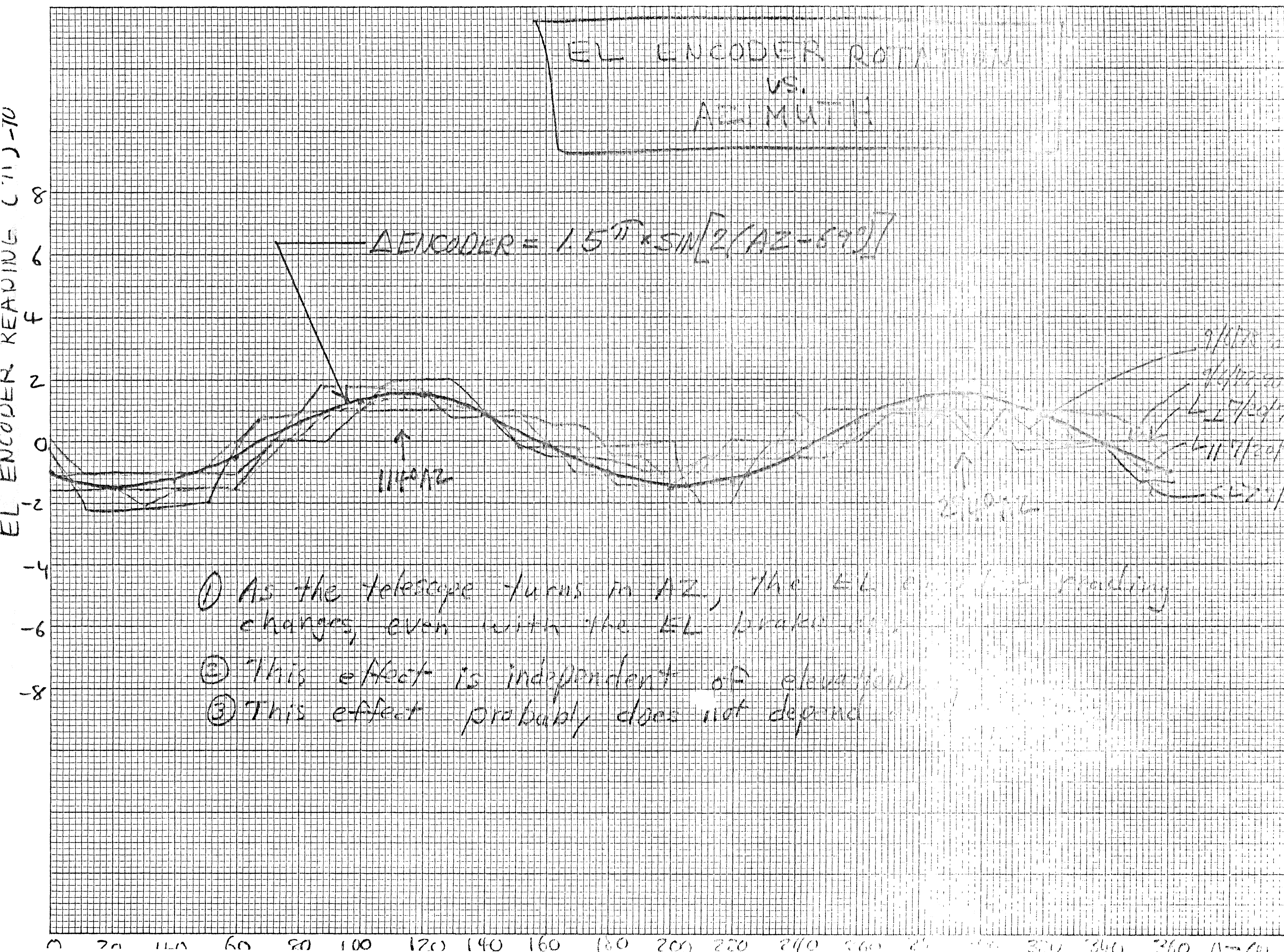
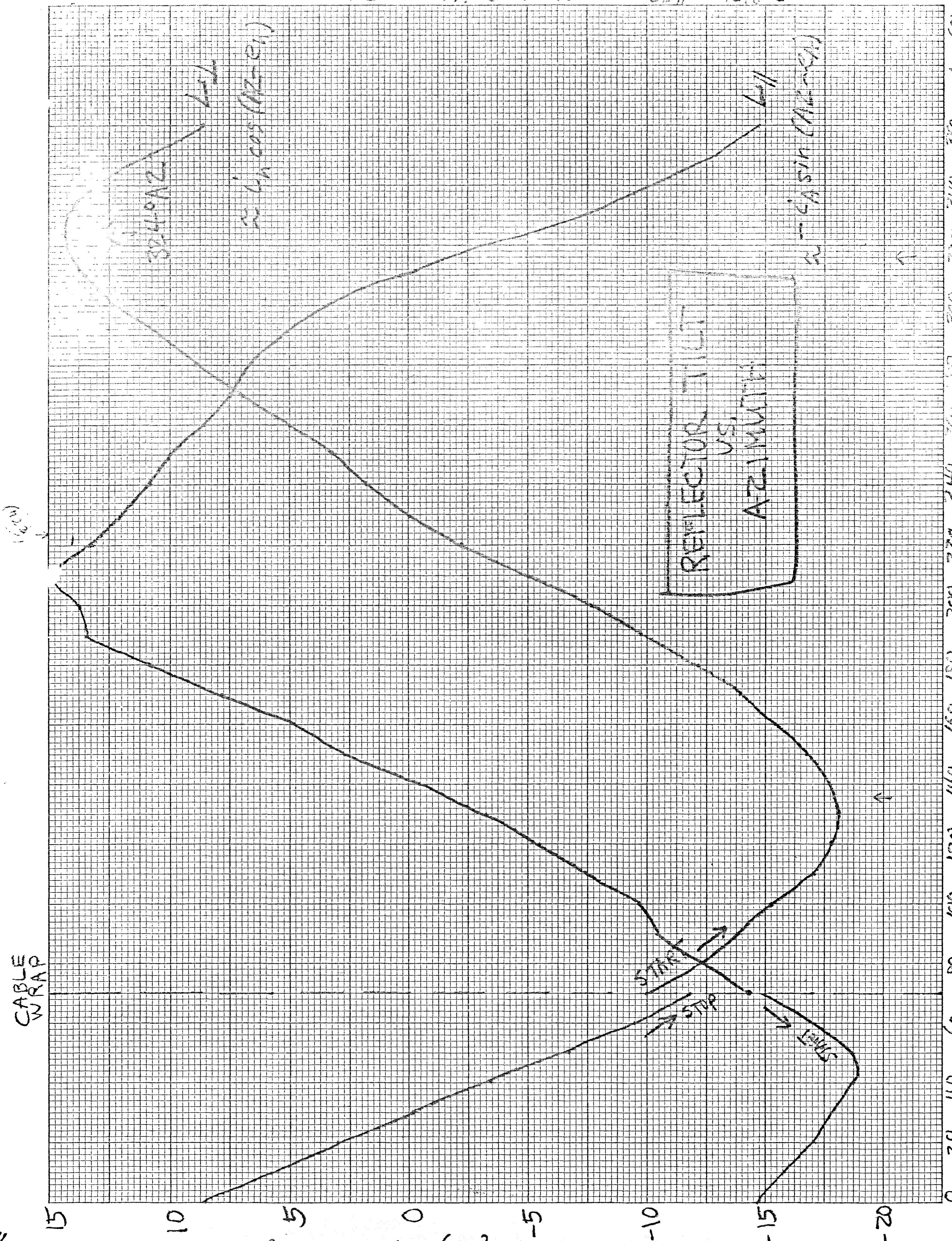


FIGURE 6

E.L. ULICH (FIGURE 1) 9/15/82

$T_{AXLE} = 18.15°C$ $T_{AMB} = 15.15°C$ $T_{DISH} \approx 15.6°C$



B.L. ULICH

FIGURE 8