# 140-FT DEFORMABLE SUBREFLECTOR

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ENGINEERING MEMO #45

## I. The Goal

At present, the surface errors (deviations from best-fit paraboloid) of the 140-ft are:

$$\left.\begin{array}{ll} \text{surface error at zenith,} & \text{rms} = 0.80 \text{ mm (astronomical efficiency)} \\ \text{gravitational deformation, observing south, } 20° \text{ elevation} & \\ & \text{rms} = 1.68 \text{ mm (computer analysis)} \end{array}\right\} \begin{array}{l}\text{total rms} \\ = 1.86 \text{ mm}\end{array} \tag{1}$$

$$\text{max} = 5.10 \text{ mm.}$$

This means the shortest wavelength for observation is

$$\lambda = 16 \text{ rms} = \begin{cases} 1.3 \text{ cm at zenith,} \\ 3.0 \text{ cm at } 20° \text{ elevation.} \end{cases} \tag{2}$$

Three future improvements are possible. First, new accurate surface measurements are planned, and readjustments of all panel supports; this may reduce the zenith error from 0.8 to 0.6 mm. Second, the remaining internal bumpiness of the panels could be corrected for by a subreflector with similar proper bumps (a paper "The Design of Correcting Secondary Reflectors" has been submitted); a factor of three seems possible, reducing the error from 0.6 to 0.2 mm. Third, gravitational deformations can be counteracted by squashing the subreflector mechanically by an elevation-dependent amount; a reduction by a factor of four is possible and may be set as a goal. Assuming an rms error of 1.5 arcsec for the new surface measurements, and using some old thermal estimates for good nights, the future error budget may look as follows:

| | | |
|---|---|---|
| surface measurements | 0.15 mm rms | total = 0.63 mm |
| panel bumps | 0.20 | $\lambda$ = 1.0 cm |
| gravity | 0.42 | |
| thermal (night) | 0.35 | (3) |

This Memo considers only the correction of gravity with the deforming subreflector and our goal then is:

$$\begin{aligned} \text{rms residuals} &\leq 0.42 \text{ mm} = 0.016 \text{ inch,} \\ \text{max residuals} &\leq 1.28 \text{ mm} = 0.050 \text{ inch.} \end{aligned} \tag{4}$$

The gravitational deviations are shown in Fig. 1 and 2. Fortunately, observing east gives a very similar contour as observing south (gravity in z-direction giving much more deformation as in x and y-direction); thus only <u>one</u> type of deformation is required for all the sky. Fig. 3 shows the center lines, where the strong bumps in the EW line are caused by the stiff elevation bearings (violation of equal-softness demand). The other obvious feature in Fig. 1 is the well-pronounced astigmatism, calling for an astigmatic deformation of the subreflector, too.

A computer study (paper mentioned above) has shown that the subreflector must be deformed in almost exactly the same shape as the main dish is. Thus, Fig. 1 represents the goal, to be approached within the residuals of (4).

## II. Check and Improvement of Analysis

The present computer analysis calculates the deformations of the main joints of the backup structure, which is 17 points per quadrant of the surface. The panels, however, are supported by 60 points per quadrant, partly in the middle of heavy beams. Two things should be checked: first, the bending of these beams under dead loads and panel weight; second, the sag of the panels themselves. Maybe both are small, but it must be checked.

Third, Fig. 1 and 3 show some NS-asymmetry, probably caused by an imbalance of the telescope (tailheavy) working against the asymmetric constraint of the elevation drive at the elevation wheel. Since the NS-difference of Fig. 3 looks amazingly large, this needs a careful checking.

## III. Computer Model of Subreflector

It seems best to go ahead with getting a deformable subreflector first (and correcting the internal bumps of the panels later, by gluing-on several layers of foil on the subreflector).

The deforming forces must be applied to the thin subreflector shell at certain points, and they must be distributed over a certain area by thicker pads. The strong points and stiff pads should be provided by the manufacturer. In order to find out exactly where and how stiff we want these pads and points, we need first of all a computer model, on which to work by trial and error until Fig. 1 is approached sufficiently well. The model will then also yield the needed forces and resulting stresses, both valuable for the manufacturer.

Fig. 4 gives the suggestion of a model, replacing the continuous shell by a finite grid of structural pipes whose dimensions are derived in Fig. 5. Since equal and isotropic stiffness of the shell interior is more important than a smooth rim, an isometric grid was chosen throughout. As compared to our present nutating subreflector, the stiff ring must be replaced by a stiff cross along both 45° diagonals (constraining $\Delta z = 0$). Neglected in Fig. 5 are the additional (compression and bending) stiffness of the actual shell resulting from the aluminum core of the honeycomb, and the additional (bending) stiffness of the grid diagonals of the model. Both items are estimated to be small, and also they will partly cancel each other.

## IV. Further Procedure

If there are no objections or better proposals, I would suggest the following.

1. Check 140-ft analysis

    beam action

    panel deformation

    NS-asymmetry

2. Computer model subreflector

    prepare input data, keep pads and points variable

    change pads and points until Fig. 1 is approached within (4)

    find forces and stresses

3. Design mechanical setup

    1 or 4 motors needed for deformations?

    weight and size of motors, gears and rods

    estimate dynamical properties for nutation

4. Contact several firms

    give them: design as developed by computer model

    specified static deformation, Fig. 1 with accuracy (4)

    dynamic specifications

    ask them: who can and wants to do it?

    cost estimate

    detailed analysis: static deformation

    dynamic (nutation) deformation and time

    thermal deformation

    stresses

If possible, the emphasis should be on: Structural Technology, Inc., Milpitas, California. They have made our present nutating subreflector, including a complete static, dynamical and thermal analysis.

5. Buy one

check (undeformed) surface accuracy

deform, and measure one quadrant (30-40 dial indicators on a jig)

mount on 140-ft, measure efficiency astronomically

with and without subreflector

both at zenith and at low elevation

both with and without nutation.

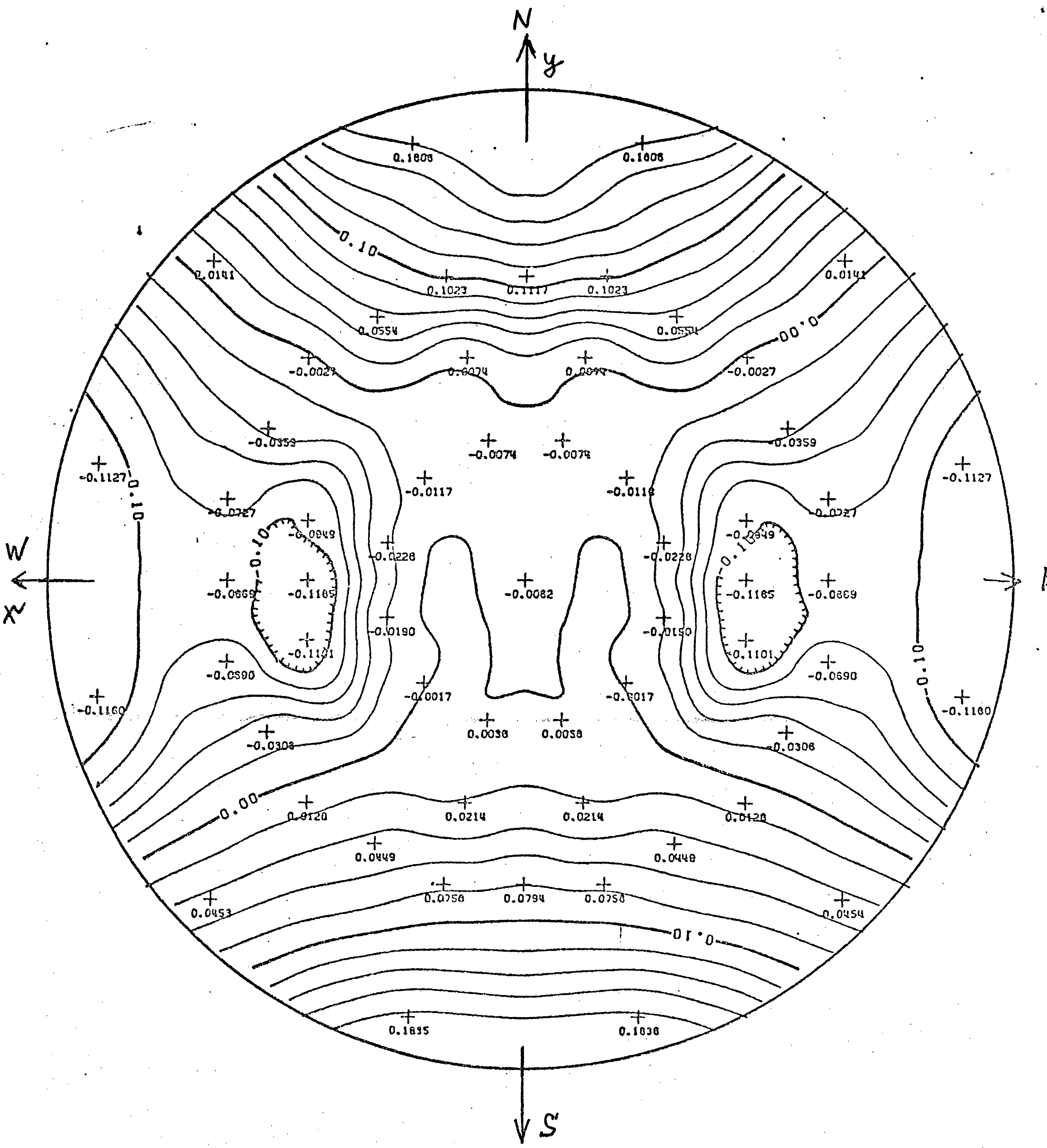



Fig. 1. Gravitational deformation of 140-ft surface (computer analysis)

adjusted: zenith

observing: south (meridian, $20^{\circ}$ elevation)

rms($\Delta z$) = 0.066 inch = 1.68 mm

contours: deviation (inch) from best-fit paraboloid

15 db taper

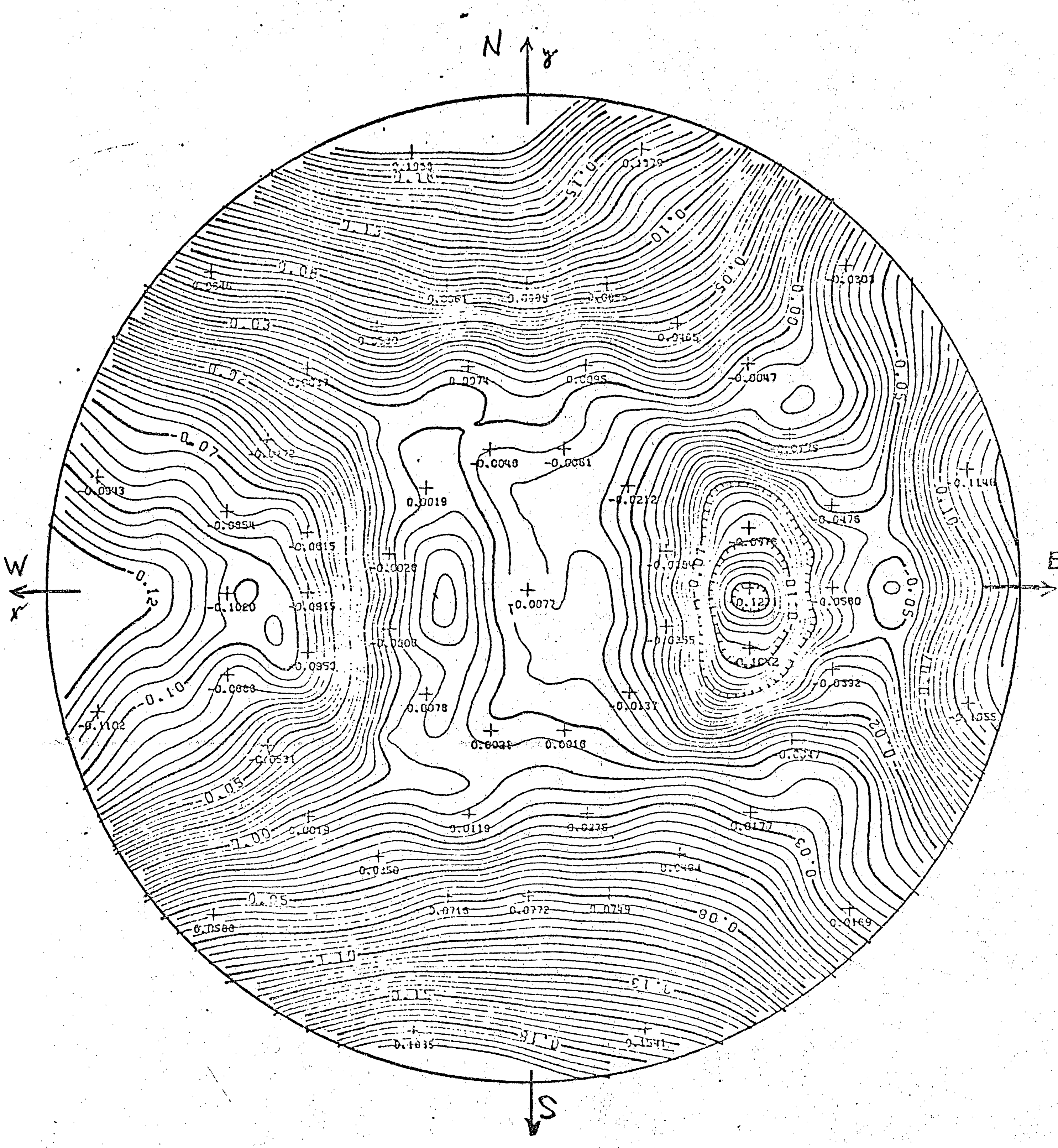



Fig. 2. Gravitational deformation of 140-ft surface (computer analysis)

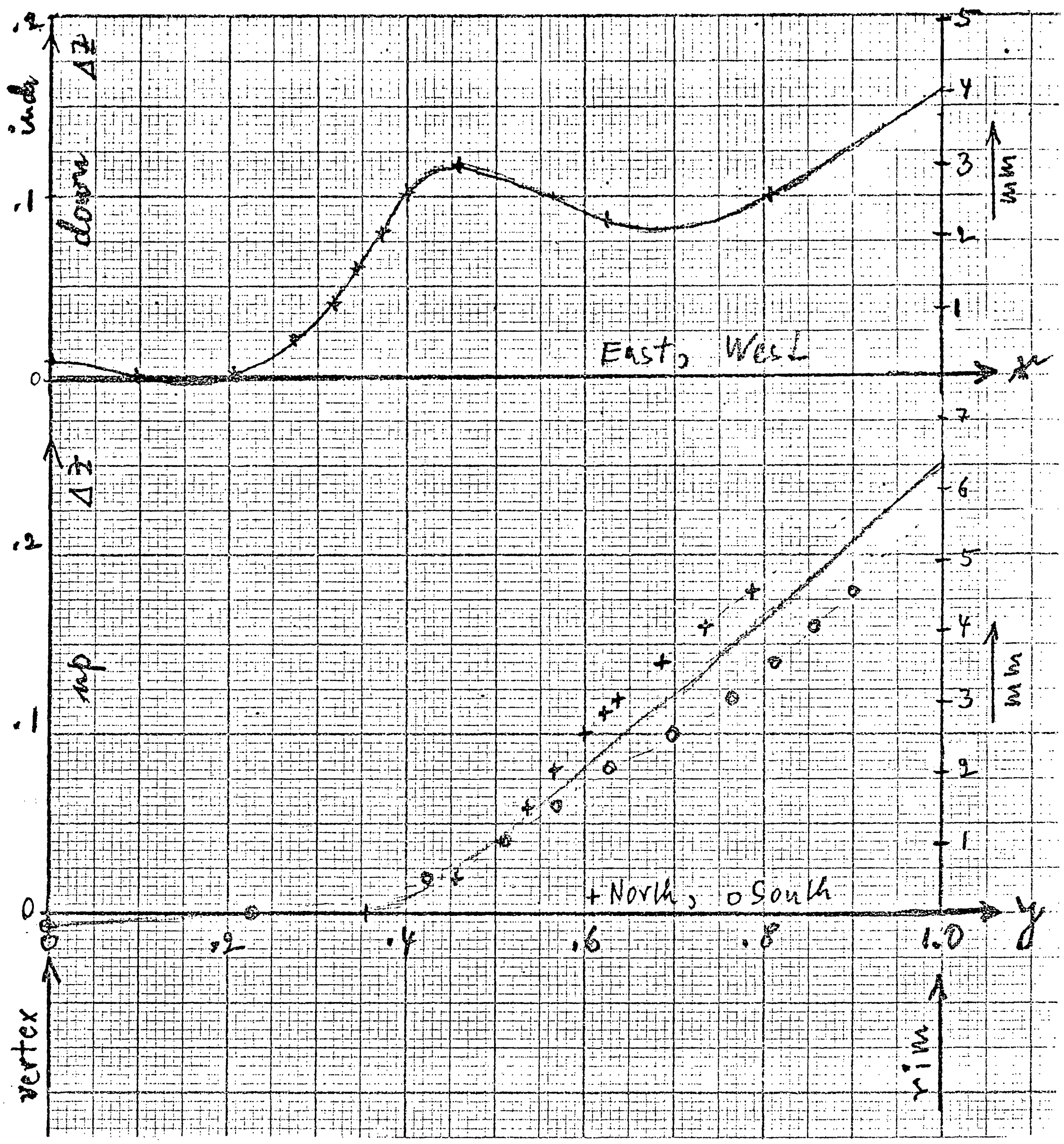
adjusted: zenith

observing: east (equator, 20° elevation)

rms($\Delta z$) = 0.062 inch = 1.57 mm

contours: deviation from best-fit paraboloid

15 db taper

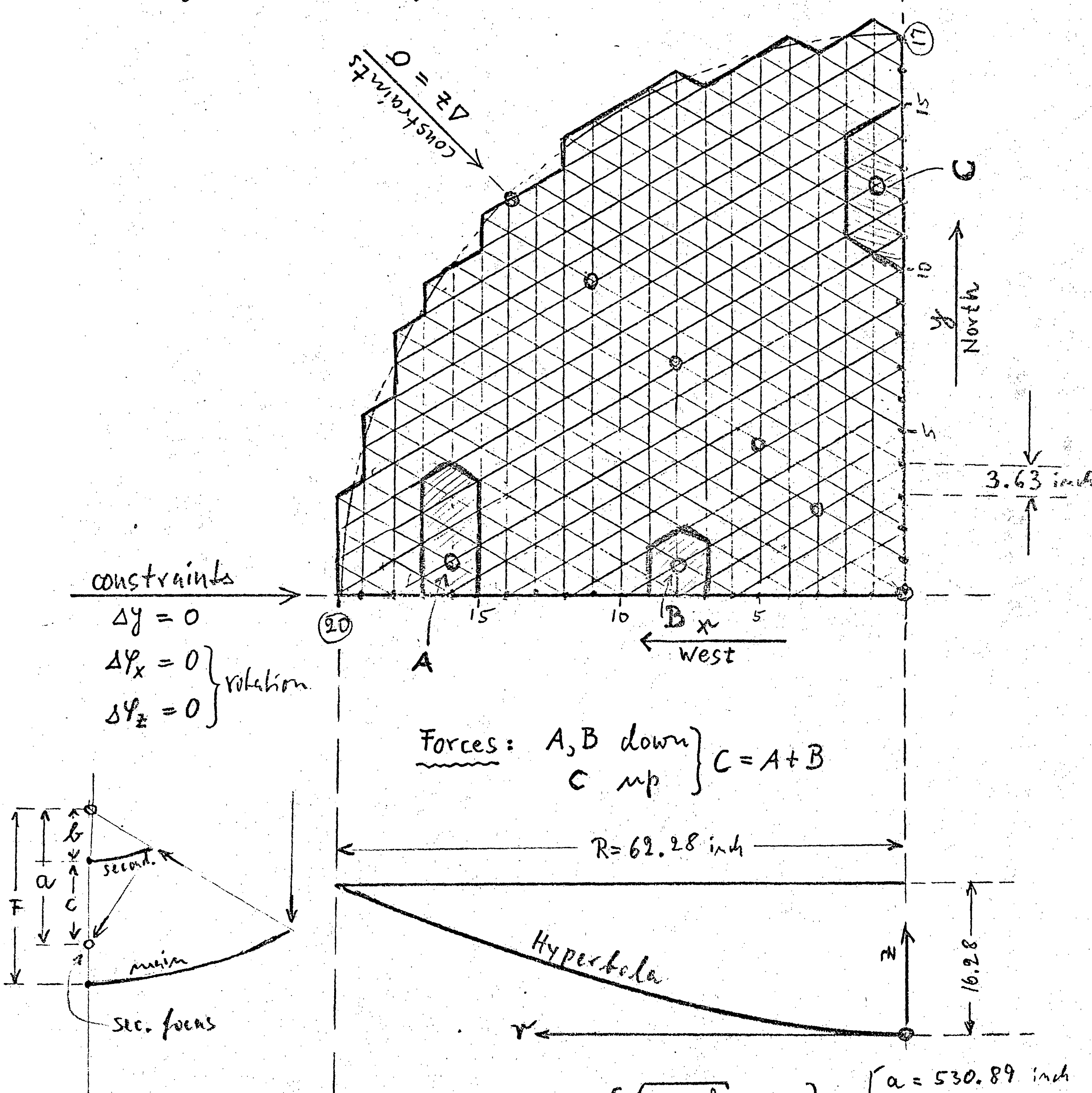



<u>Fig. 3.</u> Deviations Δz along center lines (from Fig. 1).

Adjusted zenith, observing <u>south</u>.

Fig. 4. Computer model, for 140-ft deformable subreflector (frame analysis).

| | | |
|---|---|---|
| 306 joints, total | } | unchanged, |
| 43 joints constrained | | |
| 848 members, total | | |
| 76 thick members | } | to be varied. |
| 3 joints with loads | | |




$$z = \left(c - \tfrac{1}{2}a\right)\left\{\sqrt{1 + \frac{r^2}{bc}} - 1\right\}$$

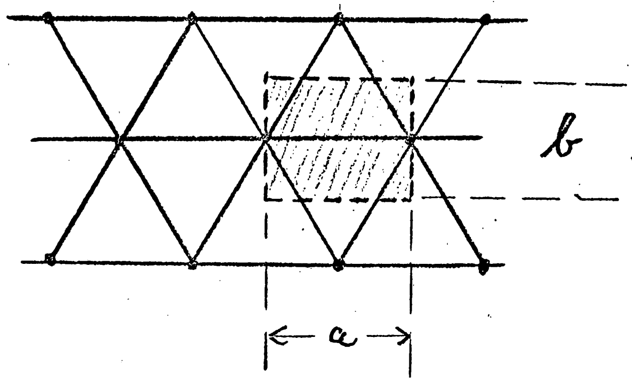
(symmetrical, not tilted.)

a = 530.89 inch
b = 51.26 "
c = 479.63 "

a) Top view, grid model

$a = 3.63$ inch

$b = \frac{\sqrt{3}}{2} a = 3.14$ inch

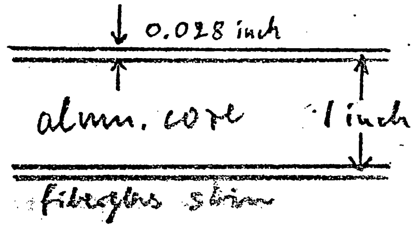



area:

$A = 2\,b\;0.028$

$= 0.176$ inch$^2$

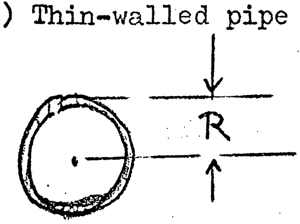
b) Side view, actual shell




radius of gyration:

$r = 0.5$ inch

c) Thin-walled pipe




radius of gyration:

$r = R/\sqrt{2}$

d) Use: pipe, with

$\left.\begin{array}{l} A = 0.176 \text{ inch}^2 \\ R = 0.707 \text{ inch} \end{array}\right\} I = A\,r^2 = 0.044 \text{ inch}^4$

$E = 3 \times 10^6$ psi (elasticity, fiberglas)

Fig. 5. Replacing the shell of the secondary mirror by a grid of pipes. To be used for the computer model.