NATIONAL RADIO ASTRONOMY OBSERVATORY
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ENGINEERING DIVISION INTERNAL REPORT NO. 114

COMMENTS REGARDING THE 30-M RADIO TELESCOPE FOR THE NATIONAL ASTRONOMICAL OBSERVATORY OF IRAQ

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I. Introduction

This report is in answer to a letter from Dr. Hamed Al-Naimy, Director of the Iraqi Astronomy and Space Research Center at Baghdad. I received 14 pages of specifications and 10 drawings for the gear boxes of the azimuth and elevation drives; and 66 pages of a measuring report which showed that the gear boxes were less stiff and had more backlash than specified.

The second item of the letter mentioned that for the (very similar) German 30-m telescope, the Cassegrain subreflector had been changed from the original aluminum design to a carbon fiber honeycomb, which now might also be considered for the Iraqi telescope.

Regarding both items, I was asked to discuss them with our NRAO engineers and to give my opinion.

II. Gear Boxes

The tests were performed on two azimuth gear boxes with a gear ratio of 13,134; and on four elevation gear boxes with a gear ratio of 15,661. The specifications regarding stiffness and backlash were the following, to be measured at the drive shaft with fixed output shaft:

	azimuth	elevation
spring stiffness (N m / rad)	126.44	95.19
backlash (degrees)	90	75

The measuring report shows, briefly summarized, that all six measured values of the stiffness were too low, in the average by 43% (max. 51%). And all six values of the measured backlash were too high, in the average also by 43% (max. 48%).

Dr. Al-Naimy mentioned in his letter that design and specifications were made by MAN, the main contractor; and that the gears were manufactured by a subcontractor, Lohmann & Stolterfoht. After the test, MAN people gave the following explanations:

A. Technically it is not possible to reach a better result;

B. MAN used hard specifications to make the subcontractor try his best;

C. The results are still better than those of the German 30-m telescope;

D. The errors caused by these results will be compensated by the servo system;

E. MAN will be responsible for the telescope's final over-all performance.

After some discussions and considerations, I would like to offer the following comments:

1. Regarding the past, items A and B mean that the specifications should have been called "design goals", not "specifications". And the subcontractor should have realized item A before starting to manufacture.

2. In general, if specifications are not met by a large margin, there are several alternative actions to be taken:

    (a) Accept the things as they are, without further action;

    (b) Accept them, but ask for a credit (cost reduction or refund);

    (c) Reject them, and ask for re-manufacture as specified.

3. Regarding the present case, action (a) seems to be too lenient, considering the very large margin (43% average difference, 51% maximum). Action (c) seems to be not necessary, regarding items C and D, and it would also cause a long delay. Thus, I would recommend to take <u>action (b)</u>. Negotiating an acceptable credit may also be considered for both sides as a good face-saving action.

4. Regarding the future, it would now be the right time to re-negotiate with MAN the exact meaning of item E. Make a clear distinction between design goals and specifications; let MAN re-calculate the final pointing error and dynamical modes for the measured values of the gears; decide about future possible actions, in case the final over-all performance does not meet the specifications.

III. Subreflector

In order to find out how crucial the thermal deformations are, and how strongly they may influence any decisions about material and geometry, I will present a rough estimate. First, Fig. 1 shows the cross section of a sub-reflector which may consist of a skin with ribs behind of height H, or a backup structure of this height, or maybe just a thick honeycomb of height H. We replace it by a simplified model of a cantilevering two-member truss, and we assume $H \ll L$. We call α = coefficient of linear thermal expansion. For this model, we obtain for the thermal rim deformation Δz_o:

$$\left.\begin{aligned} \Delta L &= L\,\alpha\,(1/2)\,\Delta T \\ \Delta z_o/\Delta L &= L/(H/2) \end{aligned}\right\} \Delta z_o = \alpha\,\Delta T\,L^2/H. \tag{1}$$

Since we want the rms (Δz) instead of the maximum rim deformation (factor 1/2, say), and since the subreflector is supported not at its center but at some distance (factor 2/3, say), we may use roughly

$$\sigma = \mathrm{rms}(\Delta z) = (1/3)\,\alpha\,\Delta T\,L^2/H. \tag{2}$$

Second, we must specify the maximum permitted σ, which may be chosen comparable to the specified manufacturing accuracy of the subreflector. From Dr. Al-Naimy's letter I have the values

$$\sigma = \left.\begin{array}{ll} 25\ \mu\text{m} & \text{demanded} \\ 35 & \text{warranted} \end{array}\right\} \text{Iraqi design}$$
$$\left.\begin{array}{ll} 50 & \text{specified} \\ 25 & \text{design goal} \\ 14 & \text{achieved} \end{array}\right\} \text{German telescope} \qquad (3)$$

Thus, for the present estimate I will specify

$$\sigma \leq 30\ \mu\text{m}. \qquad (4)$$

Third, the diameter of the subreflector is 200 cm, thus L = 100 cm. And for the first try, I will choose a medium-large value of H = 10 cm, meaning either a fairly thick honeycomb, or fairly thin ribs (behind a skin or a thinner honeycomb). We use $\alpha = 6 \times 10^{-6}/°\text{C}$ for carbon fiber, and $\alpha = 24 \times 10^{-6}/°\text{C}$ for aluminum. At NRAO, we have done many thermal measurements on different structures and plates, and we found, for white protective paint (titanium oxide):

$$\Delta T = \begin{cases} 5°\text{C in full sunshine,} \\ 1°\text{C at night.} \end{cases} \qquad (5)$$

From equations (2) and (5) we then obtain:

	Night, $\Delta T = 1°C$	Sun, $\Delta T = 5°C$	
aluminum	80 μm	400 μm	$\Big\} = \sigma$ (6)
carbon fiber	20 μm	100 μm	

Fourth, comparing results (6) with specification (4), we conclude that thermal deformations are indeed crucial and will influence the design. In particular, we conclude, using $\sigma \sim 1/H$ from (2)

1. Carbon fiber, at night: needs only about H = 7 cm thickness.
2. Carbon fiber, in sunshine: } need thick ribs or structure, about H = 30 cm.
   Aluminum, at night: }
3. Aluminum, in sunshine: not feasible with slender structure.

Although the carbon fiber would double the price, our estimate yields a strong preference for carbon fiber over aluminum, in addition to its much lower weight (55 kg versus 350 kg).

Another question was raised in the letter: about the long-term stability of carbon fiber honeycomb if exposed to rain and winds. Unfortunately, we have no such experience at NRAO. But I would like to mention our deformable subreflector at the 140-ft (correcting the gravitational deformations of the primary). This has a diameter of 3.17 m; it is a honeycomb of aluminum core, sandwiched between two fiberglass skins. This shell is 2.5 cm thick, and has four radial ribs behind, of fiber glass. The combined height at center is H = 15 cm. It is carefully sealed against humidity, all around the rim and at the support points. In addition to the weather, it suffers other demanding stresses: it is rocked forth and back (beam switching) at 2-5 Hz, it is mechanically deformed up to ± 9 mm as a function of elevation, and it is removed and mounted back about 6 times a year. The weight is 135 kg, the surface accuracy about σ = 300 μm, and the price would be about $25,000 in

1983. We installed it in 1976, and from there to 1983 it has not shown any deterioration as far as we can say.

Although there is no long-term experience with carbon fiber yet, someone has to lead the way. And since its cost is not a major item in the total budget, I would recommend to try carbon fiber. (Unless some other argument comes up which has not been considered so far.) Also with our deformable and rocking subreflector, there was no experience beforehand. It was considered an experiment. The manufacturer dared only to guarantee a lifetime of 4,000 hours, but meanwhile it has been up and rocking for over 20,000 hours.

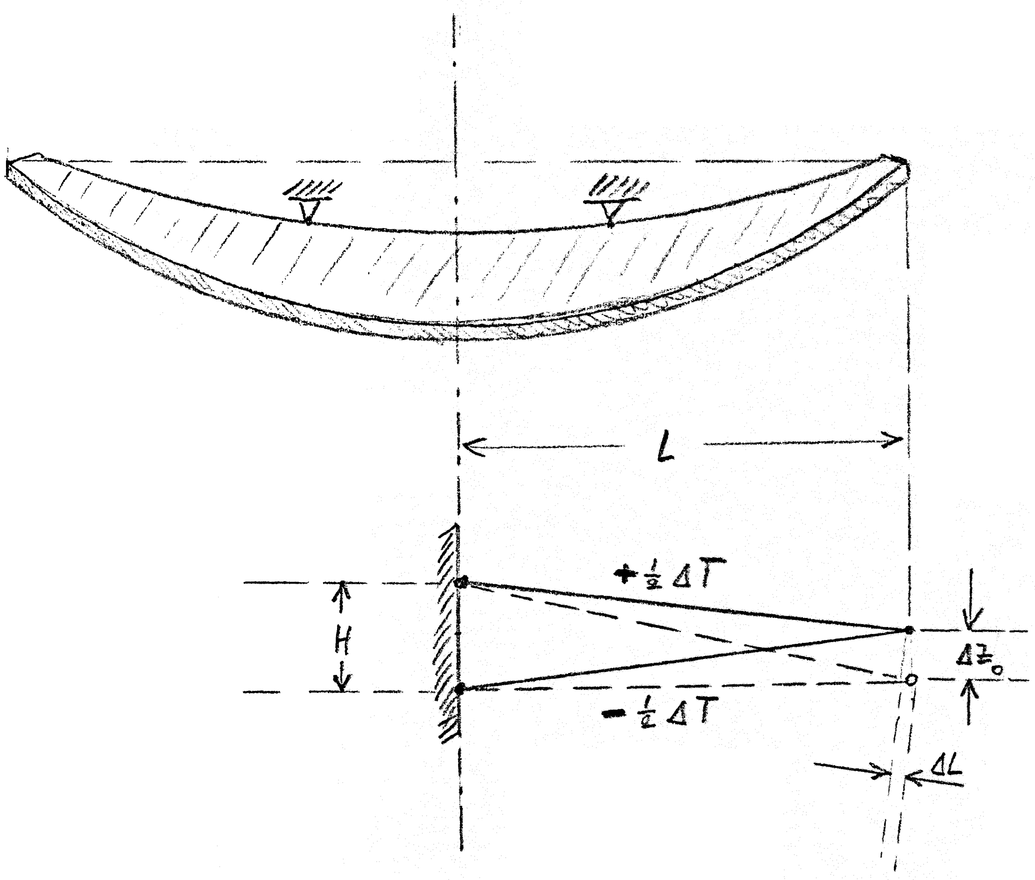

Fig. 1. Cross section of a subreflector, and simplified model to estimate its thermal deformations.