Interoffice

National Radio Astronomy Observatory

Charlottesville, Virginia

October 1, 1975

To: Addressee

From: W. Y. Wong

25 METER - MILLIMETER WAVE TELESCOPE

MEMO # 33

Subject: Surface Plates of 25-m Telescope

J. Marymor and I visited Mechanical Specialties Co., Rohr Industries, Inc., Aeronutronic, and Tinsley Lab, Inc. to inquire about their abilities to achieve 40 μm rms in manufacturing tolerance in plate manufacturing and the costs of making test plates. I myself visited Professor R. E. Leighton of Caltech. He had recently finished one 10-m dish with his innovative method that achieved a total surface accuracy of 50 μm rms.

Mechanical Specialties Co.

Address: 5700 West 96th Street
Los Angeles, California 90009
Tel: 213-776-0150
Date: September 22, 1975
Attendant: William Leslie
Richard Getz
Arthur Dawson (Sales Manager)

They are manufacturing oriented. They have marginal design capacity but not capable of handling analytical work. Their commercial tolerance usually reach 64 μm (2.5 mil) rms with 3 machine passes. They believe they might reach 38 μm (1.5 mil) with 4 machine passes. Machinery cost is estimated $25/hr. Each pass requires 25 hours, cost $625. The tolerance, cost relations are given as follows:

Tolerance (μm)	Cost Factor
64	1.0
50	2.5
38	3.5
25	8.0

For tolerance of 30 μm,, it might take 150-175 hours including the time for stress releases. They will take a fixed price for machining one casting with a guaranteed tolerance at three machine passes, and would give us a price for each additional pass necessary to reach 38 μm and then they will give us a firm fixed price for additional quantities. Wooden pattern for sand cast would cost $1500 to $2000 each. Casting would cost $800 to $1000 each for small quantities.

Rohr Industries, Inc.

Address: Rose Canyon Facilities
4605 Morena Boulevard
San Diego, California 92117
Tel: 714-272-4410
Date: September 23, 1975
Attendant: John H. Hamel - Chief Antenna Engineer
Chuck Sutherland - Chief Production Manager
Chuck W. Buchanan - Manager, Quality Control
Anson Coulson - Management
Jerry A. Cooper - Chief, Manufacturing Engineering
H. E. Kastan

They have large numbers of N/C machines capable of machining large size components. Most machines are not in temperature-controlled environment. But it is possible to establish temperature control environment without much difficulty. Measurement capacity is excellent; the 'Portage Dimension Qualifier' provides 2.5 μm resolution. They have the engineering design and analysis capacity. Casting is not done in-house.

Their latest design efforts included the 7-m off-set telescope for Bell Lab. They made a 76" x 25" test plate for this telescope, with an error of 46 μm rms after 'best-fitting'. They believe 40 μm (1.6 mil) rms without best-fitting is rather difficult. Their manufacturing manager estimates four instead of their usual three machine passes might achieve this tolerance. Their chief manufacturing engineer believes 40 μm (1.6 mil) is within their machine capability. Their manufacturing tolerance is 100 μm (4 mil) at three passes without any environmental control. They have copies of our draft specifications. As a result of their quick review, they indicated that our requirements may be too detailed and therefore limit their method or technique in manufacturing, hence might not be most economical. They will suggest to us revised manufacturing and testing specifications for our review.

In general, we agreed on the A356 aluminum alloy with 125 to 63 ($\times 10^{-6}$ in) surface finish. They are investigating a new superior material from Kaiser Aluminum. Cost of wooden pattern for casting is about $1800. Each blank cast costs $800 to $1000. It will take 20 to 25 hours for each machine pass. They indicated that they will do the design and analysis and casting on a fixed price, according to a very detailed manufacture plan. They will propose a minimum tolerance. Fixed price for measuring, testing and report.

Aeronutronic (Philco-Ford)

Address: WDL, 3939 Fabian Way
Palo Alto, California 94303
Tel: 415-494-7400
Date: September 24, 1975

Attendant: L. E. Becker
D. M. Kelly
Sharad Mehta

They designed and built the 7-M offset cassegrain antenna for Bell Lab in Homedale, New Jersey. The surface panels were cast by Qualco Casting (Acworth, Georgia, 30101), machined by N. C. Metal Working Inc. (6315 Maple Street, St. Louis). These A356 aluminum panels measured 60" by 40" on average. Their design goal is 50 μm (2.0 mil) rms or less. Three measurements show 41, 28 and 20 μm rms. These measurements were confirmed by a Portage measuring machine owned by United Airlines in San Francisco Airport. Surface finished to 125, weighted 6.7#/S.F. The dead weight deformation is estimated 25 μm peak, 6 μm rms. The weight of panels could be reduced by relaxing the dead weight deformation. These panels required only one rough cut and one finished cut. Each machine pass took approximately 50 hours. It was stress released once after the rough cut. They were ambiguous about the unit cost of the plates. Their guess was between $50 to $100 per square foot. The unit cost of the 7-m antenna was about $150/S.F. This is because of a high number of types (17) and a small number of repetitions (27 plates in total). Their estimate for a pattern was about $200 each, and for the blank cast about $1800 each. They would propose to produce surface plates meeting the manufacturing tolerance of 40 μm (1.6 mil) rms with fixed price. The design and analysis would be priced separately.

Tinsley Lab. Inc.

Address: 2448 Sixth Street, Ber
Berkeley, California 94710
Tel: 415-843-6836
Date: September 25, 1975
Attendant: Herb E. Oas

Tinsley is a precision optical shop for lenses and mirrors. They don't have experience in the radio telescope area. All machinery is for circular symetrical lenses.

Their recent experience with a project of producing a 12' x 6' parabolic mirror for a British flight simulation for pilot training is worth noticing. They have made a steel mold of optical tolerance (cost: $25,000, time: 4 months). Using graphite epoxy as surface material, polyurethane as stiffening and fiberglass as covering material in the back, they produced one mirror. The mirror failed to meet the specifications, but the measurement is 2.5 μm rms. Each panel required 10 days to produce.

Professor R. B. Leighton, Caltech, Pasadena.

Date: September 26, 1975

Attendant: R. E. Leighton
Berry Shenton
Richard Hills

The structure of the telescope was analyzed by one segment due to its symetry. The feed support leqs were not included during the study. The structural weight is optimized by trial and success method. The structure is supported on a "rigid" elevation mount. The configuration appears very geometric and the size of tubing is very uniform (only 4 types of tubing were used). The joint design involved one aluminum casting (spider), in which the structural members jointed together. The reduction of stiffness due to the 'spider' was compensated by the length of each member during the analysis. Professor Leighton believes the shape of the spider (like a heat sink) and the steel members enable him to apply thermal control on the structure in order to reduce surface deformation. He developed a program to calculate the shaded area on the surface (but not the shade between members), given the telescope position, time and date. The measurement on the surface panels showed that the thermal gradient is 4^{o}C under bright sun. The time constant of the panel is 30 sec. Based on this data, his calculations showed a 10^{o}C temperature difference on the back up structure with a broad-side illumination, the surface error degrades by the amount of 43 μm in rms. The telescope is not protected by any enclosure. The operational wind speed is 30 mph, survival at 150 mph.

The structure was analyzed only in zenith position. Measurement on the prototype telescope No. 0 showed a degradation of 100 μm rms in horizontal position. This is probably due to the large depth and lack of analysis in that position. He did not confirm, nor dispute, the surface accuracy of 50 μm rms, quoted in "Sky & Telescope". He believes further improvements are possible for the second telescope.

The procedures of surface fabrication are:

1. Cut the commercial honeycomb into a hex-shape.
2. One aluminum plate is glued by epoxy to one side.
3. Two of the panels are glued together for rigidity.
4. Place the panel on the supports (toothpick). Each panel has three supports.
5. Surface is cut by a circular blade called toothed bologna slicer. No problems encountered during this operation, even though the industry people thought it would be a hazardous operation.
6. The cuts were done with the cutter remaining stationary, while the surface and the back-up structure, supported by a large air bearing, rotated.
7. The final cut shaved off 1 mm at every 3" step, so that the ripple is kept within 25 μm.
8. The aluminum sheet is then glued by epoxy onto the top of shaped honeycomb. Suction is applied at the bottom of the panel to keep the sheet tightly pressed against the core.
9. The surface is measured by the Hewlett-Packard interferometer, with contour maps drawn by felt-pen on the surface.

10. Polyethylene sheet is used as pattern for the contour (division is 25 μm). The pattern is glued on the surface.
11. Sodium hydroxide is poured on the surface. The concentration and the submerge time determined the thickness of the etching.
12. Step 11 and 12 are repeated for each contour, starting from the 'hill'down to the 'valley'.

A special device is attached to the back of each panel to pre-strain the panel in order to compensate the elastic rebound of the panel during the cutting.

The weight of surface is 3000 lbs, and costs 10K$. The weight of the back-up structure is also 3000 lbs, and costs 15K$. (He will increase the back-up structure to 6000 lbs for the second structure. This might be due to the large deformation of the first one.)

He estimated it will take six months to produce one identical reflective structure (up to the interface of elevation mount), and cost about 100K$. Elevation mount will cost 180K$, encoder 20K$, bearing 50K$, and complete telescope will cost 350K$.

He does not believe individual cutting of surface panels by his method is good, since the method is capable of doing the surface in one operation. The heavy suspension cone members of the 25-m could be a large problem. He doesn't recommend the epoxy-centrifuge method. These are too many practical problems such as the uniformity, differential curving, etc.

Conclusion:

1. Manufacturing tolerance: The surface plates of the 7-m Bell Lab telescope seem to be a good proof that the tolerance of 40 μm is achievable. Bob Wilson of Bell Lab will provide more information on the surface measurements. Decision on making more plates for our own purpose should depend on Wilson's measurements.
   R. E. Leighton's method of etching could be used to improve the surface accuracy.

2. Cost: No departure from our cost estimate.

3. Material: A new material called Precedent 71 could be superior to the A356 in strength, hardness and machinability.

4. R. E. Leighton's Method: Might not be practical for the 25-m telescope for the large numbers of heavy cone members and its large diameter. It is a strong, viable alternative nevertheless. His existing facilities and low cost production could be very attractive for the replacement of the 11-m reflector in Tucson.

5. Sub-reflector: Tinsley Lab believed that it is within their capabilities to produce any circular symetrical shaped mirror to optical tolerance. Standard Tool & Die Co. (1931 North Broadway, Los Angeles, California, Tel: 213-227-8888, Mr. Guy Williamson) has a template following device, capable of producing sub-reflectors with an error of 50 μm peak to peak. Cost estimate is 12K$.

Addressee: H. Hvatum
J. Findlay
J. Marymor
B. Turner
B. Peery

Oct. 13, 1975

Meeting on 25-m telescope

- Opinion on prospective plate manufacturers after the visit

	mechanical Sp.	Rohr	Philco	Tinsley	Leighton
Design Capacity	4	2	1	4	1
Manufacturing tolerance to 40 μm rms	4	4	3	1	2
Cost	4	3	2	5	1
Experience in plate	5	3	1	4	2

1 - Best 5 - Worst

Conclusion

① Plate design and analysis ~~should~~ approach should be approved by NRAO before casting and machining.

② NRAO should be responsible for most of the testing and measurements.

③ Should study the measurements on 'Bell Tel. Lab. - 7-m' plates.

Next meeting : Nov. 5, 1975