25-Meter Memo 111

November 17, 1978

FOCAL ADJUSTMENTS, WIND-INDUCED POINTING ERRORS, AND OTHER ITEMS

Sebastian von Hoerner

This Memo tries to answer, or at least to discuss, some of the questions raised by John Findlay in his Memo 110 (October 10) about "Things To Do."

Summary

The Sterling mount at the feed leg apex needs two computer-controlled adjustments as functions of the zenith distance θ:

Axial adjustment $\Delta F_a = 4.62 \text{ mm } (1 - \cos\theta)$ $\pm$ 0.21 mm error,

Lateral adjustment $\Delta y_a = 4.14 \text{ mm } \sin\theta$ $\pm$ 0.05 mm error.

Rotational adjustment is not needed.

Strong wind forces on the astrodome give its foundation some small tilt which propagates through the soil to the telescope foundation. Fortunately, the resulting pointing error is negligible up to 100 mph wind.

Pointing errors from ventilation with closed door are barely tolerable. Errors from wind with open door are too large ($\geq$ 1 arcsec) for certain angles of incidence and if the wind is above 20 km/h; these conditions prevail for 13% of all observations. But the present estimates are very uncertain, and we need wind tunnel tests with a model of our dome and telescope. A certain stiffening of some structural members may be needed and seems feasible.

Seven more items are mentioned or briefly discussed; for example, the pointing program, and the effort and money already spent (or wasted).

I. Focal Adjustments Needed (with W. Y. Wong

1. Axial Adjustment

When the telescope is tilted in elevation, the main reflector changes its focal length, and the feed support legs deform, too. The net effect of these two changes must be compensated by an axial movement of the Sterling mount, to be done automatically by the on-line computer as a function of elevation.

This adjustment has already been installed, for example, at the 140-ft (Electronic Division Int. Rep. 160, May 1975). With θ = zenith distance, the automatic adjustment is

$$\Delta F_a = F(\theta) - F(o) = -17.6 \text{ mm } (1 - \cos\theta); \quad \text{for 140-ft.} \tag{1}$$

For the 25-m telescope, Figure 1 shows several structural points. For gravitational loads, looking at zenith, the analysis yields

$$\left.\begin{aligned} \Delta z_1 &= +\ 4.71 \text{ mm} \\ \Delta z_{16} &= +\ 3.96 \text{ mm} \\ \Delta z_{57} &= +\ 3.52 \text{ mm} \end{aligned}\right\} \text{ structural deformations,} \tag{2}$$

$$\Delta F = -\ 3.43 \text{ mm}; \quad \text{change of best-fit paraboloid.} \tag{3}$$

It is interesting to note that our 25-m design sags less at the rim than at the center, giving a shorter focal length at zenith, which is the opposite from most other telescopes. The maximum ΔF_a between zenith and horizon is $\Delta z_1 - \Delta z_{57} - \Delta F = 4.71 - 3.52 + 3.43 = 4.62$ mm. The computer thus must provide the automatic adjustment

$$\Delta F_a = +\ 4.62 \text{ mm } (1 - \cos\theta); \quad \text{for 25-m telescope.} \tag{4}$$

The need for making this adjustment, and its required accuracy, can be found from Ruze's* equation (5) and Figure 1, giving the axial gain loss L (with $G/G_o = 1 - L$) from axial defocussing δF as

$$L = 0.15\ (2\pi\delta F/\lambda)^2\ (4F/D)^{-4} = 0.677\ (\delta F/\lambda)^2. \qquad (5)$$

For $\lambda = 1.2$ mm, and demanding a loss of less than 2%, we find that the error of the axial focal adjustment (4) must be

$$\delta F \leq 0.21 \text{ mm}. \qquad (6)$$

The total available range for F_a, by manual control from the console, must of course be much larger than the 4.62 mm of equation (4), in order to allow for different sizes of feeds, receiver boxes, and Cassegrain mounts. For the 140-ft, this range was made very large in order to ease the exchange of receiver boxes:

$$\text{available range of } \Delta F_a = 36 \text{ inch} = 91.4 \text{ cm}; \quad \text{for 140-ft.} \qquad (7)$$

2. Lateral Adjustment

Fig. 2 shows the telescope looking at horizon. The numerical values from the computer analysis are

$$\left.\begin{aligned} \Delta y_1 &= 3.59 \text{ mm} \\ \Delta y_{16} &= 5.03 \text{ mm} \\ \Delta y_{57} &= 6.59 \text{ mm} \\ \Delta z_{16} &\ \ \ 6.44 \text{ mm} \end{aligned}\right]\ \text{structural displacements} \qquad (8)$$

$$\left.\begin{aligned} \Delta\phi_c &= 4.15 \times 10^{-4} \text{ rad} = 1.43 \text{ arcmin} \\ \Delta y_c &= \Delta y_{57} + c\Delta\phi_c = 6.84 \text{ mm} \end{aligned}\right]\ \left.\begin{matrix} \text{rotation} \\ \text{displacement} \end{matrix}\right\}\ \text{of Cassegrain} \qquad (9)$$

$$\left.\begin{aligned} \Delta y_H &= 6.84 \text{ mm} \\ \Delta\phi_H &= -1.27 \text{ arcmin} = 3.7 \times 10^{-4} \text{ rad} \end{aligned}\right]\ \text{best-fit paraboloid} \qquad (10)$$

* John Ruze: "Small Displacements in Parabolic Reflectors", Feb. 1, 1969 unpublished.

For <u>prime focus</u> observation, we calculate the needed lateral adjustment Δy_a:

$$\begin{aligned} \Delta y_a &= \text{best-fit focus} &&- \text{receiver box displacement} \\ &= \Delta y_H - F\Delta\delta_H &&- \Delta y_{57} \\ &= 6.84 + 3.89 &&- 6.59 \text{ mm} = 4.14 \text{ mm} \end{aligned}$$

with θ = zenith distance, the on-line computer then should provide a lateral adjustment of

$$\Delta y_a = 4.14 \text{ mm} \sin\theta. \qquad (11)$$

Regarding the needed accuracy, we first consider a lateral feed offset of δy (= adjustment error), with a subsequent "peaking-up" of the changed pointing, keeping the source at beam center. For this case, Ruze's equation (10) and Figure 4 yield a gain loss L of

$$L = 0.021\ (2\pi\ \delta y/\lambda)^2\ (4F/D)^{-6} = 0.032\ (\delta y/\lambda)^2. \qquad (12)$$

For λ = 1.2 mm, and demanding again a loss of less than 2%, the error of the lateral adjustment must be

$$\delta y \leq 0.95 \text{ mm}. \qquad (13)$$

Result (13) applies either to repeatable lateral errors (for example, elevation dependent) where the peaking-up can be automatically included in the pointing program, or to the case of a manual peak-up, or a computer-driven peak-up.

Second, in case of random errors without peak-up, we apply Ruze's equation (7) and Figure 2 for axial gain loss from lateral displacement, and obtain instead of (12)

$$L = 1.06\ (2\pi\ \delta y/\lambda)^2\ (4F/D)^{-2} = 14.1\ (\delta y/\lambda)^2. \qquad (14)$$

The demand $L \leq 2\%$ leads now to a much more restrictive requirement for the accuracy:

$$\delta y \leq 0.045 \text{ mm}. \qquad (15)$$

The total available range for Δy_a must again be much larger than given by (11). We must be able to compensate for erection tolerances of the feed legs, and for maladjustments of a subreflector. I do not know how much lateral range one can "easily" obtain with a "reasonable" design, but we should have, say,

$$\text{available range of } \Delta y_a = \text{a few centimeters.} \tag{16}$$

3. Rotational Adjustment

For Cassegrain observations, we assume that the lateral adjustment of (11) has already been performed. In addition, we have the rotation of the Cassegrain mount about the point of the prime focus, of $\Delta\phi_c = 1.43$ arcmin according to (9), shifting the exact secondary focus down by $F\Delta\phi_c = 4.36$ mm below the height of the best-fit primary focus, which itself had moved down by $\Delta y_H = 6.84$ mm. In total, the secondary focus, after lateral adjustment (11), has moved down by an amount $\Delta y_{sf} = \Delta y_H + F\Delta\delta_c = 6.84 + 4.36 = 11.20$ mm. The feed, however, has moved down only by $\Delta y_1 = 3.59$ mm. The resulting offset of the feed from the secondary focus then is

$$\Delta y_{ff} = \Delta y_{sf} - \Delta Y = 11.20 - 3.59 = 7.61 \text{ mm.} \tag{17}$$

We divide (17) by the magnification factor, $M \approx D/d - 1 = 16.9$, and obtain a comparable lateral feed offset at the prime focus, δy, which would give the same amount of gain loss:

$$\delta y = 7.61/16.9 = 0.45 \text{ mm.} \tag{18}$$

The resulting beamshift is repeatable, going with the sine of the zenith angle; thus the peak-up can be part of the pointing program, and equation (12) can be applied to the value (18). The resulting gain loss is negligibly small:

$$L = 0.5\%. \tag{19}$$

In summary, the Sterling mount at the feel-leg joint (prime focus location) needs two computer-controlled adjustments:

$$\begin{array}{llcll} \text{axial adjustment} & \Delta F_a & = & 4.62 \text{ mm } (1 - \cos\theta) & \pm\ 0.21 \text{ mm error,} \\ \text{lateral adjustment} & \Delta y_a & = & 4.14 \text{ mm } \sin\theta & \pm\ 0.05 \text{ mm error.} \end{array} \qquad (20)$$

But we do not need a rotational adjustment.

The available range should be a few centimeter lateral; the axial range will be given by the receiver exchange procedure which has not yet been discussed. Its discussion remains as one of the "Things To Do." Lateral, by the way, means down in horizon position.

II. Wind-Induced Pointing Errors

1. Strong Winds Blowing at Radome (With Lee King)

Findlay raised the question: if a strong wind blows against the closed astrodome, the dome and its foundations will suffer a slight tilt, which will propagate through the soil and will give some smaller but comparable tilt to the telescope foundations. Is the resulting pointing error negligible, or do we have a problem?

We did have a similar problem for the 65-m design: Otto Heine investigated the influence of the moving telescope weight, via foundations and soil, on the foundations of the lazer beacons which were the reference for our optical pointing system. Since the result was not negligible, we decided to install tilt sensors in the beacon foundations. It seems now, however that this result was only caused by a misprint in a textbook (translated from Russian), showing Young's modulus of elasticity, E, for various kinds of soil with unreasonably small values as compared to other sources for E; probably this is a mixup between kg/cm^2 (as printed) and kg/mm^2 (which seems more likely). Otto Heine had used E = 500 kg/cm^2 = 7000 lb/inch^2.

From the University of Hawaii we got these data for two types of possible soil (with ν = Poisson's ratio):

	E lb/inch^2	ν
Lava	805,000	0.166
Cinders	121,000	0.279

(21)

In the following, we will use the low value of cinders, for being on the safe side. And for the wind force on the astrodome, we will use a drag coefficient of $C_d = 0.64$, which gives the lateral force F on the dome as a function of the velocity v as

$$F/\text{lb} = 17.9\ (v/\text{mph})^2. \tag{22}$$

This force acts (in the average) on half the dome's height. The dome and its foundations have about the same radius. For our simplified models to be used, we will say that the foundations are pressed down on one side, and lifted up on the other side, each with the load

$$P = \frac{1}{2} F = 9.0\ \text{lb}\ (v/\text{mph})^2. \tag{23}$$

As to the wind statistics, we have the cumulative distribution for v = 10, 20, 30 mph of Appendix A. We took the all-year average and plotted it in Figure 3 on a probability paper, where a Gaussian distribution would give a straight line. Extrapolating, and picking the 95% level for our application, we find

Wind on Mauna Kea is 95% of all time below v_{95} = 38 mph = 61 km/h. (24)

Inserting this velocity v_{95} into equation (23) then says that the pressing or lifting loads will be 95% of all time below

$$P = 12{,}000\ \text{lb} = 5{,}900\ \text{kg}. \tag{25}$$

Regarding the soil deformation which results from the loads on the dome foundation, the true case (Fig. 4a) could be described as "deformation of semi-infinite body, under sinusoidal pressure applied to annular ring." It seems this case is not treated in the literature, and it is difficult to use any of the treated cases* for a sufficiently realistic model. As a crude first approach, we used Models 1 and 2 of Figure 4, which were supposed to estimate just the order of magnitude to be expected and were felt to underestimate the resulting pointing error. Therefore we then went to the trouble of Model 3 and its replacement of Figure 4d, which is the most realistic we could do and which was felt to overestimate the result. To our surprise, all three models gave very similar results. Using the soft cinders of (21), with $E = 121{,}000\ \mathrm{lb/inch}^2 = 8515\ \mathrm{kg/cm}^2$, Model 3 yields for the telescope foundation

$$\left.\begin{array}{l}\Delta z = 0.0035\ \mathrm{mm}\\ \Delta\phi = 0.060\ \mathrm{arcsec}\end{array}\right\}\quad \text{for}\quad v = 36\ \mathrm{mph} = 61\ \mathrm{km/h}. \tag{26}$$

This means that the pointing error from external wind force on the dome, via soil deformation, is completely negligible even for soft cinders. Even at 100 mph we would get only $\Delta\phi = 0.4$ arcsec for cinders, and 0.06 arcsec for lava.

2. <u>Deformation of Telescope Structure in Uniform Wind</u> (With Woon-Yin Wong)

The effect of a uniform wind on the unshielded telescope was investigated by W. Y. Wong (25-m Memo 48, Aug. 6, 1976). He used JPL wind tunnel data regarding the pressure distribution across a paraboloidal surface, for five pitch angles between wind and surface. Structural analysis then yielded the pointing error for each angle, and its break-down into four detailed contributions. The result was an rms pointing error of 9.4 arcsec for a wind speed

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* Raymond J. Roark: "Formulas for Stress and Strain", 1965, McGraw-Hill; page 322-323.

of 30 km/h = 16.6 mph, or in general:

$$\text{rms}\ \Delta\phi = 9.4\ \text{arcsec}\ \left(\frac{v}{30\ \text{km/h}}\right)^2 \tag{27}$$

First, we could accept this result because the VLA antennas of same size give 14 arcsec instead of our 9.4. Second, however, the detailed results look a bit odd: four detailed contributions for five pitch angles is a total of 20 contributions, only one of which is exceptionally large (18.6 arcsec axial tilt of best-fit paraboloid for 60° pitch), whereas the remaining 19 contributions have an individual rms of only 2.6 arcsec, and would add up to rms $\Delta\phi$ = 4.3 arcsec instead of 9.4. Woon-Yin has agreed to investigate this problem again, in more detail and looking for possible errors.

Third, if this new investigation should confirm the old result (9.4 arcsec, caused mainly by only one contribution), and if equation (27) would yield untolerable pointing errors for realistic velocities inside the dome (see the next two sections), we think that $\Delta\phi$ could be considerably reduced by a moderate stiffening of only a few dish members; to be followed by a new homology optimization. We do not foresee a serious problem, but certainly a lot of work.

Meanwhile, in lieu of an improved analysis or a stiffened structure, the following two sections will use equation (27) unchanged.

3. Pointing Errors from Ventilation with Closed Door (With Buck Peery)

During days the door must be closed for shielding the telescope from direct sunshine. But a fraction of the solar heat radiation (about 10%) may still permeate the door skin, and some smaller amount of heat will also come through the insulated dome walls. Buck Peery has suggested a ventilation system (one of the next Memos), where ambient air is sucked in by strong fans in twenty ducts, in various directions and locations around the lower part of the dome, while several holes on top of the dome let the inside air go out. He found that a sufficiently fast heat exchange may need an average air velocity inside the dome about

$$v_a = 15 \text{ km/h} = 9.3 \text{ mph, average for ventilation.} \tag{28}$$

There will always be some balance between winds in front and in back of the surface, as well as some balance between winds on the left and right halves of it. I think it is conservative to assume that the effective or residual air speed is at least down by a factor of two:

$$v_e = \frac{1}{2} v_a = 7.5 \text{ km/h.} \tag{29}$$

Application of equation (27) then gives an rms pointing error of

$$\Delta\phi = 0.59 \text{ arcsec.} \tag{30}$$

Whether or not this is tolerable should be discussed in connection with the last part of the previous section.

4. Pointing Errors from Wind with Open Door

During nights with moderate winds, the door may be open. Figure 6 shows the open dome with the telescope in the worst position (horizon), which gives an impression about the amount of shielding provided against the wind. The velocity v inside the dome will be smaller than the outside velocity v_o by an unknown factor $q < 1$ which will depend on the incidence angle α

$$v = q(\alpha)\, v_o. \tag{31}$$

I think the worst case will be $\alpha \approx 60°$ and I would guess $q \approx 0.5$ for this case. If we demand, for example, $\Delta\phi \leq 1$ arcsec, then equation (27) and

Figure 3 would yield

$$v_o \leq 19.5 \text{ km/h, which holds for 41\% of all time.} \tag{32}$$

This is an unpleasant result. If we leave it as it is, this would mean we must tell the observers that for certain incidence angles, say 30° - 70° (22% of all directions), and if the outside wind is above 20 km/h (60% of all time), which both occur together in 13% of all cases, then the wind pointing error with open door would exceed 1 arcsec.

First, we should remove the uncertain estimate of equation (27) and the wild guess of $q(60°) \approx 0.5$ by wind tunnel tests, using a good model of our astrodome and telescope. The tests should measure the torques acting on the telescope, in declination and in hour angle, as a function of the wind incidence α and the telescope zenith distance θ. From these torques and the known stiffness of telescope and towers we would obtain the pointing errors.

When scaling down to a small model, one must watch the Reynolds number

$$R_e = v\,\ell/\nu \tag{33}$$

where v = air velocity, ℓ = typical narrow dimension in flow, and ν = kinematic viscosity (= viscosity/density). In our case,

$$\left.\begin{aligned} v &= 10 \text{ km/h} \\ \ell &= 10 \text{ m} \\ \nu &= 0.133 \text{ cm}^2/\text{sec} \end{aligned}\right\} \quad R_e = 2 \times 10^6 \gg R_{crit} \approx 5000. \tag{34}$$

$R_r \gg R_{crit}$ means we have a well-developed turbulence inside the dome, which then must also hold for the model. Scaling down by a factor of 40 to a dome size of 1 meter, for example, and demanding at least $R_e \geq 20{,}000$ for a good turbulence, and assuming $q \approx 0.5$, the air speed in the tunnel must be at least $v \geq 10$ km/h x 40 $(20{,}000/2 \times 10^6)/q$, or $v \geq 8$ km/h which is a very moderate demand.

Second, if the results of these tests are still unpleasant, we must look for the "weak spots" of our structure and stiffen them with minimum change, as discussed in Section II,2.

Any wind-induced pointing errors could also be improved by installing four little gadgets (N, E, S, W) on the surface, measuring the pressure difference Δp between front and back. The readings would be fed to the computer and would give corrections to the pointing program. But I would leave this only as a last resort, sticking to the general philosophy that avoiding errors is better than correcting them.

III. Miscellaneous

1. Telescope Backup Structure

Woon-Yin Wong has started to simplify the intermediate panel structures, and to modify the homology program, such that a uniform treatment of the whole structure becomes possible (Memo 109, Sept. 1978). This is a difficult job, but it should get finished this winter.

2. Design of Joints

Woon-Yin suggests that he will work out a basic design and provide guidelines which are sufficient for some firm to fill in details and (if we want it) to produce one or two prototypes; which I think would be good.

3. Design of Drive and Control Systems

I would suggest that we at NRAO do only the basic work, and have some firm work out the final details.

4. Thermal Effects

These have been treated in some detail by Woon-Yin, Memo 92, May 1977, regarding both of their causes: vertical thermal gradient, and different thermal lag for members of different wall thickness. The surface plates are treated in Memo 86, April 1977. A good summary is also contained in Memo 101, Nov. 1977. I would consider this as sufficient. Or are there any problems left?

Later on, after having received the new carbo-fiber surface plates, and after having decided on the material for the dome door, we should repeat the measurements of Memo 86 about thermal conditions inside a ventilated tent.

5. Pointing Program

For comparison: the improved pointing program of the 140-ft (Eng. Int. Reports 101 and 106, 1976) works as follows. It receives five inputs:

Declination, Hour Angle;

Air temperature, dew-point temperature, atmospheric pressure.

The on-line program uses 11 empirical pointing parameters, an improved refraction equation, and equation (1) for the focal adjustment. It then yields three outputs:

Δ Dec, Δ HA (pointing corrections);

ΔF (axial focal adjustment).

The pointing program for an alt-azimuth mount is similar but less complicated (fewer parameters), except maybe for the azimuth rail calibration mentioned on page III, 10 of our proposal. In addition, we need one more output because of our higher precision demands: Δy_a of equation (11) for the lateral focal adjustment.

As already mentioned in Section II,4 we could have pointing corrections according to real-time measurements of pressure differences above and below the surface; we also could have corrections depending on measured temperature differences in the structure. I would suggest keeping these things in mind as possibilities, but to plan and mention them only if and when needed (improving existing telescopes is easier than getting new ones funded).

Regarding the necessary on-line computer, we need not worry about the pointing program, only about the demand for on-line data reduction which is much more involved. If the latter can be done sufficiently, the former will be no problem.

6. Black-Box Pointing Reference

The ideal pointing system would use a black box mounted right at the telescope center close to the vertex, containing a gyro-stabilized platform, or a north-seeking gyro plus an inclinometer. This avoids the major part of all pointing errors, from wind, temperature, azimuth rails, and gravity. John Findlay investigated this fascinating possibility about nine years ago, at the beginning of our 65-m project. But at this time, all available things were either not accurate enough, or could not work in fast motion (or were classified).

Would it make sense to try again?

7. Effort Already Spent (or Wasted)

At our October meeting it was suggested that we add up all effort spent up to now on the 25-m project (including the preceding 65-m), in terms of both time and money. The result should then be presented to NSF. All this effort and money would be a complete waste if the project does not get funded.

As a starter, I attach (Appendix B) a note I had sent on November 8, 1978.

8. Wind-Cloud Correlation?

At most places, higher winds occur mostly together with clouds which prevent millimeter observation anyway, thus making the wind-induced pointing errors irrelevant. How is this on Mauna Kea?

To answer this question, we need at least a year of data about wind and clouds, preferably at night because only then the door will be open. Mark Gordon will inquire about available data.

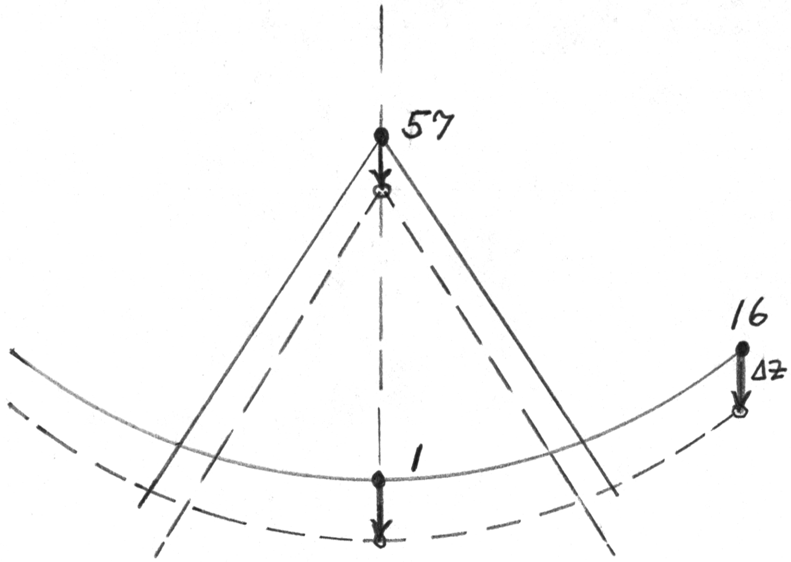


Fig. 1. Telescope looking at zenith.
Three structural points, with their numbers and deformations.

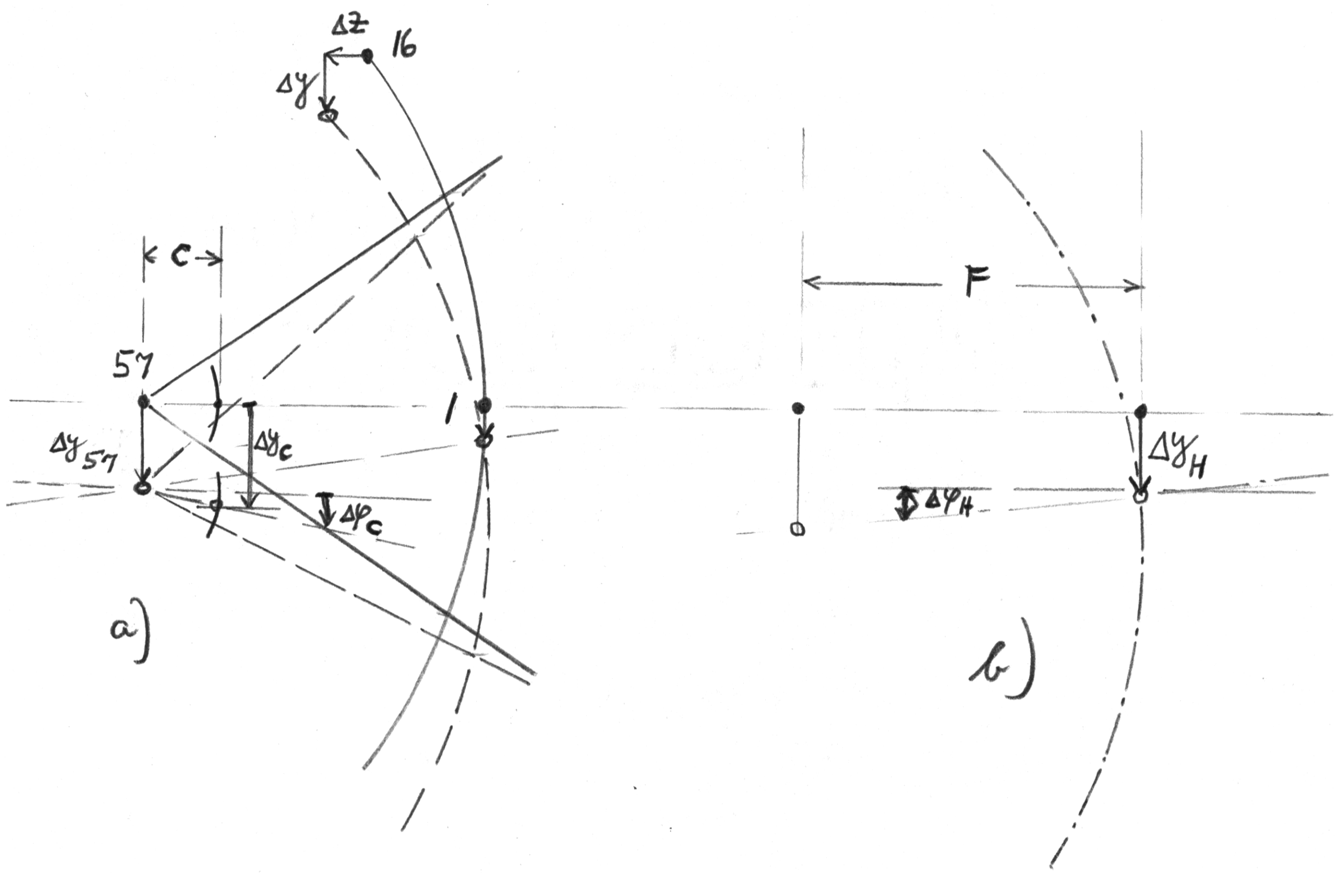


Fig. 2. Telescope looking at horizon.
a) Structural deformations;
b) Best-fit paraboloid.

F = 10.5 m
c = 0.6 m

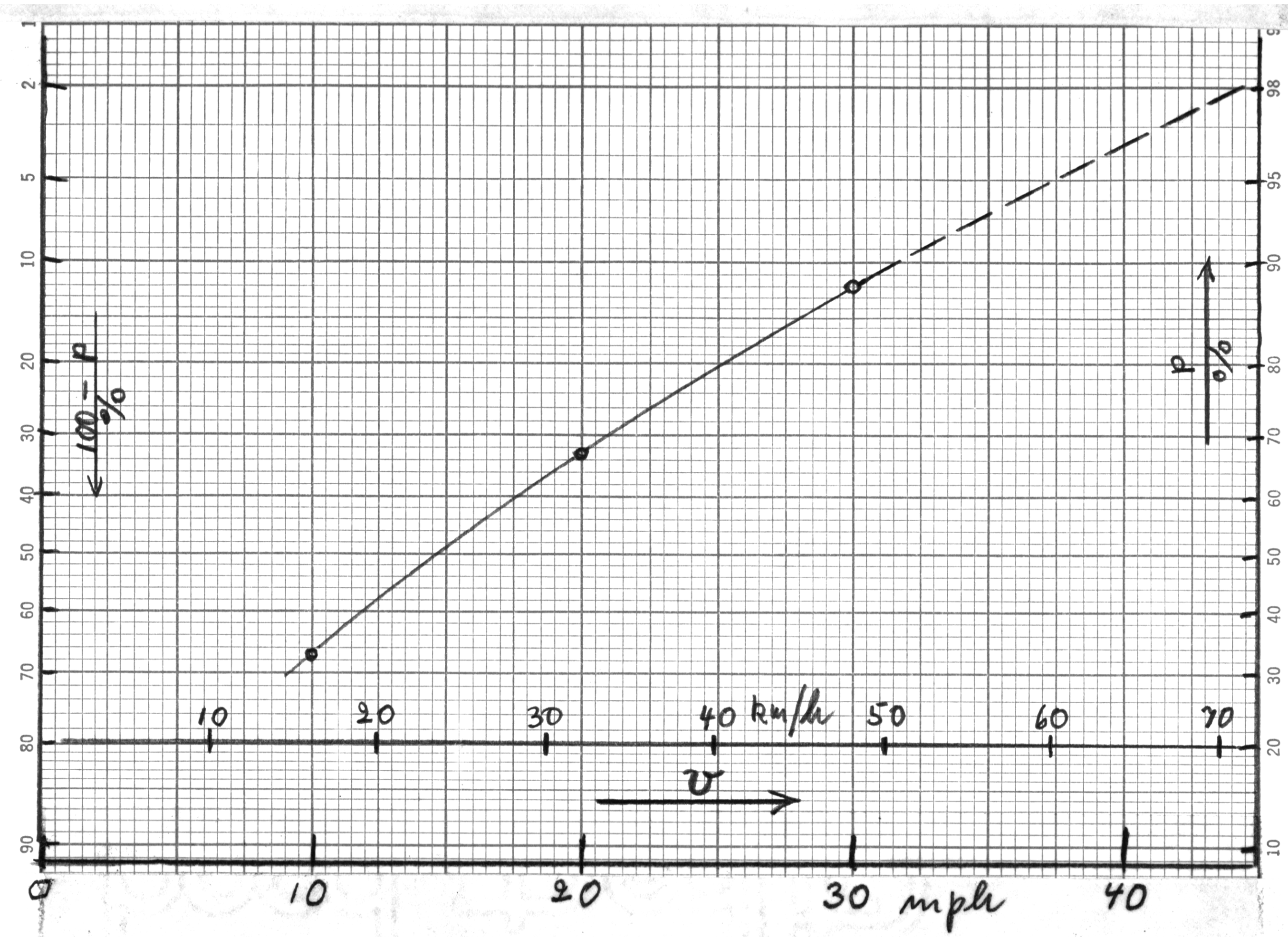
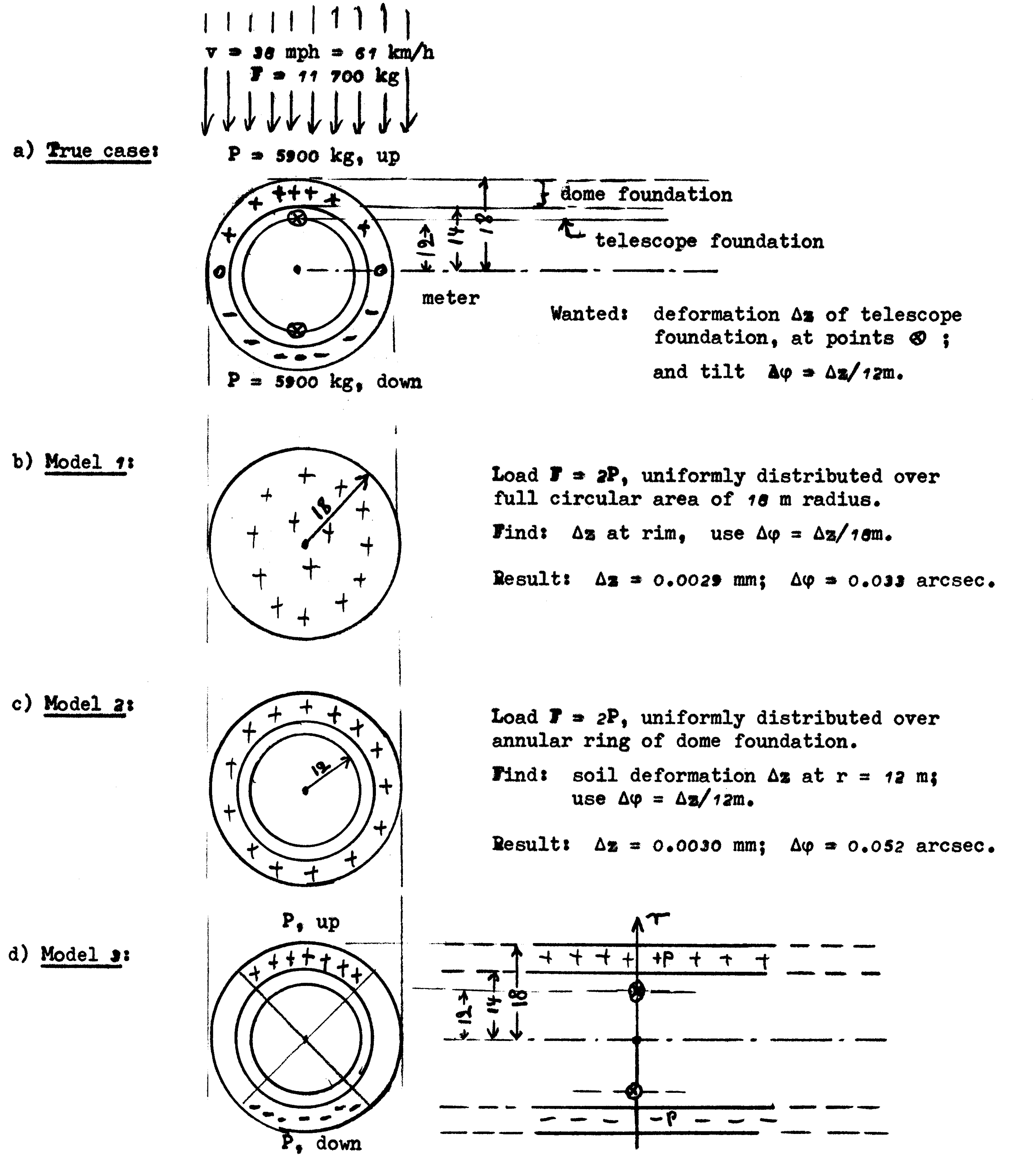


Fig. 3. Cumulative distribution of wind velocity on Mauna Kea, all-year average. Plotted on this probability paper, a Gaussian distribution would give a straight line.

p = percentage of time when wind speed is below v.

o = three measured values, Appendix A.



Two loads P, up and down, uniformly distributed over area $A = (1/4)\pi(18^2 - 14^2)$
$A = 100.5\ \mathrm{m}^2$;
gives pressure $p = P/A$.

Replacement Model:

Two infinitely long strips with uniform pressure $p = P/A$ of opposite sign.

Find: soil deformation $\Delta z(r)$, see Fig.5.

Result: $\Delta z(12) = 0.0035$ mm; $\Delta\varphi = 0.060$ arcsec.

Fig. 4. Various models for estimating the pointing error $\Delta\varphi$, resulting from strong wind force on astrodome.

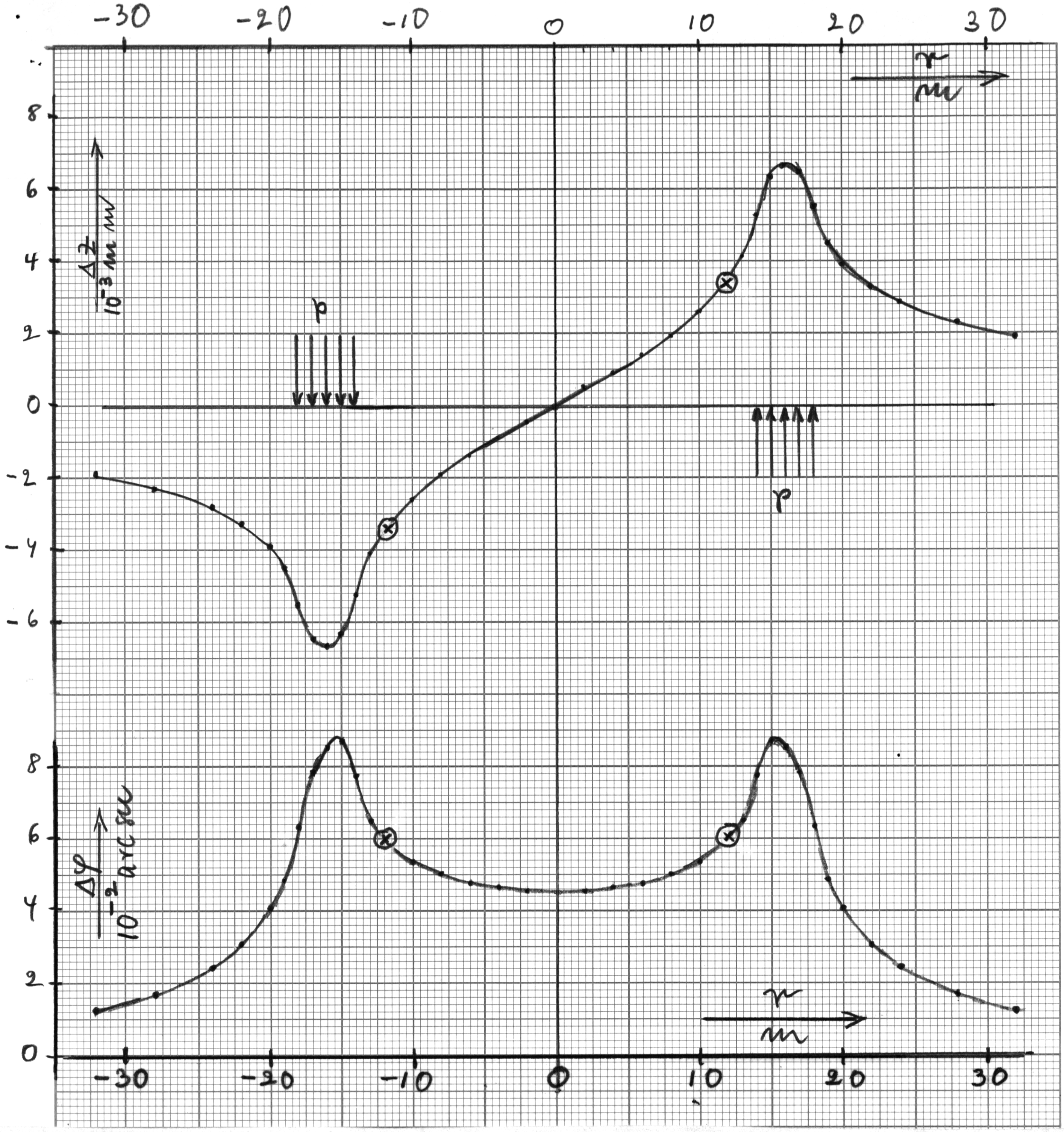


Fig. 5. Soil deformation Δz as function of distance r from center, for the replacement model of Figure 4d.

$\Delta\varphi = \Delta z/r$ = angular tilt with fixed center,

p = uniform pressure under dome foundation,

⊗ = values at location of telescope track foundation.

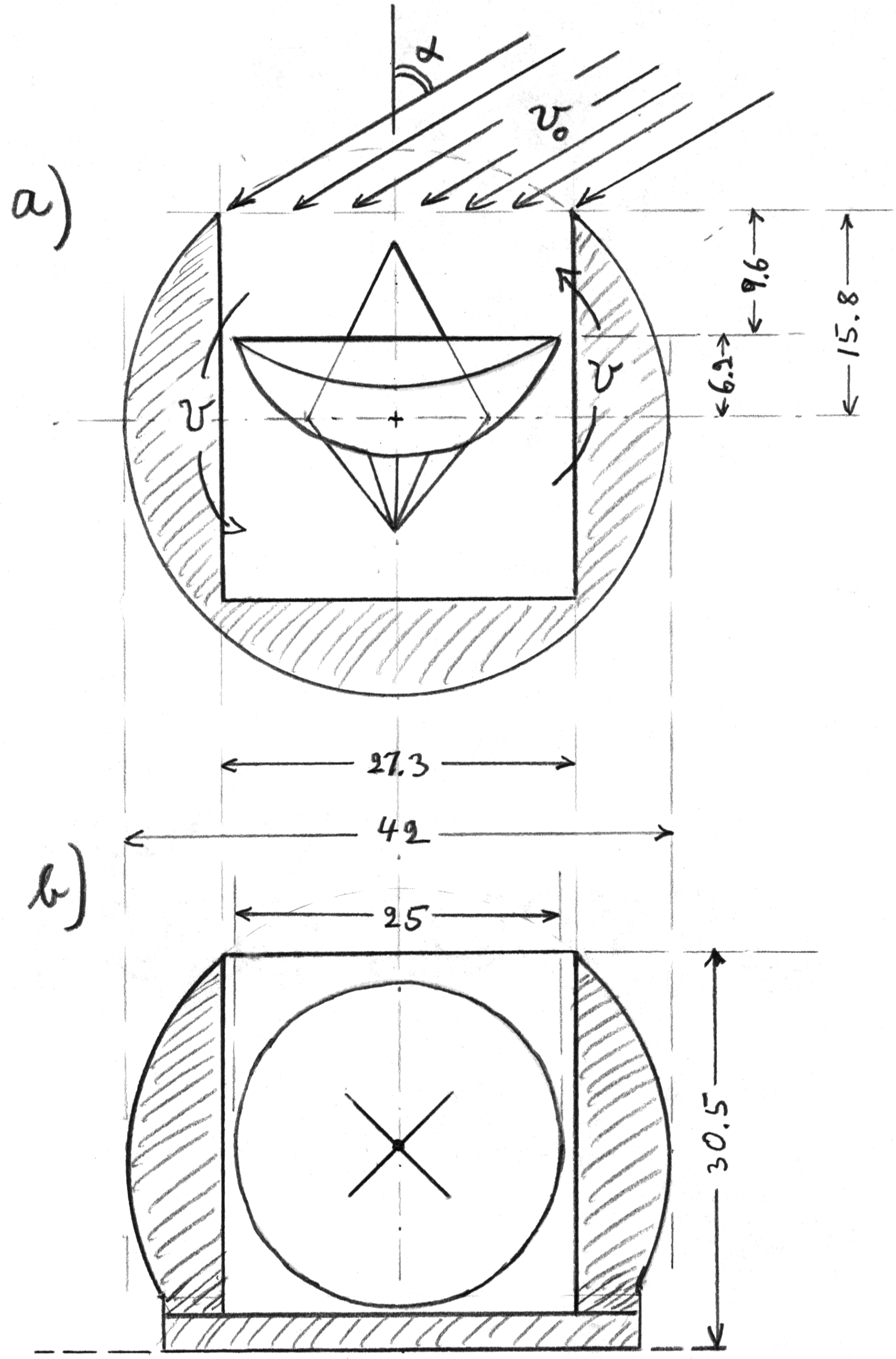


Fig. 6. Open door with wind, telescope pointing at horizon.

a) Top view; } dimensions in meter
b) Front view.

APPENDIX A

FIGURE 14

MAUNA KEA OBSERVATORY SITE

PERCENTAGE OF TIME WHEN WIND SPEED WAS BELOW:

Month	30 mph	20 mph	10 mph
Nov. '65	68	36	5
Dec. '65	86	69	34
Jan. '66	90	70	50
Feb. '66	95	79	50
Mar. '66	96	64	41
Apr. '66	68	50	32
May '66	79	59	31
June '66	97	72	27
July '66	92	72	30
Aug. '66	98	78	38
Sept. '66	100	85	23
Oct. '66	88	69	31
Average:	88.0 %	66.9 %	32.7 %

Source: Institute for Astronomy, University of Hawaii, Notes on Mauna Kea, November 20, 1973.

FROM IRTF E.I.S.

Interoffice

APPENDIX B

National Radio Astronomy Observatory

Charlottesville, Virginia

To: J. Findlay, H. Hvatum, M. Gordon

November 8, 1978

From: S. von Hoerner

Subject: Effort Already Spent (or Wasted) on Telescope Design Projects

1. S. von Hoerner:

   1964 - 1978; about 60% of all time. LFST, Homology; 300-ft, 65-m, 25-m.

2. W. Y. Wong:

   1967 - 1978; 90% of time. Homology program, stability, performance, detailed design problems. (Oct. 1969 start of 65-m project.)

3. L. King:

   1970: 3 months, full time; panel design.
   1976: whole year, full time; astrodome.
   1977: 25%, astrodome.
   1978: 25% astrodome; 50% analysis + dynamics.

4. Special Employments:

A. Rahim	1966,	300-ft, built-up members;
C. Yang	1970,	65-m, intermediate panels;
P. Jenson	1968,	6 months, 50% (draftsman);
L. Napier	1968,	6 months, 100% (programmer).

5. Computer Time:

   1967 - 78: about 1 hour/day = 3600 hours total.

6. GB-Workshop:

   Made and tested 3 surface panels (int. adjustments)

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7. Further Estimates needed from:

   J. Findlay, H. Hvatum, M. Gordon, B. Turner, B. Horne, G. Peery.

8. Outside Jobs

   O. Heine; Simpson, Gumperz + Heger; Surface plates.