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Report 39

Wind deformations of the Backup Structure

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Summary

Wind forces acting on the telescope backup structure will produce deformations of the surface resulting in a pointing error and a surface error contribution to the error budgets.

Computer stiffness analysis of the telescope backup structure, for a variety of pressure distributions, are used to determine these contributions using experimental data for similar antenna structures from wind tunnel measurements, and measurements of wind pressure fluctuations carried out at Green Bank.

For velocities up to 18 mph, the total wind induced rms pointing error is 3.2 arcseconds, and the rms surface deformation is 0.0029 inch. The preceding quantities are averages over all possible orientations of the telescope with respect to the wind.

Basic measurements

Wind gusts

Wind pressure fluctuations have been analyzed in detail by S. von Hoerner in the following references:

a) Statistics of wind velocities at Green Bank
Report # 16   December 8, 1966

b) Wind and temperature deformations of the 300-ft homologous telescope
Report # 23   March 1, 1969

c) Wind data and gust coefficients
Memorandum April 26, 1971

Aerodynamic pressures

Wind tunnel test data for antennas are available from a number of sources. Results have been summarized in the following references:

a) Large steerable antennas- Climatological and aerodynamic considerations. Edward Cohen, Editor.
Annals of the New York Academy of Sciences, 116, 1, 1964.

b) Structures technology for large radio and radar telescope systems. J.W. Mar, H. Liebowitz, Editors.
MIT Press, 1969.

c) Mechanical engineering in radar and communications. C.J. Richards, Editor.
Van Nostrand, 1969.

Structural analysis

A number of pressure distributions have been analyzed. In each case, one quadrant of the reflector structure is used, with boundary conditions appropriate to the symmetry properties of the loading. The reflector surface is divided into 20 areas, one for each of the 20 surface joints where the panels are held in the quadrant, and the force due to the wind pressure acting on the area is concentrated at the joint.

The joint displacements are then computed and a program determines the best fitting paraboloid and computes:

a) rms surface error

b) defocusing losses expressed as an equivalent rms surface error

c) the total equivalent surface error resulting from a) and b)

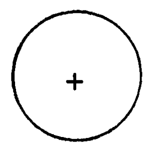
d) the angular pointing error

These results do not include effects due to the Cassegrain mirror. They are considered separately in the detailed design of the prime focus support legs and the secondary mirror mount.

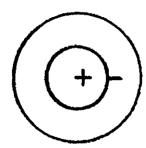
Tabulation of structural results

The following basic cases have been computed:

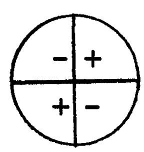
1) Uniform



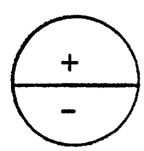
2) Central gust



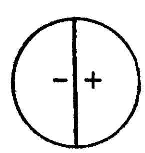
3) Quadrant gust



4) Semicircular gust



a) X axis



b) Y axis

In each case, the + and - signs refer to the unit dynamic pressure (equal to the kinetic energy per unit volume) due to an 18 mph wind and given by:

$$p=0.00255\ V^2 \tag{1}$$

where p is expressed in lb/ft^2 and V in mph.

The following table lists the results with surface errors expressed in thousandths of an inch and pointing errors in arcseconds.

Table I

Type	Surface	Defocusing	Pointing
1	2.01	0.83	0
2	1.66	4.46	0
3	13.82	0.34	0
4a	3.99	0.78	8.33
4b	2.43	0.90	10.00

Weight factors for gusts

A total equivalent surface rms value may be computed from the surface and defocusing errors of table I and a weight factor which represents the amplitude of a given gust mode in the analysis of the random pressure fluctuations. Values are taken from von Hoerner's memorandum of April 26- 1971 and are:

Table II

Type	Weight
2	.121
3	.128
4	.190

More complex modes give small contributions.

Averaging procedure for wind direction

Since the aerodynamic pressures depend on the angle of incidence of the wind with respect to the antenna, surface and pointing errors will also depend on wind direction.

To give a representative figure for these random errors, a weighting criterion has to be adopted. We will assume the telescope will be used randomly over the entire celestial hemisphere. Then, defining α as the angle of attack of the wind relative to the plane of the rim of the antenna, it is immediate that the weighting factor for the surface and pointing errors, averaged over all angles of attack, is

$$w(\alpha) = \cos(\alpha)/2 \tag{2}$$

Aerodynamic pressure data

We have adopted for the final computations Cohen and Vellozzi's data reproduced in Fig. 1.

Since we are interested in pressure gradients (which produce important pointing errors), it is convenient to compute for each of the 13 angles of attack a mean pressure, a mean pressure gradient, and a rms value of the deviation of the pressure from the linear gradient, as follows:

Table III

Angle of attack	Mean pressure	Mean gradient	RMS
-90	-1.3	0.	0.30
-75	-1.1	0.4	0.20
-60	-0.9	0.9	0.15
-45	-0.7	0.95	0.10
-30	-0.6	0.95	0.10
-15	-0.5	1.20	0.10
0	-0.2	1.10	0.25
15	0.4	1,55	0.40

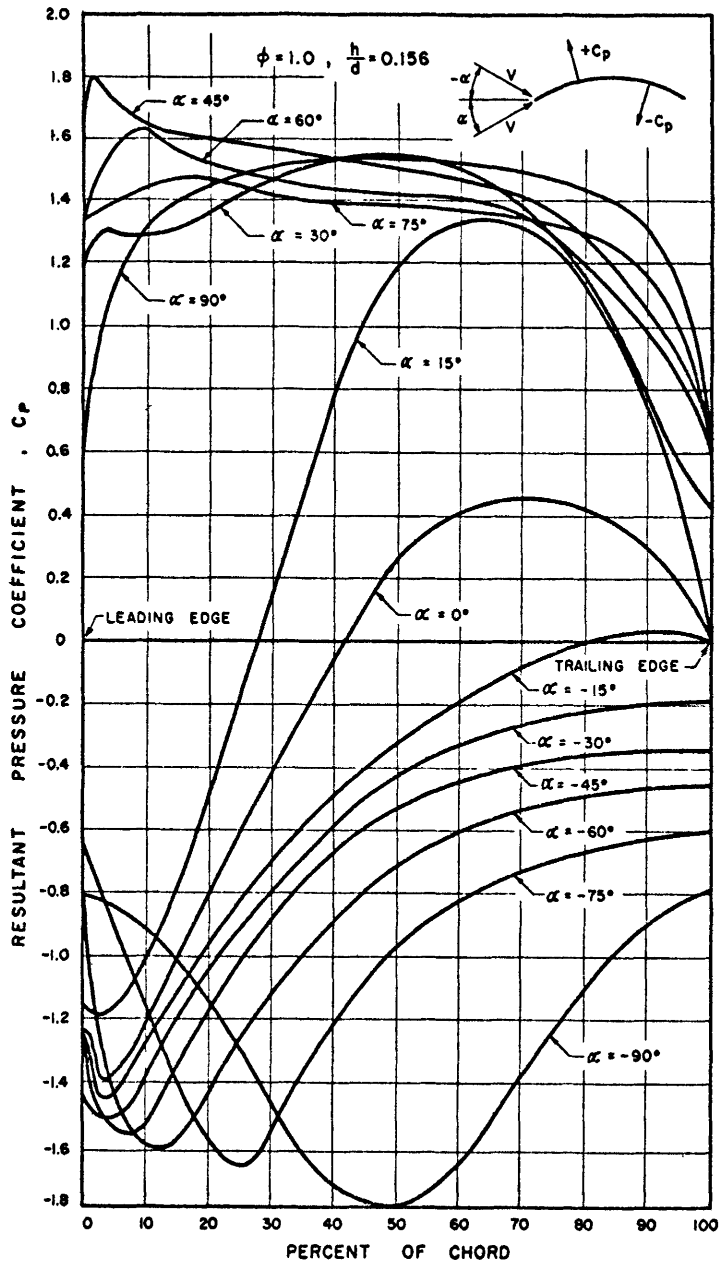


FIGURE 25. Chordwise pressure profiles.

Fig. 1 Reproduced from Cohen and Vellozzi, Annals of the New York Academy of Sciences, 116, 161, 1964.

30	1.0	-0.1	0.20
45	1.3	-0.7	0.20
60	1.2	-0.8	0.20
75	1.1	-0.3	0.10
90	00.8	0.	0.30

The pressure gradient is also shown in the graph of Fig. 2. Results are expressed in units of dynamic pressure. The angle of attack is positive for incidence from the front.

Weighted averages

From table III, with the weight factors given by Eq,(2), we obtain the following averages, representative of a random orientation:

Table V

Mean pressure	0.77
Mean gradient	0.99
Mean RMS	0.21

Surface errors due to gusts

Combining the surface and defocusing errors of table I with the appropriate weight factors for gusts we obtain:

Table VI

Type	Error (10^{-3} inch)
2	0.58
3	1.77
4	0.65
total rss	1.97

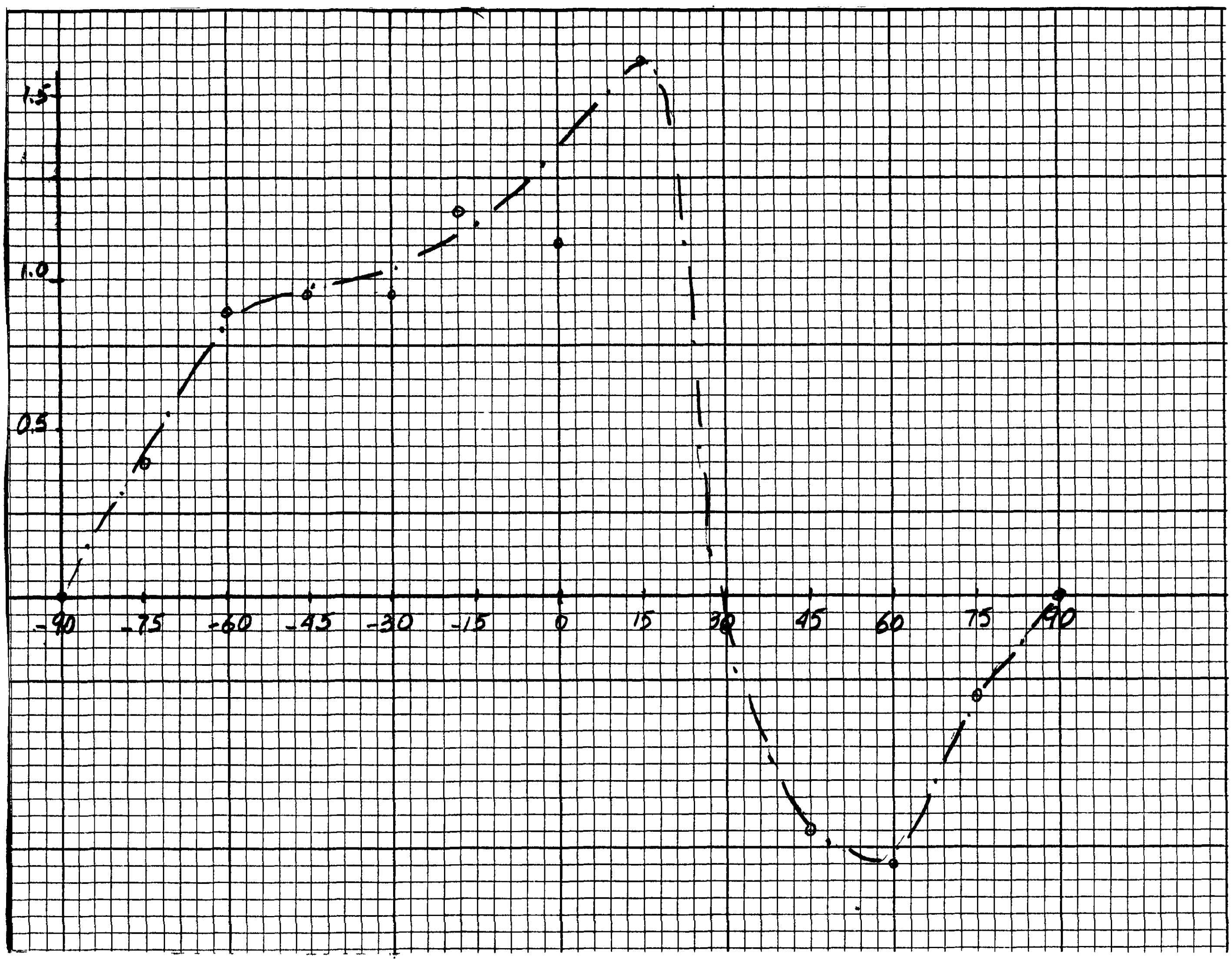


Figure 2. Average linear pressure gradient, expressed in units of dynamic pressure, as a function of the angle of attack.

Cases 4a and 4b have been combined into an rms of 3.41 (surface plus defocusing) for gusts of random orientation.

Surface errors due to aerodynamic pressures

Using results listed in tables I and V :

Table VII

Uniform pressure rms	1.67
Pressure fluctuation	1.23
total rss	2.07

Total surface errors due to wind

Table VIII

Aerodynamic pressure	2.07
Gusts	1.97
total rss	2.86

Pointing error

Averaging from table I for cases 4a and 4b, we obtain an rms pointing error of 9.2 seconds of arc. Combining this result with the weighting factors for gusts from table II and the average pressure gradient from table V we obtain:

	arcsec.
Gust pointing error rms	1.75
Aerodynamic pointing error	2.69
total rss	3.21