NATIONAL RADIO ASTRONOMY OBSERVATORY
Green Bank, West Virginia

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MEMO TO: 65-m Design Group

FROM: S. von Hoerner

WIND DATA AND GUST COEFFICIENTS

This memo is my contribution to Report 39 on "Wind Deformations", to be finished by Victor using his computer analyses. Part I summarizes our wind data and tells where they come from; Part II gives a more rigorous derivation of gust coefficients for the major gust types.

I. Basic Measurements

1. Survival

Originally from Report 16, but adding one more year of data mentioned in Report 25. The demand "one chance in 200 years" gives, with the two best-fitting curves extrapolated, 79 and 75 mph. With some safety margin we then adopted

$$v_{surv} = 85 \text{ mph.} \qquad (1)$$

2. Azimuth Drive

The strongest wind for driving the telescope (with dish in horizon-position) was discussed in Report 25 and adopted with 50 mph. If I remember right, this was later reduced and given to Otto as

$$v_{drive} = 45 \text{ mph.} \qquad (2)$$

3. Short-Wavelength Observation

In discussions with several observers, it was agreed to use the third quartile; meaning that 1/4 of all time is lost due to wind, on shortest wave-length. Report 16 gave 16.6 mph; in Report 25 we included one more year of data and obtained

$$v_{obs} = 18 \text{ mph.} \qquad (3)$$

4. Time-Resolution for Gusts

Report 23, Fig. 1, explains the definition of $P(\tau)$ as the rms gust coefficient for adjacent averages of duration τ regarding the pressure. Measurements were taken with a hot-wire anemometer, with a (measured) time-constant of 0.5 sec. Below this, we use a Kolmogorof law, $P \sim \tau^{1/3}$, for extrapolation. Fig. 2 of Report 23 gives the resulting $P(\tau)$ to be used; but Table 1 contains some errors and should not be used.

5. Other Sites

All data (1), (2), (3) and $P(\tau)$ are valid for Green Bank, 150 ft. above ground. The values for v include already gust factors (measured was always the highest reading per hour). In a desert site, the average winds will be higher but the gust factors lower (less shielding, less turbulence). Thus, I think the net result will be about the same, especially now at 110 ft. above ground.

If wind measurements at a possible site are to be used later on, this also needs a measurement of $P(\tau)$ at this site (or a Fourier analysis, if available).

II. Gust Coefficients

1. Problem

Unfortunately, the original hot-wire data cannot be found and are probably thrown away. Available is only $P(\tau)$ from Report 23, Fig. 2.

This $P(\tau)$ may be called the rms difference of line-averages. What we actually need for the telescope is the rms difference of area-averages. This can be obtained from the rms differences of points, to be defined as

$$P_o(\tau) = \frac{\text{rms}\{p(t+\tau) - p(t)\}}{\bar{p}} \qquad (4)$$

but not from the line-averages. It thus is necessary, first, to restore the original $P_o(\tau)$ from the available $P(\tau)$; second, $P_o(\tau)$ then is used for the area-averages, P_a, of various gust types.

What we finally want is a gust coefficient, q, with which the computer output is to be multiplied. Since in the computer analyses we always used +18 mph on half the telescope, and -18 mph on the other half, we have

$$q = \frac{1}{2} P_a. \tag{5}$$

In a memo of Sept. 19, 1970, I have derived coefficients q for three gust types. Since I did not restore $P_o(\tau)$ and used a rough approximation only, I tried to be well on the safe side. Actually, so much so, that a more rigorous derivation now is necessary.

2. Restoring $P_o(\tau)$

From the definitions of $P(\tau)$ and $P_o(\tau)$ it follows that

$$P_o^2(\tau) = P^2(\tau) + 2\left\{\frac{1}{2} P(\tau/2)\right\}^2 + 2\left\{\frac{1}{2} P(\tau/4)\right\}^2 + \ldots$$

or

$$P_o(\tau) = \left\{ P^2(\tau) + \frac{1}{2} \sum_{k=1}^{\infty} P^2(\tau/2^k) \right\}^{1/2} \tag{6}$$

The resulting $P_o(\tau)$ is shown on the enclosed Fig. 1.

As a check, I have used $P_o(\tau)$ for recalculating $P(\tau)$ for three values of $\tau = 0.8$, 2 and 8 sec which covers the total range used; the agreement is between 0.9 and 1.7%. This recalculation was done by dividing each interval τ into 8 parts of duration $\tau/8$ to be considered as points, and adding up all possible combinations (details on request).

3. Coefficients q

We get the rms area differences, P_a, by replacing the round dish by a more convenient shape (for gust types 1 and 2) and then by dividing the total area into N equal pieces to be considered as points. We now regard all $\frac{1}{2}N(N-1)$ possible connections from one piece to the other, we note their length ℓ and whether their ends are in regions of opposite or same pressure sign. Grouping all connections in I groups of length ℓ_i, we call n_o the number with opposite sign and n_s with same sign, and we call in each group:

$$n_i = n_o - n_s. \tag{7}$$

It then can be shown that

$$q = \frac{1}{2} P_a = \frac{1}{N} \left(\sum_{i=1}^{I} n_i P_i^2 \right)^{1/2}. \tag{8}$$

The rms area difference is defined as

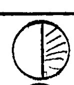
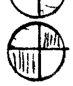
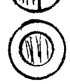
$$P_a = \frac{\text{rms}(\overline{p}_+ - \overline{p}_-)}{\overline{p}} \tag{9}$$

where the telescope surface is divided into two parts, with positive and negative pressure fluctuation, and $\overline{p}_+$ is the average pressure in the first half and $\overline{p}_-$ in the second half, and $\overline{p}$ is the pressure belonging to the average wind velocity. The factor 1/2 of (8) is explained in (5).

4. Application

Fig. 2 shows the three major gust types investigated, and their representation by N single pieces. Table 1 gives the resulting gust coefficients q. In principle, N should be infinite for exact results; if N is small, q will be high (conservative). Table 1 gives two examples of N; the lower one only for comparison, the higher one to be used. All final q values are lower than those of the memo of September 1970, and the more so the longer the telescope half is: type 1 is lower by 23%, type 2 by 16%, and type 3 by 50%. Since N = 16 or 12 is not infinite, these q values are still on the safe side.

Table 1. Gust Coefficients q.

Gust type		For comparison N	q	To be used N	q
1		4	.256	16	.190
2		4	.212	16	.128
3		6	.154	12	.121

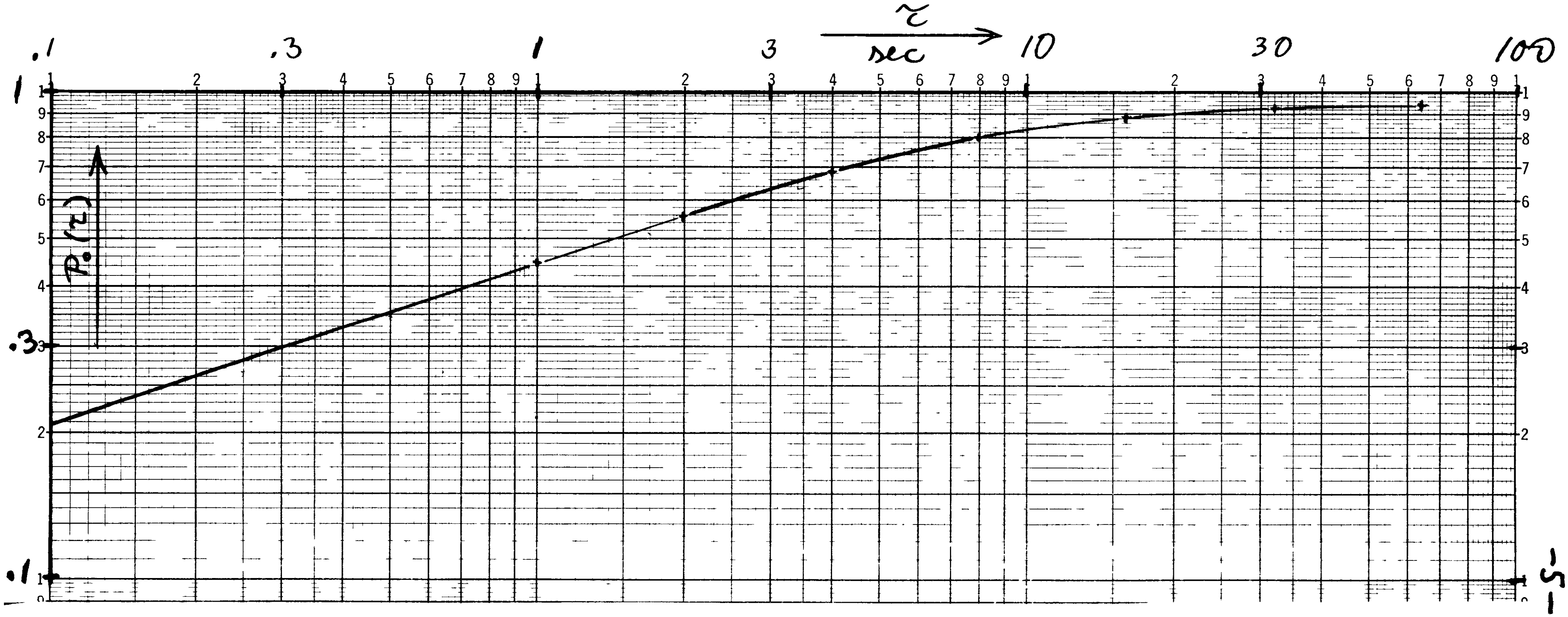
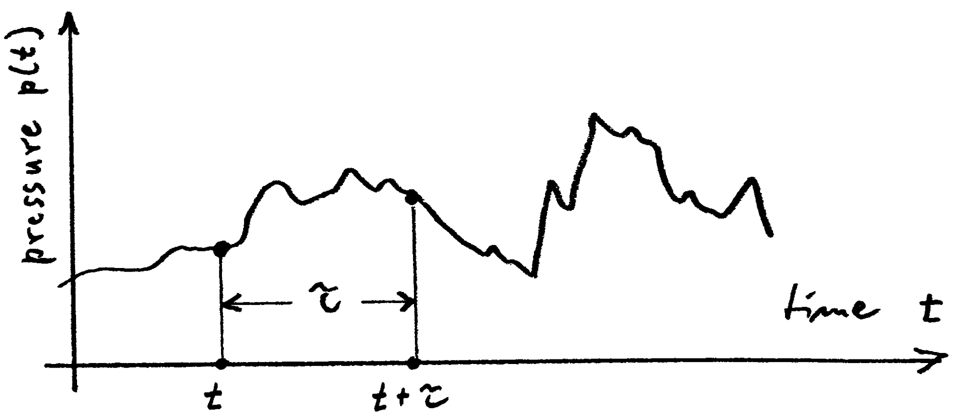
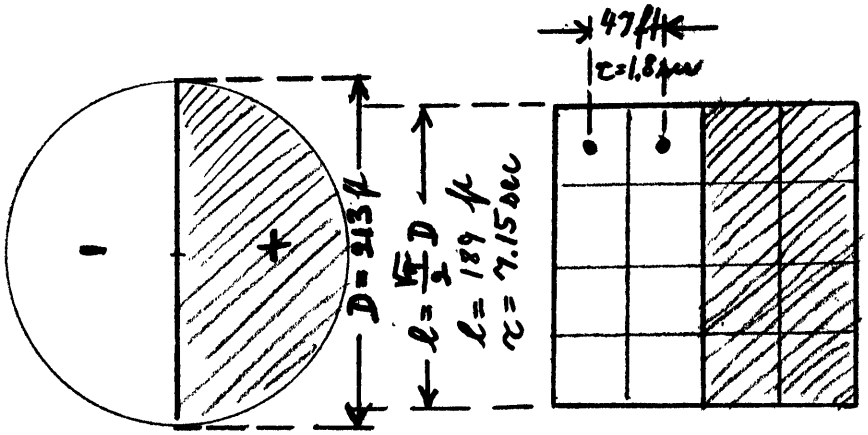


Fig. 1. The rms pressure difference at two points.

$$P_o(\tau) = \frac{\text{rms}\{p(t+\tau) - p(t)\}}{\bar{p}}$$



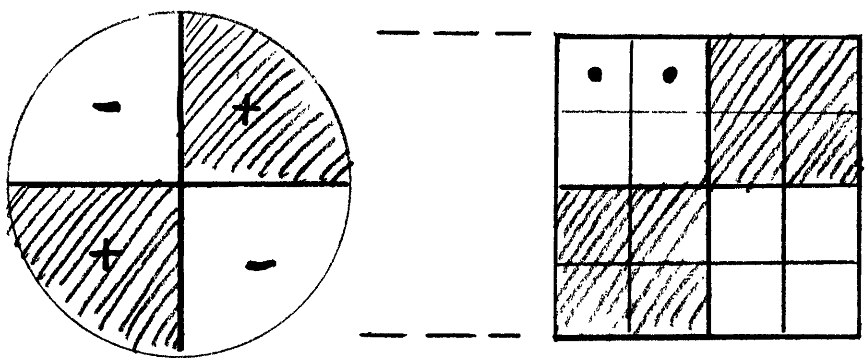
Type 1 ; Antisymmetric gust:



Square of same area,

N = 16.

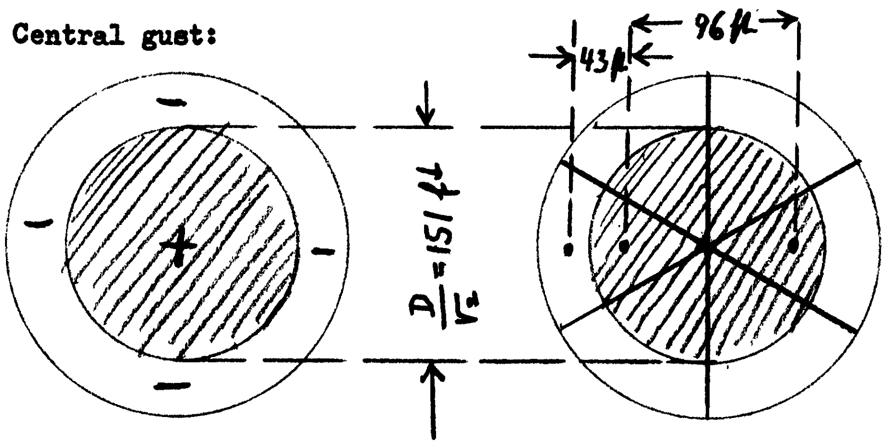
Type 2; Astigmatic gust:



Square of same area,

N = 16.

Type 3; Central gust:



Radial sections,

N = 12.

Fig. 2. Three major gust types and their representation.

N = number of equal pieces (regarded as points);

$\tau = l/v$; $v = 18$ mph.