

WIND GUST SPEED: AVERAGING TIME RELATIONSHIP

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ABSTRACT

An analysis of gust data for Sale, Victoria, together with data for other localities leads to a formulation of the ratio, $R(t : 2)$, of the t -sec gust speed to 2-sec gust speed which for times up to about 100 sec has the form:

$$R(t : 2) = a - b \log_{10} (t + 1.5)$$

The constants appropriate to a height of 10 m depend on type of terrain as follows:

	a	b
Open treeless country	1.085	0.156
Fairly numerous hedges, scattered trees and buildings)	1.095	0.175
Numerous trees and buildings; suburban areas)	1.12	0.220

One factor in the problem of estimating wind forces on structures is the relation between wind gust speeds averaged over different short periods of time. This arises from the fact that buildings differ in their response to wind gusts of different durations: a small structure will be enveloped by a gust of quite short duration whereas a large structure brings into consideration gusts of large scale and therefore longer duration. Estimates of the variation of gust intensity with averaging time ranging from $\frac{1}{2}$ sec to 10 min have been made by Durst (1960), who based his work largely on the Cardington data of Giblett et al. (1932). These relate to wind speeds at a height of 50 ft (15 m) over open level grassland. As little other published evidence on this topic is available, an analysis was made of 31 records of strong winds taken at Sale, Victoria, in a study of the variation of gust speeds with height (Deacon 1955). This direct determination of the variation of maximum wind speed with averaging times ranging from 2 to 60 sec is the subject of the present note.

The Sale wind records were taken with responsive cup anemometers on a radio mast on a slight rise amid gently rolling grazing land with but few trees. The difference between this site and Giblett's Cardington site is small enough for the results for the two places to be directly comparable. The records were taken over periods ranging between 5 and 15 min (average 8 min) and mean wind speeds were evaluated for each 2-sec interval in each case. The records at a height of 40 ft (12 m) were used for the present purpose.

In the analysis of an individual record the maximum 2-sec velocity was first found, then the maximum for two consecutive 2-sec intervals, four consecutive intervals and so on. Average ratios of t -sec gust speed to 2-sec gust speed are given in Table 1 for the runs divided into two nearly equal groups according to whether the mean wind speed for the run was greater or less than 12 m/sec (24 knots). It is apparent that there is no significant difference between the two groups so in the last two columns of the table the means for all runs are given together with the standard deviations.

Table 1 - Average ratios of t-sec gust speed to the 2-sec gust speed, per cent.

Mean wind speed, m/sec		≤ 12	> 12	All runs
Range of mean wind speeds		9.6 to 12.0	12.1 to 18.2	9.6 to 18.2
Number of runs		15	16	31
Mean ratio of t-sec	(t = 4	97.5	97.6	97.5 s.d. 1.6
gust to 2-sec gust,	(t = 8	94.3	94.2	94.2 s.d. 2.4
percent	(t = 16	89.5	89.9	89.7 s.d. 3.4
	(t = 60	81.3	80.1	80.7 s.d. 4.4

The ratios of t-sec gust speed to 2-sec gust speed, $R(t : 2)$, are plotted in Figure 1 together with the estimates incorporated by Durst (1960) in his Table 8. There is good agreement and both sets of values are represented quite well by the relationship

$$R(t : 2) = 1.085 - 0.156 \log_{10} (t + 1.5) \quad \dots (1)$$

which is shown as the full line in Figure 1.

Practical application of equation (1) depends on the form of the basic wind statistics available to the designer. This is not standardised - various countries have different systems - but in Australia the basic statistics are in terms of the extreme gusts recorded by Dines pressure tube anemometers. These are available in the tables and charts presented by Whittingham (1964). The question then arises of the responsiveness of the Dines anemometer: according to Durst (1960) the maximum gust with these instruments, as usually installed, represents the wind speed over an interval of 2 to 3 sec and this conclusion harmonises quite well with the results of Sanuki (1952) who has made the most thorough experimental study hitherto available.

Formula (1) only applies strictly to open country with few trees or other obstructions to increase the turbulence of the wind. It is, however, possible to estimate the changes introduced by more obstructed terrain. These are based in the following on the mean annual maxima of hourly wind speed and of Dines gust speed given by Shellard (1958) for some 30 localities in Great Britain and Northern Ireland. These anemometer sites cover a considerable range of terrain types and Davenport (1960) has allotted them to categories on an 8-point scale using the descriptions and photographs in "The Gazetteer of British Meteorological Stations". Davenport's subdivision is rather too fine for the present purpose and only 3 categories are used here as follows:-

Group	Davenport's categories	Description of terrain
A	1, 2, 3	Open country with few trees and short vegetation or none.
B	4, 5	Level or rolling country with fairly numerous hedges and scattered trees, wind breaks, buildings etc.
C	6, 7	More numerous trees and/or buildings as with the outskirts of large cities.

The data given by Shellard (loc. cit.) give the following mean ratios of Dines gust to hourly wind speed for the standard height of 10 m.

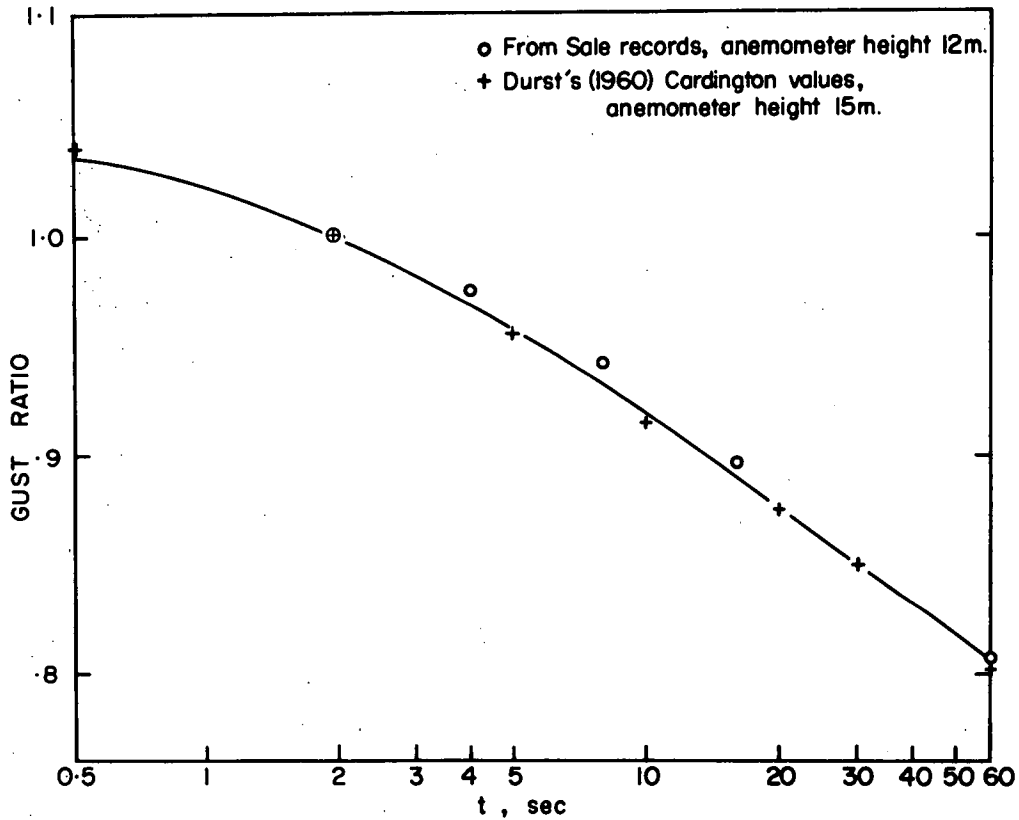


FIG. 1 Maximum wind speeds, averaged over short periods of time t , expressed as a fraction of the 2-sec value.

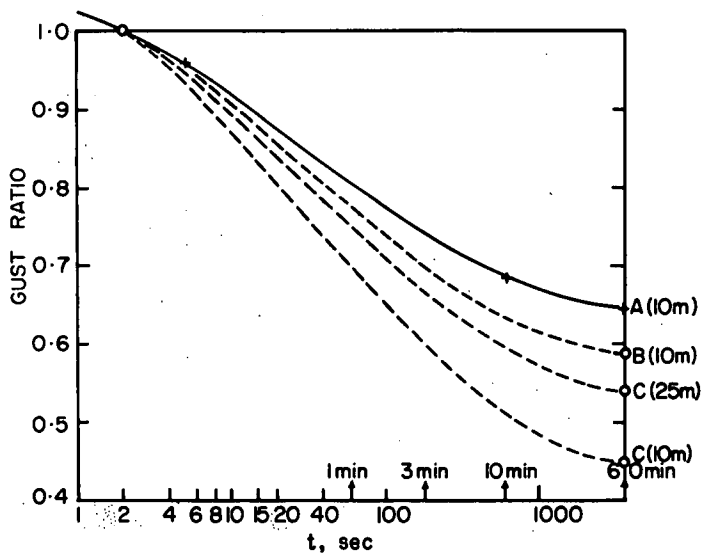


FIG. 2

Maximum wind speeds, averaged over various periods of time t , expressed as a fraction of the 2-sec (or Dines) gust speed.

- A - Open country with few trees; short vegetation or none.
- B - Terrain with fairly numerous hedges and scattered trees, wind breaks, buildings etc.
- C - More numerous trees and/or buildings such as outskirts of large cities.

Group	Number of stations	Gust/hourly speed	Standard error of mean
A	15	1.54	± 0.02
B	9	1.70	± 0.03
C	4	2.11	± 0.08

The stations in Groups A and B have anemometers of heights mainly in the range 10 - 20 m, average 14 m, (the results for the Cardington 41 m anemometer are not included) but for Group C three of the four anemometers were higher (13, 23, 32 and 36 m; average 26 m) as is usual with this type of terrain. Shellard (loc. cit.) corrected in all cases to a standard height of 10 m using a simple power law formula with an index 0.17 for mean speeds and 0.085 for gusts. These corrections should be satisfactory for groups A and B, but for group C indices 0.34 and 0.17 are probably more appropriate and these have been applied in deriving the above ratio of 2.11. The mean ratio for these four stations without any height correction is 1.85 ± 0.07 and this would apply to a height of about 25 m.

Durst's (1960) analysis of Cardington data gave, for the 15 m anemometer there, a Dines gust : hourly speed ratio of 1.55, in excellent agreement with the mean for group A stations given above. This result together with Durst's value for 10 min speeds as well as those in Figure 1, yield the full line in Figure 2. The broken curves in Figure 2 are interpolations between the 2 sec and 60 min values derived above from Shellard's data, the interpolated curves being made similar in form to the full line. Corresponding to these we have the following values of the constants in formula (1) for use over the range $t = 1$ to 100 sec:

Terrain type	Ht. above ground (m)	Const.	Coeff. of log term
A	10	1.085	0.156
B	10	1.095	0.175
C	10	1.12	0.220
C	25	1.10	0.185

Until more data become available this formulation should provide a guide in estimating the reduction factor to be applied to Dines gust values when longer averaging times are appropriate to the problem in hand.

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REFERENCES

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| Davenport, A.G. | 1960 | Proc. Amer. Soc. Civ. Engrs. <u>86</u> , No. ST5, pp. 39-68. |
| Deacon, E.L. | 1955 | Quart. J. R. Met. Soc. <u>81</u> , pp. 562-573. |
| Durst, C.S. | 1960 | Met. Mag., London <u>89</u> , pp. 181-186 |
| Giblett, M.A., <u>et al.</u> | 1932 | Geophys. Mem. No. 54, M.O., London. |
| Sanuki, M. | 1952 | Pap. Met. & Geophys. <u>3</u> , pp. 115-124. Met. Res. Inst., Tokyo. |
| Shellard, H.C. | 1958 | Met. Mag., London <u>87</u> , pp. 257-265. |
| Whittingham, H.E. | 1964 | Extreme wind gusts in Australia. Bull. No. 46, Commonwealth Bureau of Meteorology, Australia. |