Comparison of peak velocities recorded by Dines, cup and sonic anemometers

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1 INTRODUCTION

The Dines anemometer, consisting of a pressure-tube and float system, was the main recording instrument for wind gusts used by the Australian Bureau of Meteorology for more than fifty years, thus leaving a legacy of valuable historical data of importance for structural design, climate change assessment and other applications. Since the switch to cup-anemometer based Automatic Weather systems in the early nineteen nineties, questions have been asked about the response of the Dines system to atmospheric turbulence, whether the daily peak velocities were comparable to those recorded by the cup anemometers, or whether some form of correction is required to the pre-1990 data.

As early as 1931, Sherlock and Stout (reported by Whittingham, [1]) compared the response to atmospheric turbulence of pressure plate, cup-counter and pressure tube anemometers. The latter type was shown to be the least responsive of the three types, although it probably was not a Dines anemometer. Whittingham [1] reviewed previous studies of the Dines response characteristics by the British Meteorological Office and National Physical Laboratory, and concluded that '..the Dines anemometer gives a good indication of the speed of strong gusts of 2-3 seconds duration'. This assessment was based on the response of the Dines system to sinusoidal pressure fluctuations, and appears to be the basis for the nominal '2-3 second gust', used in the Australian and New Zealand Wind Loading Standard [2] to this day.

The present paper gives some early results from a current on-going project, funded by the Department of Climate Change and Energy Efficiency (DCCEE), which aims to resolve uncertainties about the response characteristics of the Dines anemometer and the validity of the historical database of peak gusts. A state-of-the-art 'Pressure Loading Actuator' (PLA) [3] was used to simulate accurately the actual pressure fluctuations resulting from turbulent velocities recorded by a sonic anemometer. The float (directly proportional to peak velocities) of a standard ('low-speed') Dines system was driven by the PLA using a pressure-time history derived from the sonic anemometer time history. The peak deflections of the float, calibrated to be directly proportional to the wind speed, were compared with the peaks recorded by the sonic anemometer, and the peaks arising from a simulated cup-anemometer response obtained by applying a moving average filter to the sonic anemometer time histories.

2 EXPERIMENTAL METHOD AND PROCESSING

The digitized time history from the sonic anemometer, with a mean wind speed of about 10 m/s was re-scaled, in both magnitude and time, to a mean wind speed of

25 m/s, this being more representative of the conditions producing extreme wind gusts of interest in structural design, and noting that the dynamic characteristics of the Dines float system change with wind speed. The digitized wind speed was then converted to a dynamic pressure, also allowing for the aerodynamic shape factor of the Dines head of 1.49, and supplied as a control signal to the PLA. The latter was connected through a manifold to the Dines head and hence via 10 metres of piping, of 30 mm internal diameter, to the Dines float system. The vertical movement of the float was measured with a Linear Variable Differential Transformer (LVDT), and scaled to give the effective wind velocity, as 'seen' by the Dines anemometer. Details of the experimental set-up, calibrations, and some other results, including the response to sinuisodal pressure variations, are described in another contribution to this Workshop [3].

To simulate the response of a cup anemometer, the sonic anemometer time history was filtered with a moving average filter with a time adjusted for the stated distance constant of the Synchrotac 706 3-cup anemometer currently used by the Bureau of Meteorology. The latter value is 13 metres (personal communication – J. Gorman, BoM). At a mean wind speed of 25 m/s, the equivalent time constant is 13/25 = 0.52 seconds.

Sixteen local maxima were selected from the Dines time history and compared with the closest maxima derived from the sonic anemometer and from the simulated cup-anemometer record, as discussed above. Ratios of these peaks were calculated and compared as a comparison of the formerly-used Dines type, and the current cup anemometer, and an indication of the ability of both types to measure the 'true' gust peak as assumed to be recorded by the sonic anemometer system.

4 RESULTS

Figure 1 shows parts of the time histories of the Dines anemometer, and of the simulated cup anemometer traces, with some of the peaks selected for comparison.

The identified peak velocities and the ratios between the Dines peak and the corresponding ones expected to be recorded by the cup anemometer system are shown in Table 1. Also shown are the ratios of the Dines peak to the 'true' peak gust recorded by the sonic anemometer.

5 DISCUSSION AND CONCLUSIONS

Table 1 shows that, for the time history of turbulence used for comparison, the Dines anemometer would have recorded peak gusts about 3% higher than the cup anemometer (Synchrotac 706) predominantly used with Automatic Weather Stations in Australia. On the other hand the Dines would have underpredicted the sonic anemometer peaks by more than 5%, for the range of peak gusts (26 to 33 m/s) compared in the time histories.

Table 1. Comparison of peaks recorded by different anemometer types

Peak No.	Sonic (m/s)	Simulated 3-cup	Dines	Dines/cup	Dines/sonic
1	28.65	26.12	26.32	1.008	0.919
2	26.79	25.29	26.36	1.042	0.984
3	30.21	26.60	27.89	1.049	0.923
4	28.45	25.69	26.77	1.042	0.941
5	32.45	29.30	30.75	1.050	0.948
6	32.05	29.57	30.00	1.015	0.936
7	30.40	26.80	27.57	1.029	0.907
8	28.45	26.90	27.52	1.023	0.967
9	30.58	28.58	29.67	1.038	0.970
10	31.47	28.85	29.41	1.019	0.934
11	31.93	29.63	30.24	1.021	0.947
12	30.70	27.69	28.82	1.041	0.939
13	28.71	26.85	27.31	1.017	0.951
14	28.97	26.78	27.09	1.012	0.935
15	29.97	27.75	28.30	1.020	0.944
16	28.97	27.44	27.90	1.017	0.963
Average				**1.028**	**0.944**

The anemometer record used for comparison had a turbulence intensity (as recorded by the sonic anemometer) of 9%. Such a value is a reasonable one for thunderstorm downdraft outflows [4], which probably account for more than 50% of the daily maximum gusts in Region A in Australia. However, for synoptic winds at the standard measurement conditions of 10 metres height in flat, open country, the turbulence intensity would be higher - about 20%.

To estimate the effect of a higher turbulence intensity on the ratios in Table 1, the peak velocities were re-scaled to a turbulence intensity of 20%, by subtracting the mean value (about 25 m/s), multiplying by 0.2/0.09, and then adding back the mean value. This process resulted in an average peak ratio (Dines to cup) of about 1.05, although for some peaks the ratio approached 1.1. This result appears to be reasonably comparable to that obtained by Logue [5], using direct measurements of peaks from a Dines and a cup anemometer (of different type), in atmospheric turbulence.

In summary, direct measurements of the response of the low-speed Dines system using a state-of the-art pressure actuator driven by an actual turbulent wind record indicates an 'overshoot' of peaks with respect to the standard cup anemometer currently in use by the BoM of 2-5% (dependent on storm type and turbulence intensity). However, with respect to the sonic anemometer, the Dines system 'undershoots' the peaks by 5-10%, for the magnitude of gusts studied.

Finally a comment should be made about the 'effective gust duration' of the various types of anemometer. Using Whittingham's definition based on the reciprocal of the half-power frequency (also advocated recently by Miller [6]), the 'effective gust duration', T, can be related to the time constant, or effective moving averaging time, τ, by the following (at least for a first-order measurement system):

$$T \cong 2\pi\,\tau = 2\pi\,(\delta/U) \qquad (1)$$

where δ is the distance constant of the anemometer

Thus a Synchrotac 706 3-Cup anemometer at a wind speed of 25 m/s, with a distance constant of 13 metres, gives an 'effective gust duration, T, of 2π (13/25), or 3.3 seconds. Based on the current work, the effective moving averaging time of the low-speed Dines system at the same wind speed, is about 0.2 seconds giving a 'effective gust duration' of 1.3 seconds, about half that suggested by Whittingham.

Other work for this project, some of which is to presented at this Workshop, [3], shows that the response of the Dines anemometer is dominated by the resonant response frequencies of the float system, particularly the first mode (although any vibrations are heavily damped). Present measurements indicate that the first-mode frequency is about 0.5-0.6 Hertz, about half that measured at N.P.L. in the 1930s, and reported by Whittingham [1].

6 REFERENCES

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ACKNOWLEDGEMENT

The authors acknowledge the financial support by the Department of Climate Change and Energy Efficiency for the work described in this paper, as part of the project: 'Extreme wind speed baseline climate investigation'.

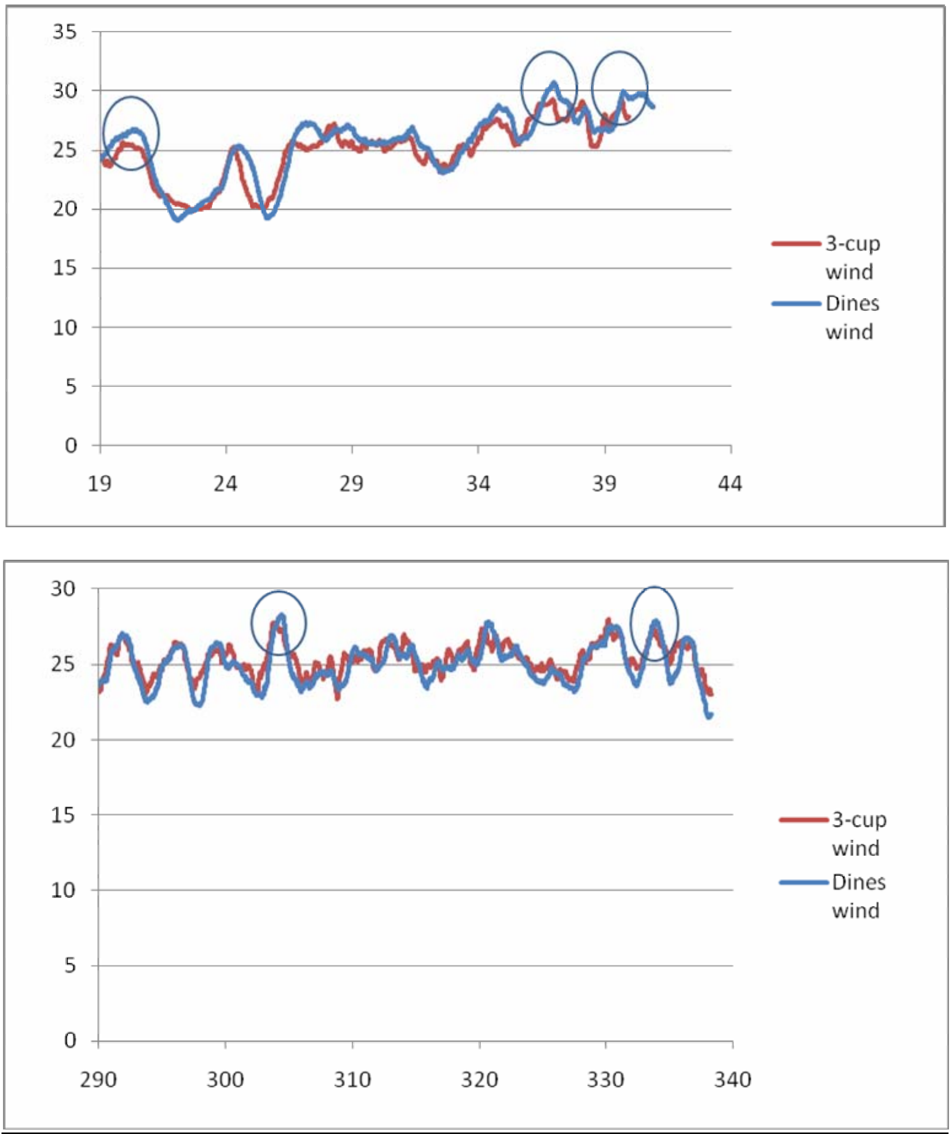

Figure 1. Extracts from wind-speed (ordinates in m/s) versus time (in seconds) histories of the Dines anemometer (blue) and of the cup anemometer (red), showing peaks selected for comparison