Response of Dines Anemometer to simulated winds

David J. Henderson[1], Murray J.Morrison[2], John D. Ginger[1] and Craig A. Miller[2]

[1]Cyclone Testing Station, James Cook University, Townsville, Australia,
david.henderson@jcu.edu.au , john.ginger@jcu.edu.au
[2]Boundary Layer Wind Tunnel Laboratory, University of Western Ontario, London, ON, Canada,
mjmorris@uwo.ca, cam@blwtl.uwo.ca

1 INTRODUCTION

Approximately fifteen years ago, the standard anemometer used by the Bureau of Meteorology to record wind speeds, including the maximum daily gusts, was changed from the Dines anemometers to the new Automatic Weather Systems (AWS). The Dines uses a pressure tube co-located in a direction vane with the pressure in the tube to raise and lower a shaped float in a water chamber, where the movement of the float is transcribed by a pen to a chart on a mechanical rotating drum. The AWS measures the wind speed via rotating cups and records the data digitally. From the few occasions that the two anemometers were operating in parallel during a storm event, the responses of the Dines and AWS differed significantly. For example, a 15% difference in the peak gust was recorded by the two anemometer types situated no more than 20 metres apart during Cyclone 'Vance' at Learmonth, WA in 1999 [1].

The wind loading standard AS/NZS 1170.2 [2] stipulates the design wind speed to be applied when designing a structure to an acceptable level of risk (i.e. set by the Building Code of Australia [3]). Reliable wind speed measurements form the basis of the estimation of design extreme wind speeds given in AS/NZS1170.2 [2], and for the forensic analysis of assessing structural damage following wind storms to evaluate code performance and for use in hazard-vulnerability models. Therefore the observational wind speed data captured by the Bureau of Meteorology at their weather station sites around the country are the key input to the assessment of the likelihood of future damaging winds. It is essential that the long-term records are compatible with the current data in order to evaluate possible long-term trends and have confidence in the estimation of extreme wind speeds for the design process.

Borges [4] evaluated a floater type pressure tube anemometer (similar to the Dines) to sinusoidal pressures of different frequencies and showed the response of the system gave an amplification of frequencies between 0.1 to 0.4 Hz at mean speeds of 20 m/s and 40m/s. The experimental setup by Borges [4] was not able to carry out tests at frequencies less than 0.1 Hz. Now, with the development of advanced Pressure Loading Actuators (PLA) that can simulate realistic fluctuating wind pressures, the response of the Dines anemometers can be directly compared with fluctuating winds. This paper summarises the outcomes form a series of experiments on Dines anemometers.

2 EXPERIMENTAL PROCESS

A 'low speed' Dines anemometer, including the rotating vane head and float chamber, was supplied by the Bureau of Meteorology to the Cyclone Testing Station (CTS). The 'low speed' units were typically used in non-cyclonic regions (and in cyclonic regions prior to the mid-70s). The Bureau also granted field access to a still operational 'high speed' Dines unit located at the Townsville airport.

The tests were carried out on the Dines anemometer system by applying pressures using a PLA unit, developed for the full scale house testing facility at the University of Western Ontario [5]. These tests carried out by the CTS in collaboration with UWO, applied fluctuating signals taken from wind tunnel studies and sonic anemometer records. In addition, other signals such as white noise, steadily increasing ramps and square and sinusoidal waves of varying frequency and amplitude were applied to the Dines.

Several Dines anemometer configurations were tested for assessing the contribution to the overall response from each component including its 10 m of piping (typical height of the head above ground level),. The various test setups in the lab were: (a) PLA pressure to 10 m of 30 mm internal diameter pipe to a fixed volume chamber simulating the average volume in the Dines low speed float chamber, (b) PLA pressure to the Dines head unit to 10 m of pipe to a fixed volume, (c) PLA pressure to the Dines head unit via the 10 m of pipe to the low speed float chamber, (d) PLA pressure to the Dines head unit via 2 m of pipe to the low speed float chamber, and (e) PLA pressure to the Dines head unit via 2 m of pipe to a fixed volume. Testing of the high speed unit at the airport site involved the application of the PLA pressures to the Dines head unit to the high speed float chamber via 2 m of pipe. Fig. 1 (a) and (b) shows the PLA connected to the Dines head unit at ground level as opposed to supplying pressure to the in-situ Dines head 10 m up, at the top of the tower. Both low and high speed anemometers use the same type of head units, and the laboratory experiments showed that the 10 m length of pipe had negligible effect on the response of the system to turbulent wind flow.

The robust and reliable operation of the Dines and provision of repeatable output is reliant on initial and ongoing maintenance procedures, such as ensuring the free running and balancing of the float chamber via the lead shot cup. The response of the float chamber to the applied pressure was measured using a linear variable differential transformer (LVDT) connected to the shot-cup on top of the float rod as shown in Fig. 2(a). A small universal joint was used to connect the shot-cup to the LVDT. A crucial requirement was to ensure that the weight of the universal joint, modified shot-cup and LVDT shaft was equal to the weight of the original shot-cup, lead shot and pen.

The pressure input from the PLA was measured with two pressure transducers located in the manifold just in front of the inlet of the Dines head.

3 RESULTS AND DISCUSSION

The Dines anemometer responds to changes in velocity by sensing the pressure at the head, and the pressures are converted to velocity using Eq. (1), as described in "Handbook of meteorological instruments Part 1: Instruments for surface observations" [6].

$$\Delta p = ½ \rho K v^2 \quad (1)$$

Here, K =1.49 is a constant factor based on the shape and dimension of the head [6], Δp is the applied pressure in Pa, ρ is the density of air and v is the velocity in m/s.

A step pressure trace increasing in 30 second steps to 3 kPa then decreasing was applied several times to the system. Figure 2(b) shows the response of the Dines float chamber (i.e. vertical displacement with applied pressure) reported as the velocity derived from Eq. (1). The linear relationship between the Dines response and velocity has a slope 0.59 m/s per mm. The vertical axis (wind speed) of the actual Dines paper chart measured 177 mm for the maximum of 200 knots, thus each millimeter on the chart is equivalent to 0.583 m/s. With the successful calibration of the float rod with the LVDT, the vertical movement was converted to the equivalent wind speed and then to pressure to allow a comparison with the input pressure traces.

The frequency response of the high speed Dines to a white noise pressure trace with a range of 1 to 1.5 kPa is shown in Fig. 3 with amplification of frequencies less than 0.3 Hz and attenuation beyond that. The frequency response is of similar shape to Borges [4], although the frequencies at of the peaks and troughs were different. The frequency spectra for the various sinusoidal traces were similar to that of the white noise although varying the magnitude of the sine traces did slightly alter the response of the Dines, with the float chamber response being sensitive to the frequency and magnitude of float movement.

For the various dynamic wind pressure traces run, there was no difference in the mean of the LVDT to the mean of the input pressure signal. However as expected, and as shown in Fig. 4, the Dines misses the large peak gusts. But amplifies some of the broader peaks and was “out of phase” with some of the cycles. Results reported by Holmes [7], in a companion paper show the Dines to have an effective gust response duration of approximately 1.3 seconds.

4 CONCLUSIONS

Fluctuating pressures representative of real winds were applied to two Dines anemometers. The Dines anemometers were able to accurately reproduce the mean wind speeds from various input traces. The ‘high speed’ Dines unit under-measured applied peak gusts by approximately 7%.

5 REFERENCES

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Fig. 1: (a) PLA connected to volume chamber which is connected to Dines; (b) PLA system connected to Dines head in doorway (with 3 phase generator in background)

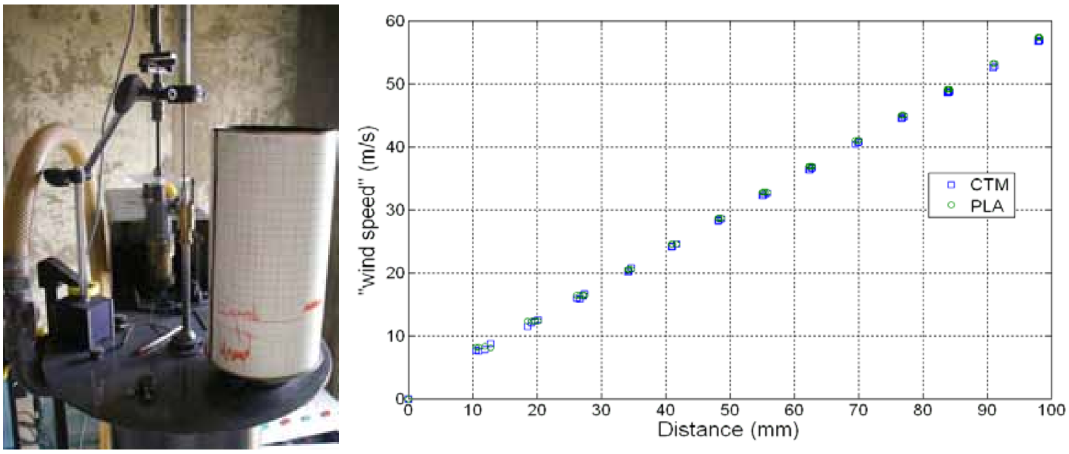

Fig. 2: (a) LVDT connected to modified shot-cup on top of float rod; (b) Plot of vertical movement of float rod (measured by LVDT) with derived "wind speed" converted from applied PLA pressure

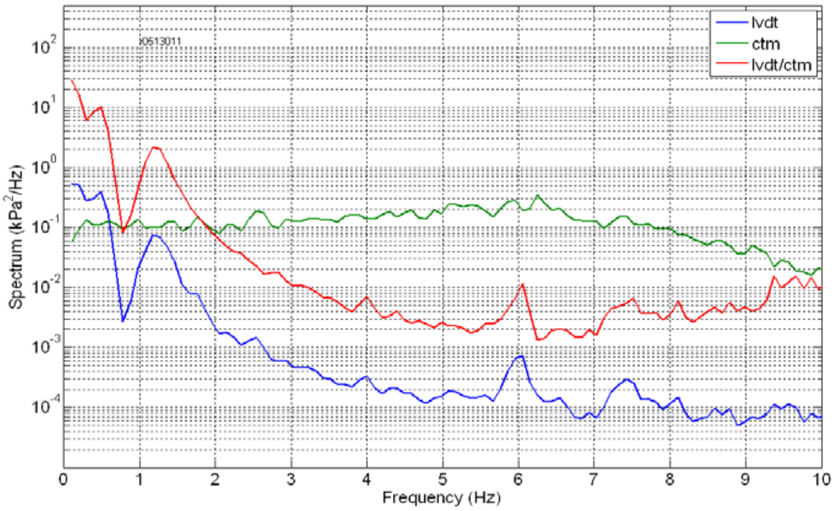

Fig. 3: White-noise spectrum (mean 1 kPa, max 1.5 kPa)

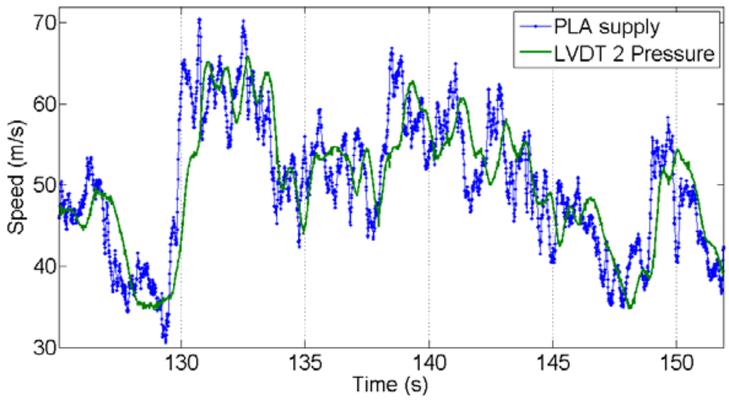

Fig. 4: Portion of applied wind trace with measured Dines response