# WIND-INDUCED DYNAMIC RESPONSE OF A LARGE LATTICE TOWER

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## INTRODUCTION

Television and FM-radio transmission antennas in Australia are commonly supported by free-standing lattice towers 100 metres or more in height. Such structures may have characteristics which make them susceptible to a significant amount of resonant vibration response induced by wind.

Structures of this type which are particularly prone to vibration are those on which impermeable shrouds, usually made of fibreglass, have been installed at the top to protect the antennas from icing up. If these shrouds are long and slender enough, they may produce significant vortex-induced vibrations at moderate wind speeds. However, this system will also result in increased excitation due to natural turbulence fluctuations in the wind, as a result of the increased area presented to the wind at the top, and reduced first-mode natural frequencies due to an increase in the generalised mass of the structure resulting from the mass of the shroud.

This paper will describe measurements of (wind speed, direction and acceleration components in two orthogonal directions) from a tower of this type located in Tasmania. Recordings were made for extended periods during the winter of 1989. Comparison of the measured along-wind response with predictions based on current design rules is also made.

## THE TOWER

The Hobart Tower is located on Mount Wellington, with its base at an elevation of 1270 metres above sea level, and serves the city of Hobart, Tasmania with television and FM radio transmissions. A large cylindrical shroud, made from fibreglass, was installed on the Tower some years ago to prevent icing up of the antenna during the winter months. The total height of the Tower is 104 metres, and the shroud encloses the top 30 metres of the structure.

## INSTRUMENTATION

In February 1989, instrumentation to record wind speed and direction at the 72-metre level, and two orthogonal acceleration components at the 74-metre level, was installed. Electronic equipment, including a digitiser, was also located at the 74 metre level, and protected from radio frequency interference and from lightning strikes. Digital data was transmitted to a computer in a building near the base of the Tower, and stored on disk. Data files were transmitted from here to the CSIRO site in the Melbourne area on the Australian mainland.

## RESULTS

Records were obtained with mean wind speeds near the top of the tower between about 5 and 32 metres/second. The largest resultant root-mean-square acceleration obtained was 26.5 millig's. The major component of the motion of the Tower was in the first mode of vibration with a frequency of 0.7 Hertz. This was very close to that computed from a free-vibration analysis of the structure.

Analysis of the acceleration response into along-wind and cross-wind components was carried out and indicated approximately equal contributions from the two components, but there was some statistical correlation between them. Both components increased monotonically with mean wind speed.

## ALONG-WIND RESPONSE

The along-wind acceleration at the measurement level of 74 metres has been plotted against mean wind speed in Figures 1 and 2. The scatter of the measurements is similar to that on other full-scale measurements on towers [1]. The scatter can be explained mainly by variations in turbulence intensity for different runs, and the short time length of some of the records which produces significant statistical errors.

A detailed analysis of the along-wind acceleration response, using random vibration theory and considering only the first mode of vibration, yields the following result for the along-wind r.m.s. resonant acceleration response at the Tower tip:

$$\sigma_{\ddot{x}}(h) = r\,\bar{F}_1 \sqrt{SE/\zeta} \Big/ G_1 \qquad (1)$$

where S is a 'size factor' representing the effect of correlation of fluctuating velocities along the structure, E is a 'gust energy factor',proportional to the spectral density of wind velocity fluctuations,at the natural frequency of the structure, $\zeta$ is the critical damping ratio, which may include aerodynamic, as well as structural damping,

$$\text{i.e.} \quad \zeta = \zeta_s + \zeta_a \qquad (2)$$

and $G_1$ is the generalised mass in the first mode. The definitions of r,S and E correspond to those given in the Australian Standard for Wind Loads [2].

Equation (1) was evaluated with a number of different assumptions for r,S and $\zeta$, the acceleration was adjusted to a height of 74 m, and the results compared with the measured values in Figures 1 and 2. $F_1$ was calculated using a mean drag coefficient for the circular cross-sections of the shroud of 0.7. The contributions from the lattice tower sections on the lower part of the Tower were small, but were included, using drag coefficients for square tower sections from the Australian Standard [2]. $G_1$ was computed from the estimated masses, computed mode shape and measured frequency. The Australian Standard, [2], was used to determine E.

The origins of the assumptions for the computed curves in Figures 1 and 2 are shown in Table I.

It is possible that the cup anemometers used on the Tower underestimated the turbulence intensity; hence the 'measured' value of r in Table I may be low for this reason. It is believed that the value of the 'size factor', S, obtained from ESDU 87035 , [3] (actually S is the product of two terms $B_R{}^2$ and $J_R{}^2$ in ESDU 87035), is more accurate as it allows for the effect of a non-linear mode shape. For this tower, the first-mode shape has a high curvature, [4].

The aerodynamic damping, estimated from ESDU 87035, is significant and exceeds the structural contribution for mean wind speeds of 20 m/s or greater. Unfortunately, it wasn't possible to accurately estimate the damping from autocorrelation records; however, the total damping ratio did appear to be significantly greater than 0.007 - the value for structural damping given in AS1170.2.

Curves (a), (d) and (e) are reasonable predictions of the along-wind response, but none of these are based on the measured turbulence intensity. Further investigation of the response of the cup anemometers used and of the turbulence intensity records in individual measurements is proceeding.

## REFERENCES


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2. Standards Australia. Minimum design loads on structures. Part 2- Wind Loads, Australian Standard AS1170 Part 2, 1989.

3. Engineering Sciences Data Unit. Calculation methods for along-wind loading. Part 2 - Response of line-like structures to atmospheric turbulence. ESDU 87035, 1987.

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TABLE 1

| Case | r | S | $\zeta_s$ | $\zeta_a$ |
|---|---|---|---|---|
| (a) | AS 1170.2* (0.262) | AS 1170.2 | AS 1170.2† (0.007) | 0 |
| (b) | Measured (0.18) | AS 1170.2 | AS 1170.2† | 0 |
| (c) | Measured | ESDU 87035 | AS 1170.2† | ESDU 87035 |
| (d) | AS 1170.2* | ESDU 87035 | AS 1170.2† | ESDU 87035 |
| (e) | AS 1170.2* | ESDU 87035 | AS 1170.2† | 0 |


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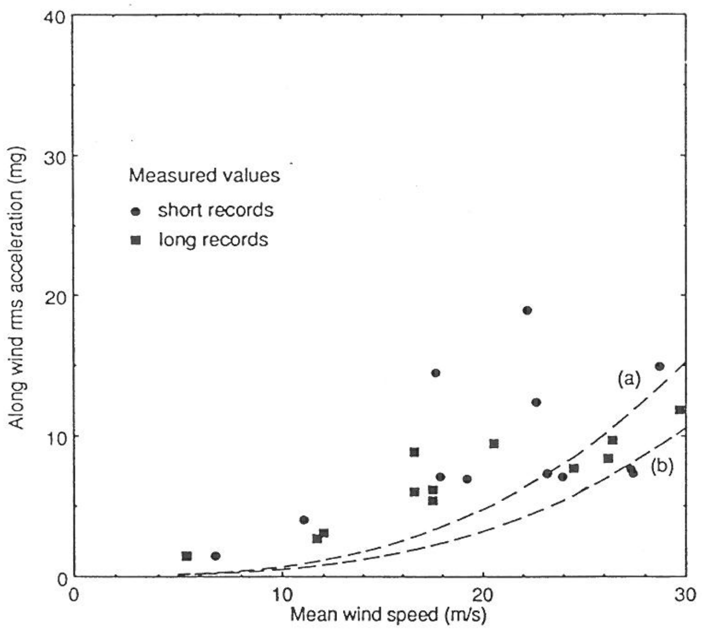


Figure 1. R.m.s. along-wind acceleration versus mean wind speed (computed curves (a) and (b) - see text)

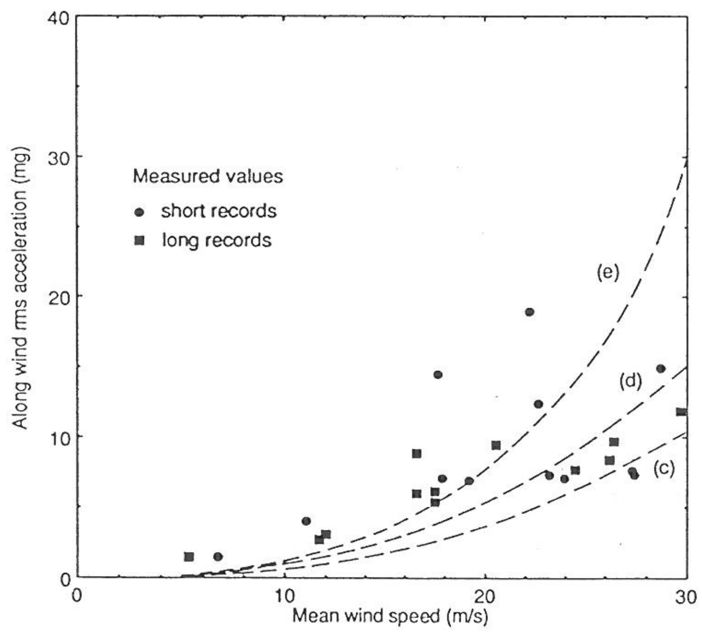


Figure 2. R.m.s. along-wind acceleration versus mean wind speed (computed curves (c),(d) and (e) - see text)