

## **Measuring noise in high wind speeds: Evaluating the performance of wind shields**

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### **ABSTRACT**

The issue of correctly assessing and monitoring wind farm noise is growing in importance as the number of wind farms in operation continues to rise with a view to increase the production of green energy. Consequently the issue of correctly monitoring and predicting wind noise has become an issue of more importance in Ireland. According to best practice guidelines this involves noise measurements at wind speeds up to 12m/s. However, international standards generally states that wind shields are only effective up to 5m/s whereas most wind turbines are operative for wind speeds between 4m/s and 20m/s. A reliable method to measure noise in high speed winds is therefore required. This paper describes an initial step towards this goal. The effect of using a windshield on a microphone was established in both flow and no flow environments. In the instances where hydrodynamic noise was an issue (i.e. a “windy” environment) the effect of exceeding the 5m/s limit was analysed. It is proposed that these measurements could be used to determine correction factors associated with wind speeds and apply these correction factors to field measurements.

### **1. INTRODUCTION**

Ireland’s geographical position and climate places it in an ideal position to harness energy from renewable sources. The total electrical output from wind in 2007 was 1,958 (GWh) which is estimated to have avoided almost one million tones of CO<sub>2</sub> emissions for that year. There is a further 892 MW of planned wind capacity with grid connection contracts and target connection dates between October 2008 and December 2012<sup>1</sup>. It is therefore reasonable to assume that the amount of wind farms in Ireland will significantly increase in the coming years.

While the increase in the amount of wind farms in the nation will benefit Ireland’s overall carbon emissions, the growth in the number of wind farms will also lead to

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more concern over environmental noise from wind farms. Generally wind turbines will generate noise that may be described as a combination of tonal, broadband, low frequency and impulsive sounds through various phases of operation. A recent study carried out in the Netherlands aimed to assess the impact noise the from a wind farm had on nearby residents<sup>2</sup>. The study found that sound was the most annoying aspect of wind turbines. It is therefore important that the noise resulting from a wind farm is controlled effectively in order to minimise the related acoustic impact on surroundings.

In Ireland the development of a proposed wind farms must meet certain planning conditions. One aspect of these conditions will involve noise limits at nearby sensitive receivers. However the application of these limits is dependent on a number of variables which must be taken into account when planning a wind farm. The level of noise generated by a wind turbine will increase with increasing wind speeds. However when the wind is blowing the noise from the turbines may be masked by the sound of the wind itself particularly if there is an abundance of trees, vegetation, etc. in the area. In general the rate at which turbine noise increases with wind speed is lower than the rate at which background noise levels increase with wind speed. The impact of wind turbine noise is therefore likely to be greater at low wind speeds, when the difference between the noise of the wind turbine and the background noise is likely to be greater.

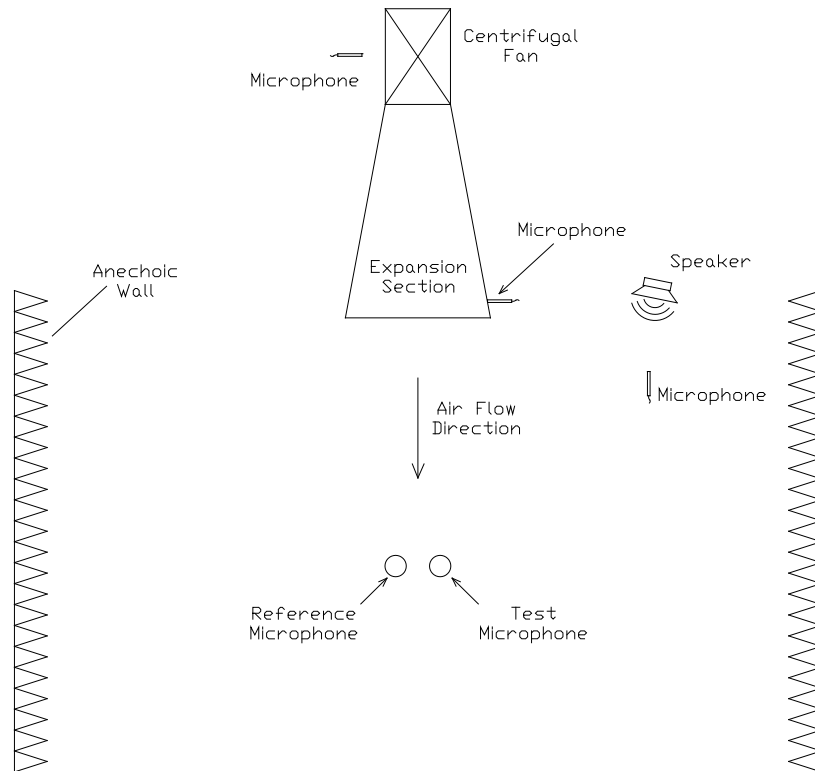
Therefore, when setting noise limits, one has to be aware of how the noise levels from the turbine will vary with wind speed and also how the existing background noise levels vary with wind speed. A detailed representation of the background noise levels is essential for setting appropriate noise limits. This will involve an in-depth background noise survey that generally requires at least 1 week's continuous noise monitoring in order to avoid results being weighted by unrepresentative condition and arrive at an accurate representation of background levels<sup>3</sup>.

This poses an interesting question to the acoustic engineer. It is generally regarded that windshields will be effective up to wind speeds of 5 m/s. In higher wind speeds the wind passing over the diaphragm of the microphone of the sound level meter can generate noise interference. However, in order to establish how the background noise varies with wind speed noise measurements of up to 12m/s may frequently be required. It is therefore evident that measurements carried out above 5 m/s may be influenced by the wind itself and may not be a true representation of the background noise environment. The main objective of this paper is to quantify the effect various wind speeds have on a microphone and use results to establish a more reliable representation of the background noise environment.

## **2. TEST PROCEDURE**

All experiments were conducted within a test chamber with a low reverberation time. Air flow in the chamber was generated using a 2.2Kw Elmot motor connected to a centrifugal fan attached to an expansion section. This setup produced air flows of 0-10m/s at the microphone locations. Air flow was measured to an accuracy of 0.1m/s. Two microphones placed 100mm apart were located at a distance of 1.5m from the exit of the expansion section and at a height of 1.3m. The microphone under test was a half inch Gras 40AE microphone while the reference microphone was a BSWA

MPA 216T half inch microphone. The Gras microphone was examined under various conditions with and without a commercially available windshield attached.



**Figure 1:** Schematic of test rig

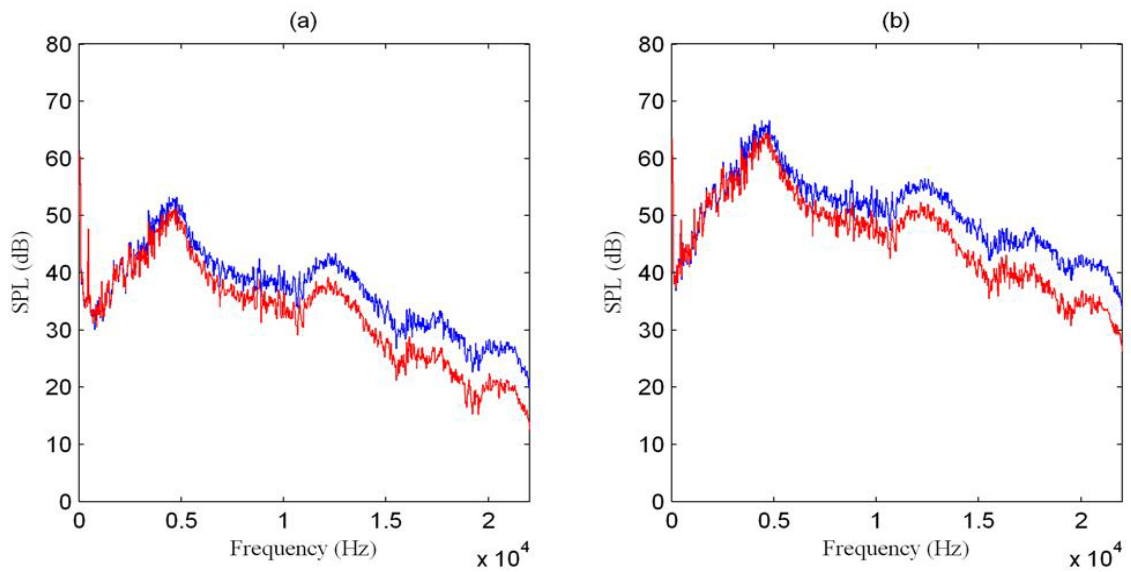
An artificial noise source was generated using a speaker which was mounted outside of the flow. A schematic of the setup is shown in Figure 1. Also shown are three other microphones: 1) flush mounted in the expansion section; 2) located at the inlet of the centrifugal fan and; 3) in front of the speaker. These microphones were used in the partial coherence techniques to remove unwanted noises (e.g. centrifugal fan) from the reference and test microphones.

The flow type produced by the fan was highly turbulent. The turbulence intensity was not rigorously quantified but the variation in the air flow rate suggested it was in the region of 20%. Finally the sensitivity of each microphone was obtained using a Bruel and Kjaer sound level calibrator type 4231 at a frequency of 1000Hz and pressure of 1Pa (94dB).

### 3. RESULTS

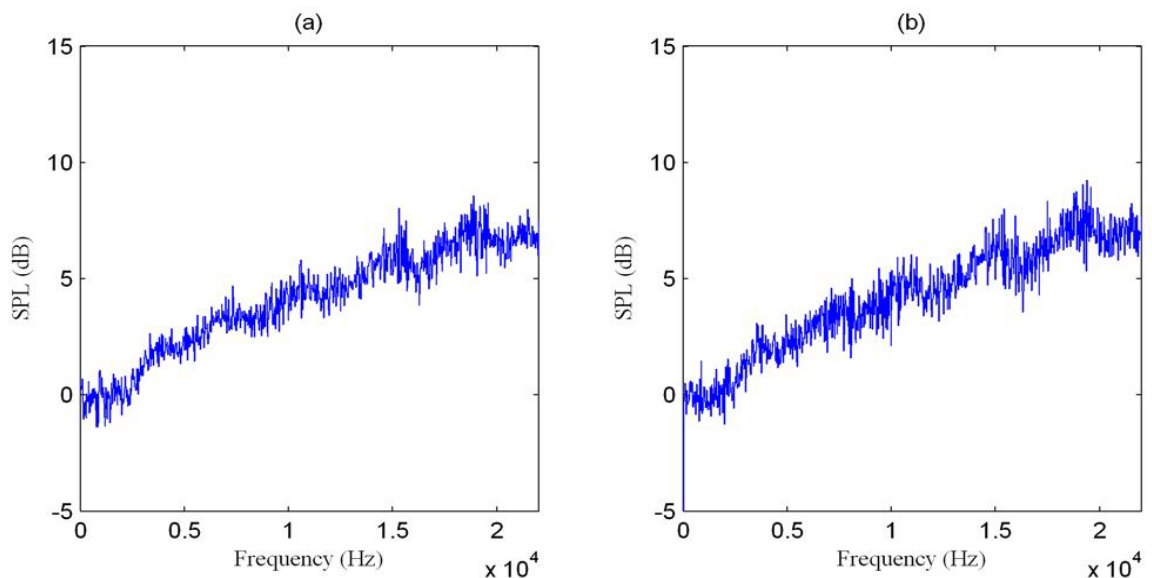
#### A. Test Series 1 – No Flow Environment

The first set of tests examined the affect of the wind shield when there was no flow. White noise was generated and output via a speaker at five different amplitudes. It was observed that the wind shield caused increased attenuation at higher frequencies. Figure 2 shows the variation of sound pressure levels with and without the windshield applied. At the lower frequency range the effect of the wind shield is minimal which is most likely due to the physical size of the wavelength of sound at low frequencies. It may be observed that as the frequency increases the attenuation effect of the wind shield becomes more pronounced.



**Figure 2(a) - (b):** The variation of sound pressure level for each frequency with (---) and without (---) the presence of a windshield for different source amplitudes.

Figure 3 shows the difference between the ‘with windshield’ case and the ‘without windshield’ case in terms of A-weighted sound pressure levels for each frequency. Again the attenuation effects of the windshield, particularly at high frequencies are evident.



**Figure 3 (a) - (b):** The A-weighted difference between observed sound pressure levels for the ‘with’ and ‘without’ windshield cases.

## B. Test Series 2 – Flow Environment

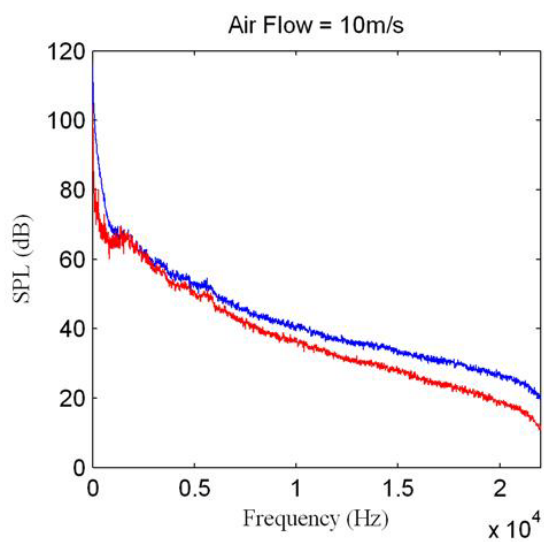
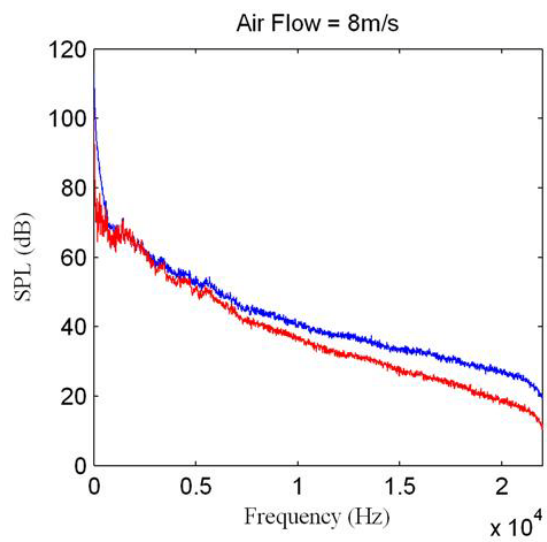
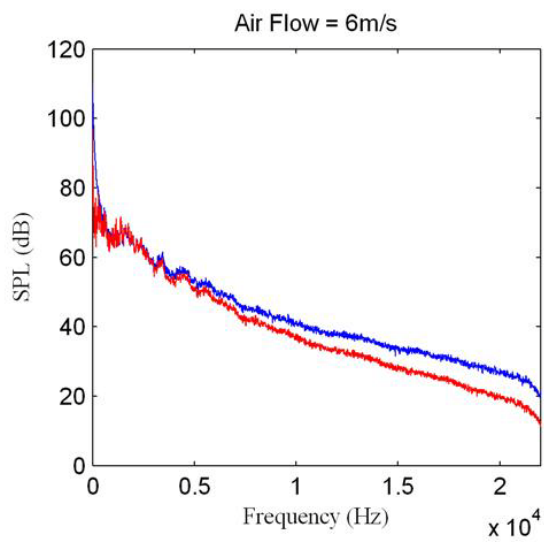
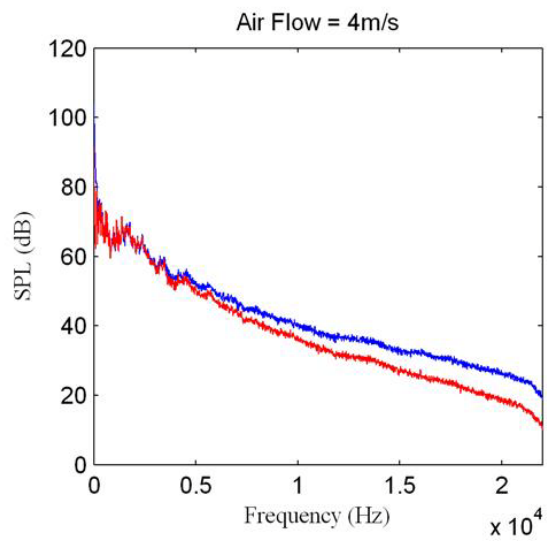
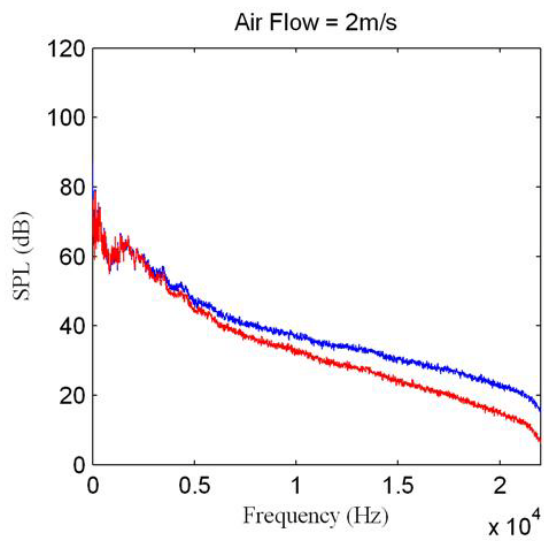
This set of tests examines the effectiveness of the wind shield for a range of different air flow velocities. The configuration for this test was similar to that described above with one of the microphones used as a reference microphone whilst the second (test) microphone was examined with and without the presence of a windshield. Three other microphones (as presented in Figure 1) were used as input the partial coherence technique described below. Tests were conducted for airflow rates of 2, 4, 6, 8 and 10m/s. The airflow was generated using a centrifugal fan. The operation of the fan itself generated noise. As such some of the noise generated by the fan was removed using a partial coherence technique. This technique is briefly summarized below. For more information on this technique the reader is referred to Bendat and Piersol and Esmonde et al<sup>4,5</sup>.

In order to remove the linear contributions from the centrifugal fan, conditional spectral analysis techniques such as those discussed in Bendat and Piersol and employed by Esmonde et al. may be used. Pertinent to this problem are results where it is calculated that if an arbitrary signal,  $i$ , is composed of at least two components, where  $r$  is one of them, then the auto-spectrum of  $i$  with the linear effects of  $r$  removed can be expressed as

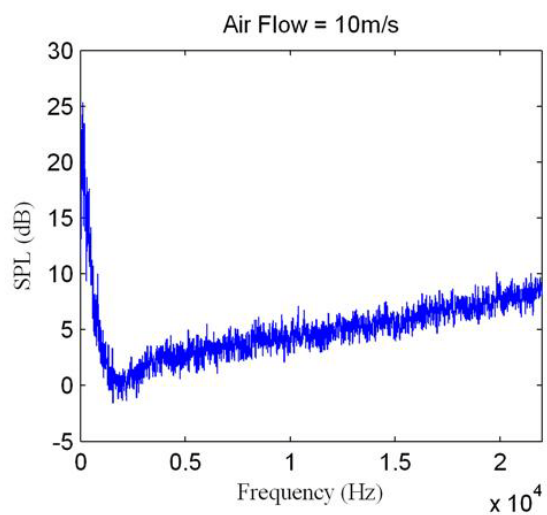
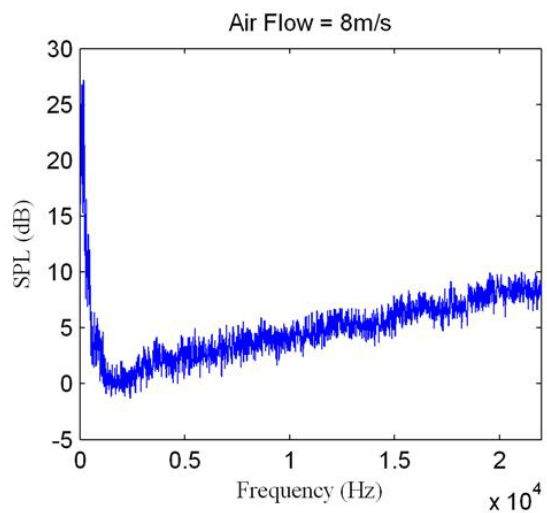
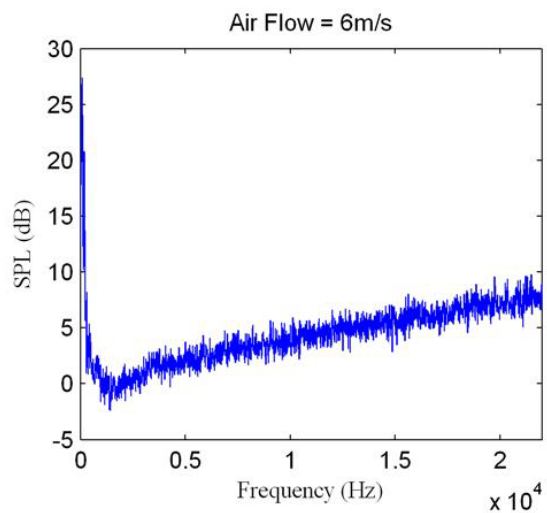
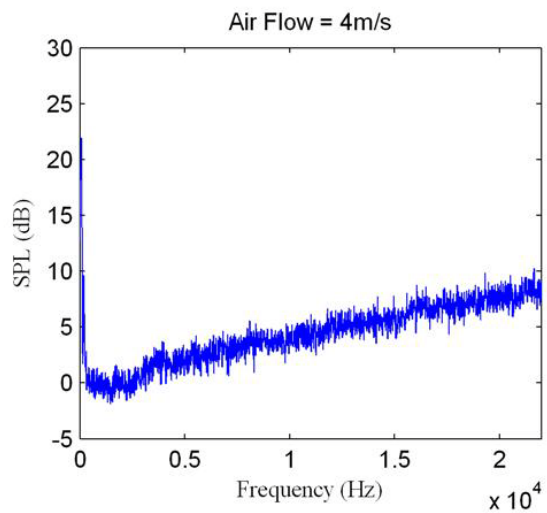
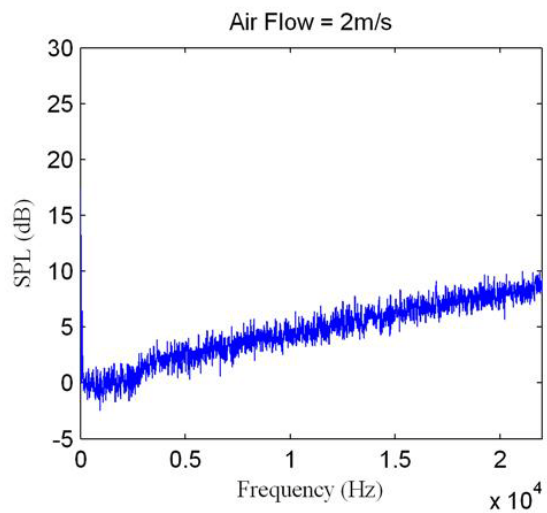
$$G_{ii-r} = G_{ii} - \frac{|G_{ri}|^2}{G_{rr}}$$

Figure 4 shows spectra of the microphone signal with and without the windshield. Similarly to the white noise tests with no flow, it was observed that the use of the windshield caused the noise levels to be attenuated. Again, the extent of attenuation is a function of frequency. It was also shown that the windshield reduced the extraneous low frequency noise sources i.e. the buffeting on the microphone. It was observed that the flow noise increased as the air flow rate increased, however, the frequency range of wind induced noise also increased with increasing air flow rate. Figure 5, showing the attenuation due to the windshield, shows the extension in the frequency range as a result of increased air flow rates.

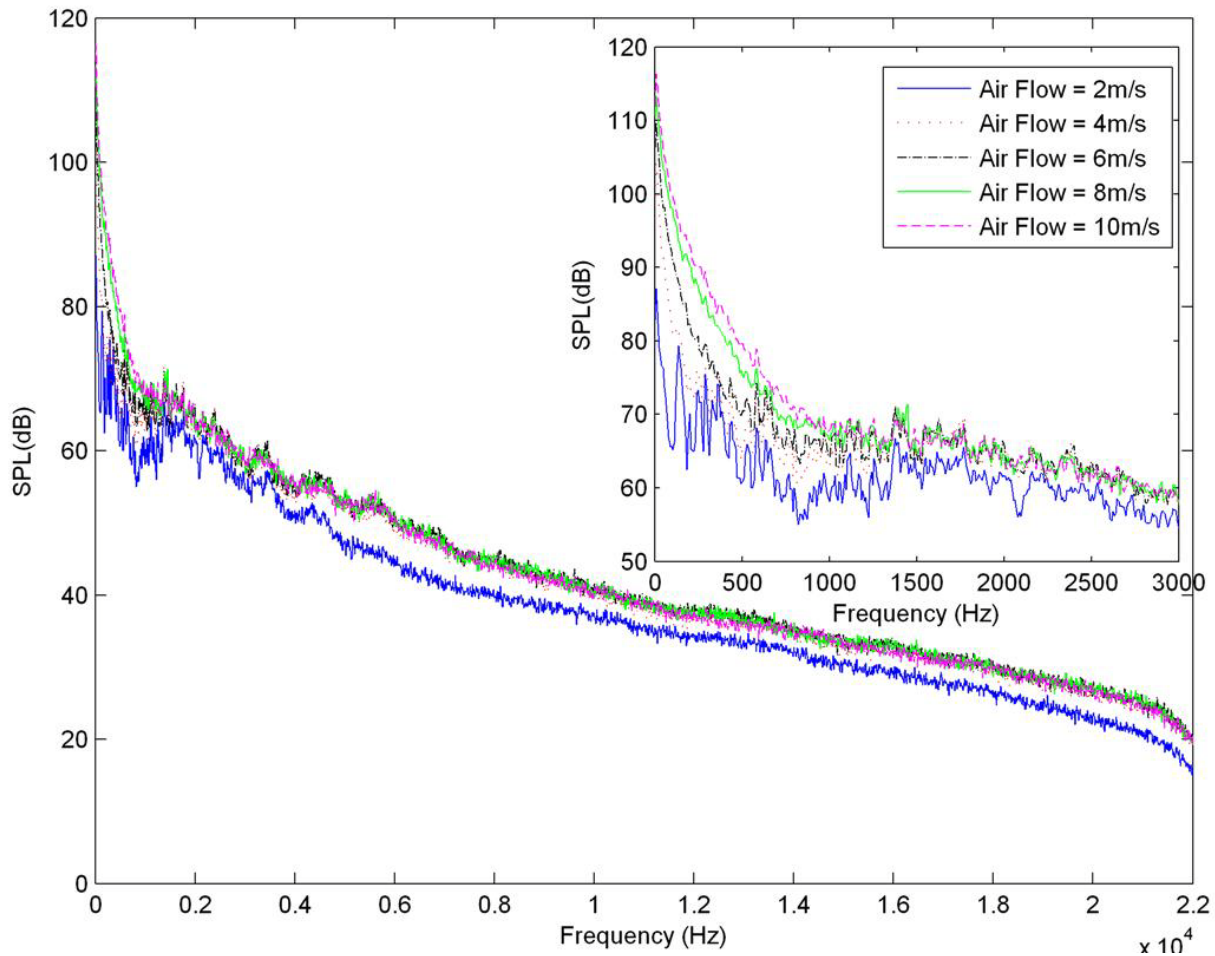
Figure 6 shows the conditioned sound pressure level of the test microphone with the windshield in place for all flow velocities. The spectra for the air flow rate with the range of 4-10m/s collapse onto a single curve whilst the spectrum at an air flow rate of 2m/s is observed to be lower in magnitude. It is not clear why this is the case and further investigation is required. However, the implication of this result could hold some significance as International Standards suggest that the effectiveness of a wind shield is generally effective up to 5m/s, yet the results presented show variation below 5m/s. Additionally, the attenuation effects of the windshield should not be ignored when analyzing data obtained while using a windshield.



**Figure 4 (a) - (e):** The variation of sound pressure level at each flow velocity for each frequency with (---) and without (---) the presence of a windshield.



**Figure 5 (a) - (e):** The A-weighted difference between observed sound pressure levels for the 'with' and 'without' windshield cases.



**Figure 6:** The conditioned sound pressure level of the test microphone with the windshield in place for all flow velocities.

#### 4. POTENTIAL APPLICATIONS AND FUTURE WORK

Users of analogue transducers may be familiar with the standardisation of a Transducer Electronic Data Sheet (TEDS). A TEDS contains the critical information needed by an instrument or measurement system to identify, characterise, interface and properly use the signal from an analogue sensor<sup>6</sup>. It is proposed by the authors that information with regards to the impact of using a windshield, specific to the microphone in question, could be incorporated in the TEDS. As such the microphone will be appropriate for use in both wind and no-wind environments.

It is evident that an impact or correction factor to be included in the TEDS would have to be tested in detail. While the test set-up described in this paper is subject to some significant limitations, the tests do demonstrate that the use of a windshield will have a significant impact on measurements. In order to fully quantify this effect a number of supplementary tests should be carried out with an improved set-up, e.g. conduct tests in a fully anechoic chamber with a more controlled wind source.

## 5. CONCLUSION

The work described in this paper has identified that when the use of a windshield with a microphone when measuring noise levels will impact measured results. However following a detailed analysis of results it may be possible to correct results due to the presences of a windshield. By extension it may also be possible to accurately measure noise in high winds environments through the development of a correction factor applied to high wind speeds. A correction factor of this sort may be included in future TEDS systems.

## ACKNOWLEDGEMENTS

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