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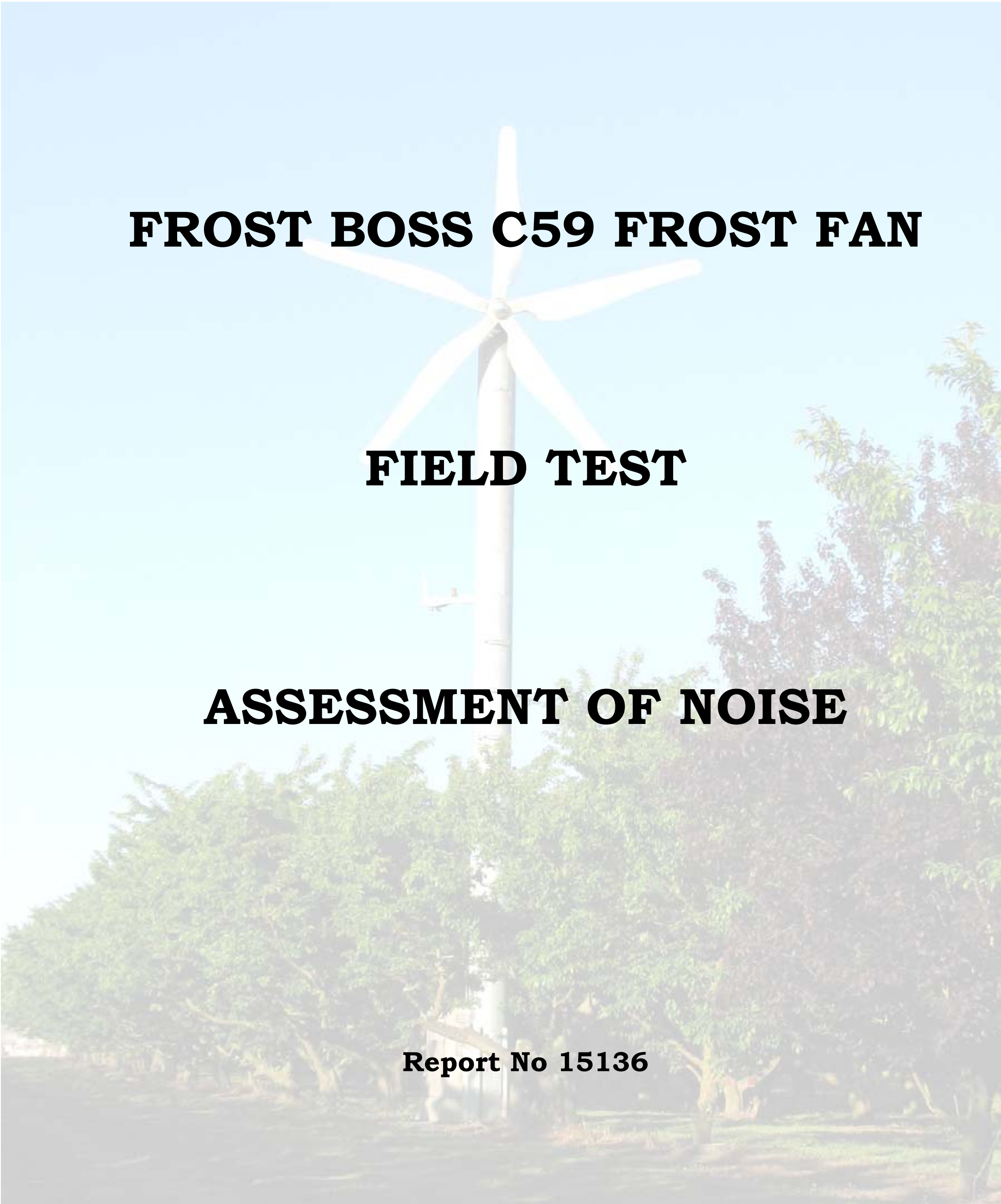

FROST BOSS C59 FROST FAN

FIELD TEST

ASSESSMENT OF NOISE

Report No 15136

Prepared for:

New Zealand Frost Fans Ltd
Hastings
August 2015

Prepared by: ……………………

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1 Introduction

This report sets out the results of field measurements undertaken on the night of Thursday 28 May 2015 of a Frost Boss C59 frost fan. Measurements were undertaken at 180m and 300m from the frost fan operating at an engine speed of 1840rpm and fan speed at 365rpm at 1445 Omahu Road, Hastings, as shown on Figure 1.

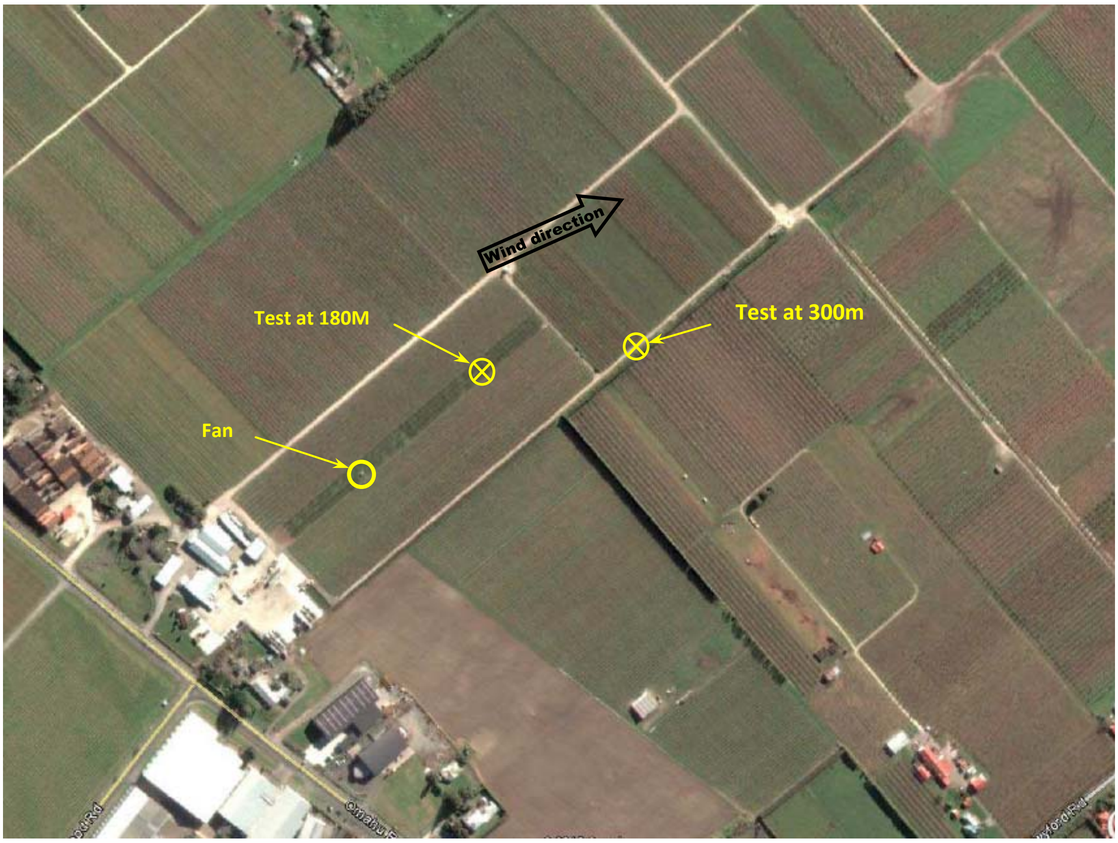

Figure 1. Test Location at 1429 Omahu Road

2 Test Conditions

The weather throughout the noise monitoring period was fine. The cloud varied between 3/8 cover at the start of testing to 4/8 cover at the completion of the testing. An ambient wind was of variable speed and throughout the testing the wind was blowing from the frost fan towards the monitoring position (south westerly). The reported wind speed is a 30 second moving average, updated every 5 seconds, and is sent to the data logger at 2 minute intervals. The canopy temperature is measured 1m above the ground and the tower temperature is measured 10m above the ground at the top of the tower. Where the tower temperature is above the canopy temperature (which occurred throughout the monitoring period) this indicates a temperature inversion is present and the wind speed is measured 6.5m above the ground from a tower mounted spar.

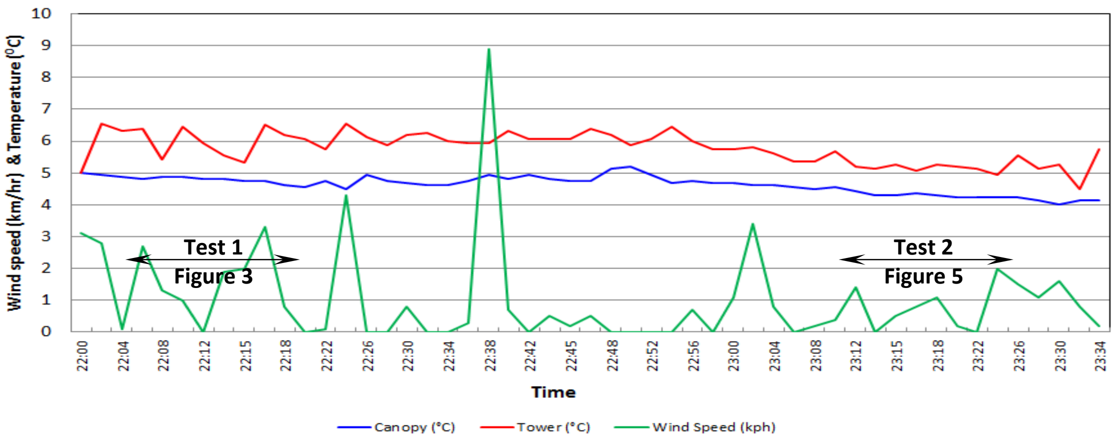

Figure 2. Wind Speed and Temperature during Testing

The meteorological conditions were compatible with those set out for Category 6 in Concawe[1], which gives enhanced meteorological conditions. When testing commenced the temperature was 5^{0}C and it dropped to 4^{0}C at the completion of

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1 The Propagation of Noise from Petroleum and Petrochemical Complexes to Neighbouring Communities, Report No 4/81, May 1981 prepared by C J Manning, Acoustic Technology for Concawe's Special Task Force on Noise Propagation

the testing. The weather conditions were considered ideal for monitoring noise from the frost fan.

The topography was flat and the apple trees in the orchard were in a dormant state with very few leaves.

The technical information of the frost fan tested is:

• Frost Fan model	FrostBoss C59 (prototype)
• Engine	Cummins 6BT5.9 Turbo diesel
• Engine cabinet	Standard FrostBoss steel cabinet
• Exhaust	Standard single chamber internal muffler
• Blade type	Standard C9 series composite blade
• Fan diameter	5.5m
• Tower height	10.5m
• Pitch	fixed
• Upper gearbox	DeRan GB11 ratio 1.68 to 1
• Lower gearbox	Amarillo 85W ratio 3.0 to 1
• Overall ratio	5.04
• Fan speed	365 rpm
• Engine speed	1840 rpm

Commercial Fan

• Frost fan model	FrostBoss C59 (production model)
• Engine	Perkins 1006-6T Turbo diesel
• Engine cabinet	Standard FrostBoss steel cabinet
• Exhaust	Standard single chamber internal muffler
• Blade type	Standard C9 series composite blade
• Fan diameter	5.5m
• Tower height	10.5m
• Pitch	fixed
• Upper gearbox	Amarillo UD105 ratio 1.6364 to 1
• Lower gearbox	Amarillo 85W ratio 3.0 to 1
• Overall ratio	4.9091
• Fan speed	365 rpm
• Engine speed	1792 rpm

As shown above, the tested frost fan has some small differences to the proposed commercial frost fan. The differences are a different engine and slightly different overall gear ratios to the C59 fan system that will be marketed by NZ Frost Fans.

The test engine was a 5.9 litre, 6 cylinder, Cummins turbo-diesel whereas the production engine will be a 6.0 litre, 6 cylinder, Perkins turbo-diesel. Both engines have similar mufflers and the cabinet design is the same for both engines with a similar noise output at the same engine speed.

The C59 fan is designed to run at 365 rpm, regardless of the engine driving it. The test fan had an overall gear ratio from the fan to the engine of 5.04, therefore the engine speed is 365 rpm x 5.04, which equals 1,840 rpm. The production fan will have an overall gear ratio from the fan to the engine of 4.9091, therefore the engine speed is 365 rpm x 4.9091, which equals 1,792 rpm. Thus, the commercially available frost fan will operate at 48 rpm lower engine speed compared to the test fan so theoretically the engine noise will be slightly lower than the engine tested. Regardless, it is noted that the engine noise does not control the measured noise; the noise into the environment is controlled by the fan itself.

The equipment used for the measurements was:

- Brüel & Kjær 2250 Hand-held Analyser platform with Sound Level Meter Software BZ 7222, Frequency Analysis Software and BZ 7225 Enhanced Logging Software. Re-calibration is next due in September 2015;
- Brüel & Kjær ½" type 4189 microphone, serial number 2650951. Re-calibration is next due in September 2015;
- Brüel & Kjær 4230 calibrator serial number 930422. Re-calibration is next due in September 2015;
- Brüel & Kjær type UA0237 90mm diameter windscreen;
- All measurements were undertaken in accordance with the requirements of *NZS 6801:2008 Acoustics - Measurement of Environmental Sound* and assessed in accordance with the requirements of *NZS 6802:2008 Acoustics – Environmental Noise*.

3 Test Results with Fan at 365rpm and 300m

Two measurements were undertaken at 300m downwind of the frost fan. Figure 3 shows the real time noise trace of the frost fan as measured over a 15 minute period, which gave two full rotations of the frost fan.

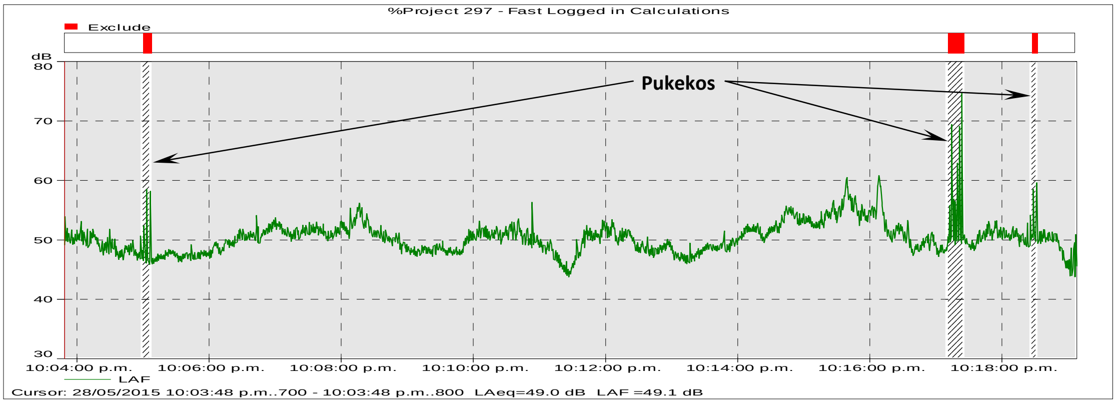

Figure 3. Real Time Noise Trace at 300m, commenced 10:04pm

Figure 4 shows the sound spectrum in one third octave bands for the test undertaken at 300m.

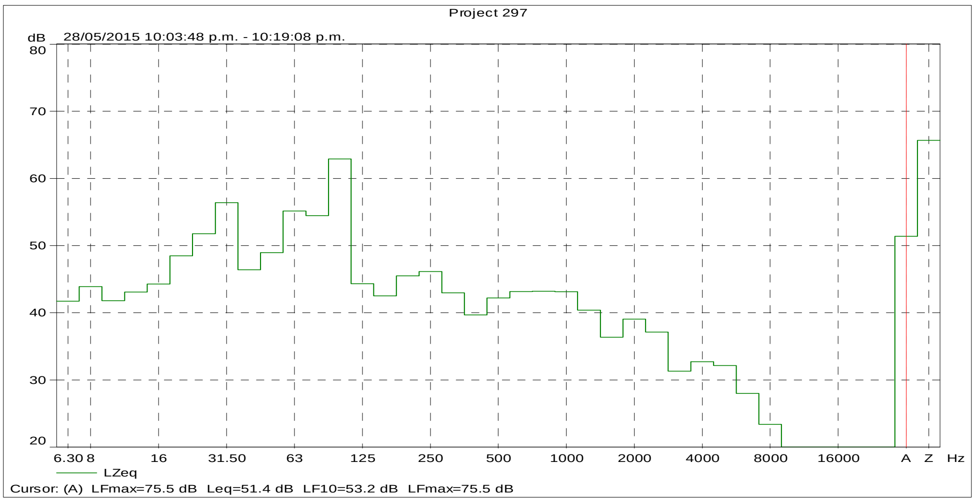

Figure 4. 1/3 Octave Spectrum at 300m – Total Test Duration

Based on the measured level at 300m the noise over a 15 minute period for the Frost Boss C59 frost fan at 365rpm is 50dB L_{Aeq}.

A second 15 minute test was undertaken from 11:11pm at the same location at 300m from the frost fan and at 365rpm as shown on Figure 5. In this case the noise level was also 50dB L_{Aeq}.

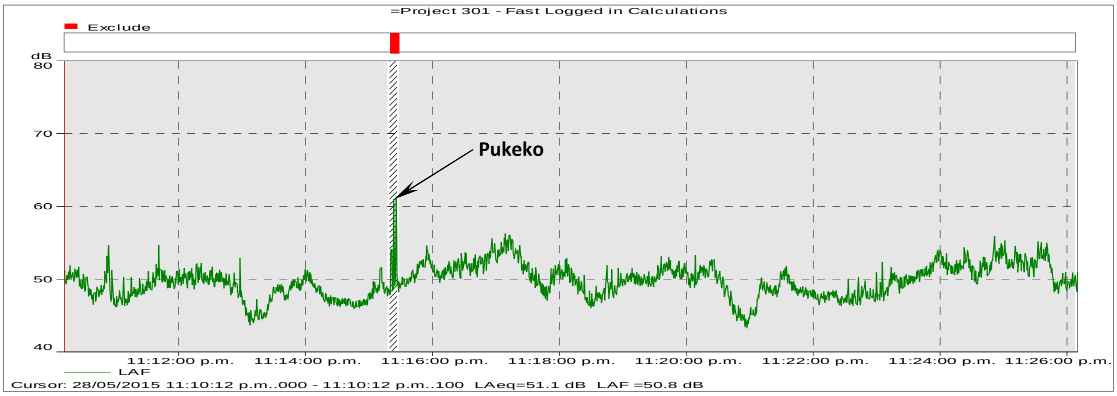

Figure 5. Real Time Noise Trace, commenced 11:11pm

Figure 6 shows the sound spectrum in one third octave bands for this second test starting at 11:11pm and at 300m.

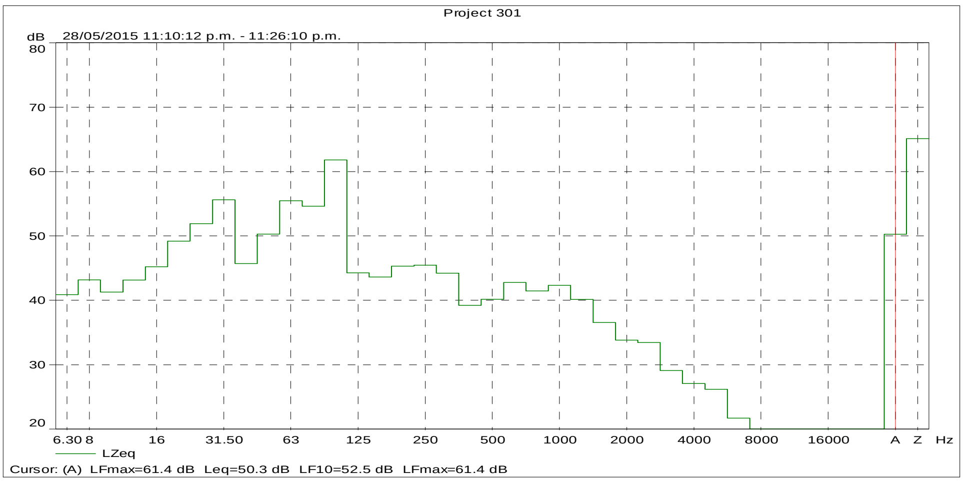

Figure 6. 1/3 Octave Spectrum at 300m – Total Test Duration

Appendix B4 of NZS 6802:2008 Acoustics – Environmental Noise sets the test to determine if there is a tone to the sound of interest. To determine if a tone is present the relevant section of the Standard states:

B4.2 Objective test methods

Where there is doubt about the presence of tonality, the following two methods provide an objective measure for tonality. The simplified test method may be carried out using one-third octave band measurement equipment. The reference test method requires the use of narrow band analysis. If the simplified method does not indicate tonality, it may still be necessary to use the reference method to confirm the presence or absence of tonality. In addition, the reference method can properly assess modulated tones or complex tones.

B4.3 Simplified test method for tonality

A test for the presence of a prominent discrete-frequency spectral component (tonality) can be made by comparing the levels of neighbouring one-third octave bands in the sound spectrum. An adjustment for tonality shall be applied if the LEQ in a one-third-octave band exceeds the arithmetic mean of the LEQ in both adjacent bands by more than the values given in table B2.

Table B2 - One-third octave band level differences

One-third octave band	Level difference
25 - 125 Hz	15dB
160 - 400 Hz	8dB
500 - 10000 Hz	5dB
NOTE - At frequencies below 500Hz the criterion could be too severe and tones might be identified where none is actually audible. For complex spectra the method is often inadequate and the reference method should be used.	

A check of the individual frequencies as set out on Figures 4 and 6 (1/3 octave bands) shows there is no tonal characteristic to the sound that warrants an adjustment to the measurements. In addition, there are no other characteristics, such as a whacking sound often associated with frost fans, which would attract a 5dB penalty due to a special audible characteristic to the sound. Thus, a level of 50dB L_{Aeq} equates to the rating level for the C59 frost fan operating at 365rpm.

4 Test Results with Fan at 365rpm and 180m

Figure 7 shows the real time noise trace of the frost fan as measured over a 15 minute period when at 180m downwind, which gave two full rotations of the frost fan.

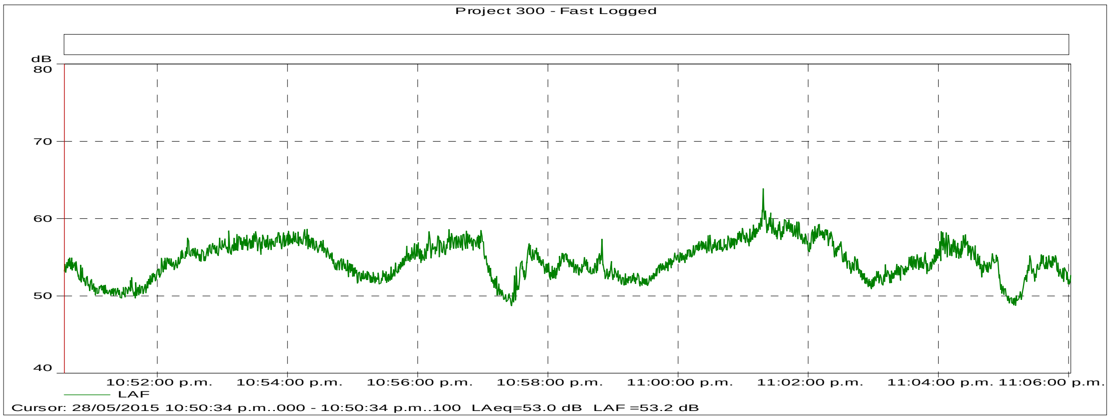

Figure 7. Real Time Noise Trace at 180m

Figure 8 shows the sound spectrum in one third octave bands for the test undertaken at 180m.

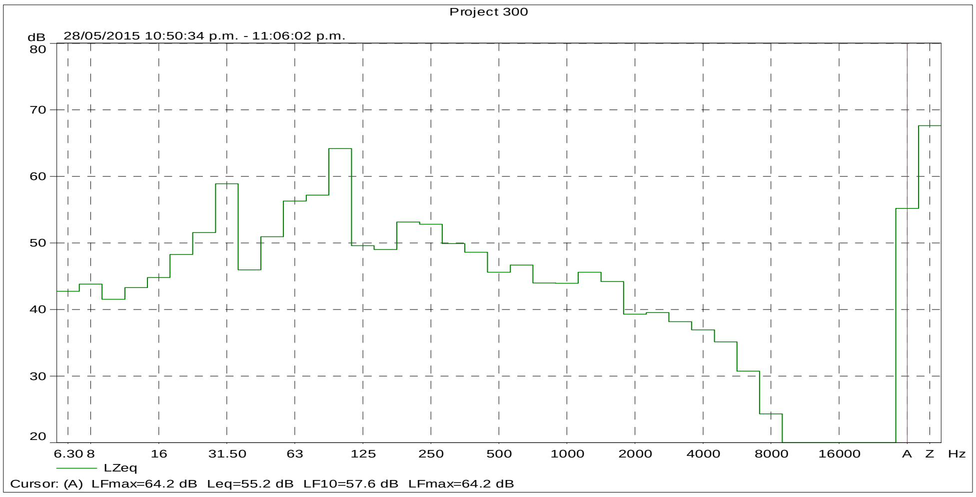

Figure 8. 1/3 Octave Spectrum at 180m – Total Test Duration

Based on the measured level at 180m the noise over a 15 minute period for the Frost Boss C59 frost fan at 365rpm is 55dB L_{Aeq}.

As for the 300m distance, there are no special audible characteristic to the frost fan at 180m.

5 SUMMARY OF RESULTS

A summary of the measured levels of the Frost Boss C59 Frost Fan is set out in Table 1.

	Octave Level , Hz									
	31.5	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**A**
365rpm at 300m – L_{Aeq}	57	59	62	50	46	46	40	32	18	50
365rpm at 180m – L_{Aeq}	60	60	64	57	52	49	46	42	27	55

Based on 15 minute measurement

Table 1. Measured Noise Levels (dB)

6 TEST VARIABLES

6.1 Wind Speed

The above testing was undertaken with wind speeds between 0 – 3km/hr although there the frost fan is designed to operate in wind speed up to 8km/hr so the effects of an increased wind speed has been assessed.

The two potential effects of a change in the wind to that will increase the noise level as received 300m downwind are the positive effects of the sound transmission of noise to the receiver due to the wind and the effects of an increase in the wind on the fan blades and hence a higher noise level or special any audible characteristics may be generated at source.

The analysis of sound propagation has been based on meteorological conditions as set out in Concawe report addressed above and checked against the requirements of ISO 9613-1 *Acoustics - Attenuation of Sound During Propagation Outdoors. Part 1: Calculation of the Absorption of Sound by the Atmosphere* and ISO 9613-2 *Acoustics - Attenuation of Sound During Propagation Outdoors. Part 2: General Method of Calculation*. Each of these documents is referred to in NZS6801:2008. The above measurements of the C59 frost fan were undertaken in Concawe meteorological category 6 conditions. Using the same method to assess the effects of an increased wind to a steady 8km/hr will give a potential increase of 0.5 – 1dB with an 8km/hr wind. A similar result is found if ISO 9613-1/2 is used.

The above is for a constant wind speed of 8km/hr. Figure 9 shows a weather trace over a random 24 hour period with wind speeds representative of the conditions required for a frost fan to operate. As shown on Figure 9 (as also shown on Figure 2) the wind varies continuously there will never be a period with a constant wind throughout any 15 minute measurement so the best that can be achieved is a typical wind pattern.

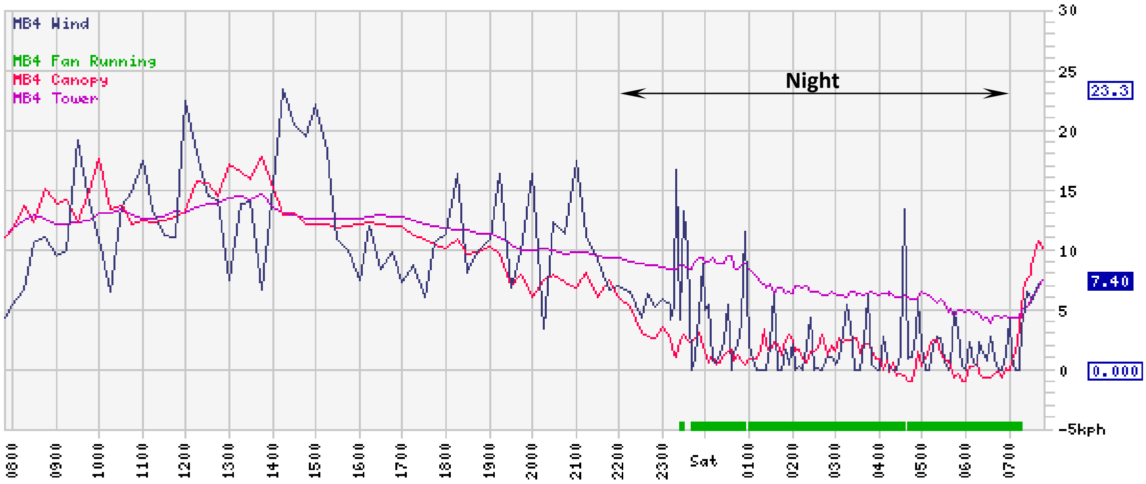

Figure 9. 24 Hour Wind Speed Plot

As set out above, when measured at the same location, and excluding outside noise influences, the same noise level of 50dB L_{Aeq} at 300m (Figures 3 and 5) was measured in different wind speeds. Figure 2 shows the wind condition during the actual measurement period with an average wind speed of 2.5km/hr (0 – 3.3km/hr) for the first measurement and an average wind speed of 1km/hr (0 – 2km/hr) for the second measurement.

In each case the wind varied throughout the 15 minute monitoring period with no apparent change to the measured noise level. The wind was from a stable direction throughout the monitoring. If the wind speed is higher the wind direction is not normally as stable so the receiver noise will drop as the wind deviates from the direct downwind situation.

From the noise trace shown in Figure 5 it can be seen the noise varies by 11dB as the frost fan rotates around the tower with a small component of this variation being be due to the variation of the wind speed.

The frost fan noise requirement in the District Plan as set out in Rule 36.2.7.1.2 states:

> a) *Subject to (b), sound levels shall be measured in accordance with the provisions of NZS 6801:2008 Acoustics – Measurement of Environmental Sound and assessed in accordance with the provisions of NZS 6802: 2008 Acoustics – Environmental Noise;*

Section 5.2 Measurement Time Intervals of NZS 6802:2008 states:

> *A sound environment shall be assessed as it relates to a prescribed time frame, for example, day, evening or night. Thus an appropriate survey period (or periods) shall be selected so that relevant and representative samples of the sound under investigation are obtained* …

In calm conditions the noise level will be similar at any point around the frost fan. However, if it is assumed the steady wind speed of 8km/hr is blowing the noise level will vary by typically 7dB due solely to the effects of being upwind or downwind of the frost fan with approximately an increase of 3dB if downwind and a 4dB reduction if upwind. Clause 7.1.2 of NZS6801:2008 Acoustics - Measurement of Environmental Sound states:

> *To demonstrate compliance, measurements should include or be appropriately adjusted to slightly positive propagation conditions, which are the upper limits of the meteorological window. Therefore when*

> *predicting sound levels it is recommended that slightly enhanced propagation is assumed. Where meteorological conditions vary so that sound from an activity might comply one day but not on another and adjustments are not practical, sufficient measurements shall be made to provide an adequate description of the variation.*

The variation in the noise level for a frost fan is from a negative to positive wind. A negative wind will obviously not fulfill the requirements of NZS6801. If an 8km/hr downwind is adopted this is at the extreme of the measurement range so considered to be more than "slightly positive" plus such a wind is not representative of the actual conditions. A positive wind of 2 – 4km/hr is in the upper noise range from a frost fan (a calculated 0.5 - 1dB lower than the maximum noise likely to be experienced for the C59 frost fan with a steady 8km/hr wind) so is considered to easily satisfy the requirements of NSZ6801.

6.2 Special Audible Characteristics

The second potential change of noise from a frost fan is related to any special audible characteristics that may develop as the wind speed increases at the frost fan.

In addressing this effect previous testing undertaken of the C49 frost fan (which has identical blades as the C59) and the C59 frost fan has been made.

When monitoring the C59 frost fan the wind varied from 0 – 3.3km/hr as shown on Figure 2 above. In addition, between testing there was one period when the wind speed increased to a high of 9km/hr. There was no subjective effect of the higher wind speed on the spectral content of the sound during the different wind speeds and no impulsive noise generated by the wind gust.

From previous tests on the C49 frost fan with a fan speed of 395rpm (engine speed of 1,700rpm) and speed of 418rpm (engine speed of 1,800rpm) in wind conditions ranging from calm to km/hr none of these tests had a tonal sound or exhibited any impulsive sound. The C59 has a fan speed of 365rpm (engine speed of 1,840rpm). Table 2 sets out the comparison of the fans and their tip speeds.

Fan Type	**C49**	**C49**	**C59**
Fan diameter (m)	5.5		
Blade type	Standard C9 series composite		
Fan speed (rpm)	395	418	365
Engine speed (rpm)	1,700	1,800	1,840
Fan tip speed (m/s)	114	120	105
Fan tip speed (km/hr)	410	432	378

Table 2. Comparison of Fan Tip Speeds

The field testing of the C49 frost fan has demonstrated the fan does not exhibit either a tonal or impulsive sound at different operating speeds. From the above table the tip speed of the C59 fan is 32km/hr slower than the C49 operating at 395rpm and 54km/hr slower than the C49 fan operating at 418rpm. In each case the only variation to the operation is the speed of the fan tip; all other aspects of the fan are identical.

As the C59 is operating at the lowest tip speed, and it is the tip speed that controls the tone and impulsive sound, it is reasonable to conclude the C59 will not have any special audible characteristics over a wind speed range of 0 – 8km/hr. This is because the C59 is operating at a lower tip speed and this is the reason the noise has been reduced compared with the C49 (and other types of frost fan).

7 CONCLUSIONS

Based on the above the Frost Boss C59 Frost Fan will not have any tonal or impulsive sound when operating in wind conditions varying from 0 – 8km/hr.

When measured in accordance with the requirements of NZS 6801:2008 *Acoustics - Measurement of Environmental Sound* and assessed in accordance with the requirements of NZS 6802:2008 *Acoustics – Environmental Noise* the noise from the Frost Boss C59 frost fan operating at 365rpm is 50dB L_{Aeq} when measured at 300m and 55dB L_{Aeq} when measured at 180m.

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