Directivity

5.3.15. Table 5-3 shows the directivity in noise emissions from the unit by comparing the noise levels at the different microphones, for a typical period of ASHP operation.

Table 5-3: Directivity Analysis of the ASHP Noise Emissions $L_{Aeq(1min)}$ dB 418 Central Buchan, normal operation

Microphone Location	Front	Left	Right	Above
Typical Microphone Level	57	55	56	54
Change from front microphone	-	-2	-1	-3

5.3.16. It is seen that the ASHP is slightly directional to the front of the unit.

Frequency analysis

5.3.17. For the frequency analysis, a Fast Fourier Transform (FFT) of the signal was performed, averaged over a representative one minute period at a frequency resolution of 2 Hz. The resulting frequency spectrum for the ASHP operating under normal conditions is given in Figure 5-22, with that for the defrost cycle presented in Figure 5-23.

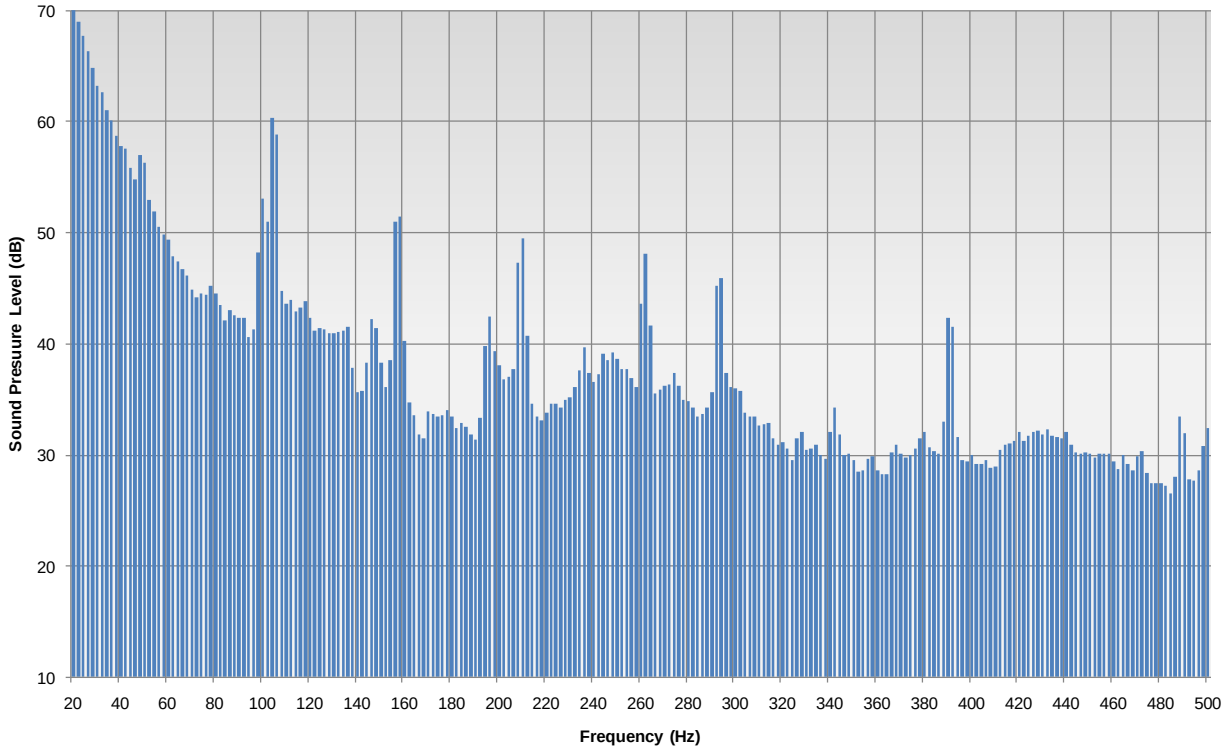


Figure 5-22. 418 Central Buchan, Sound Pressure Level Spectrum (Normal Operation)

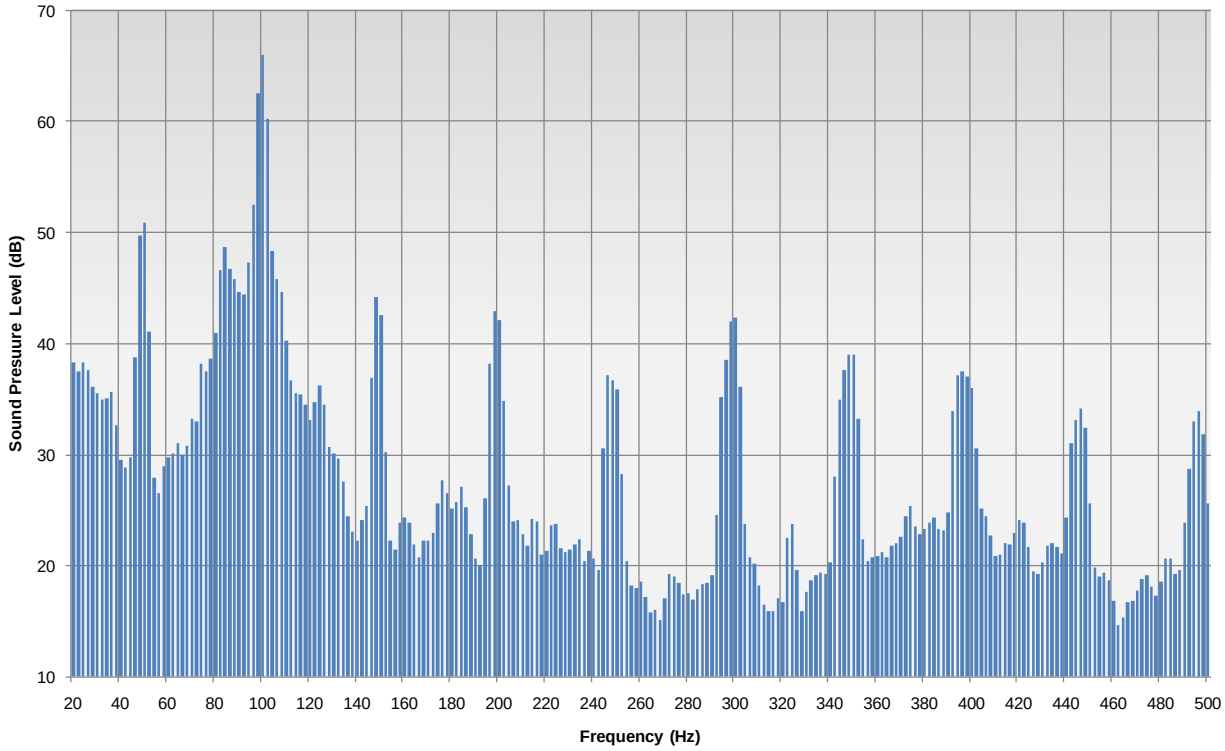


Figure 5-23. 418 Central Buchan, Sound Pressure Level Spectrum (Defrost Cycle)

5.3.18. Tonal analysis of the frequency spectra shown in Figure 5-22 and Figure 5-23 has been undertaken in accordance with the Joint Nordic Method (v2). The resulting tonal assessments are presented in Figure 5-23 and Figure 5-24, showing that the tones identified within the spectrum for normal operation would lead to a **2 dB tonal penalty**. During the defrost cycle, the tonal assessment indicates that a **6 dB tonal penalty** would be appropriate.

Figure 5-24. 418 Central Buchan Tonal Assessment (Normal Operation)

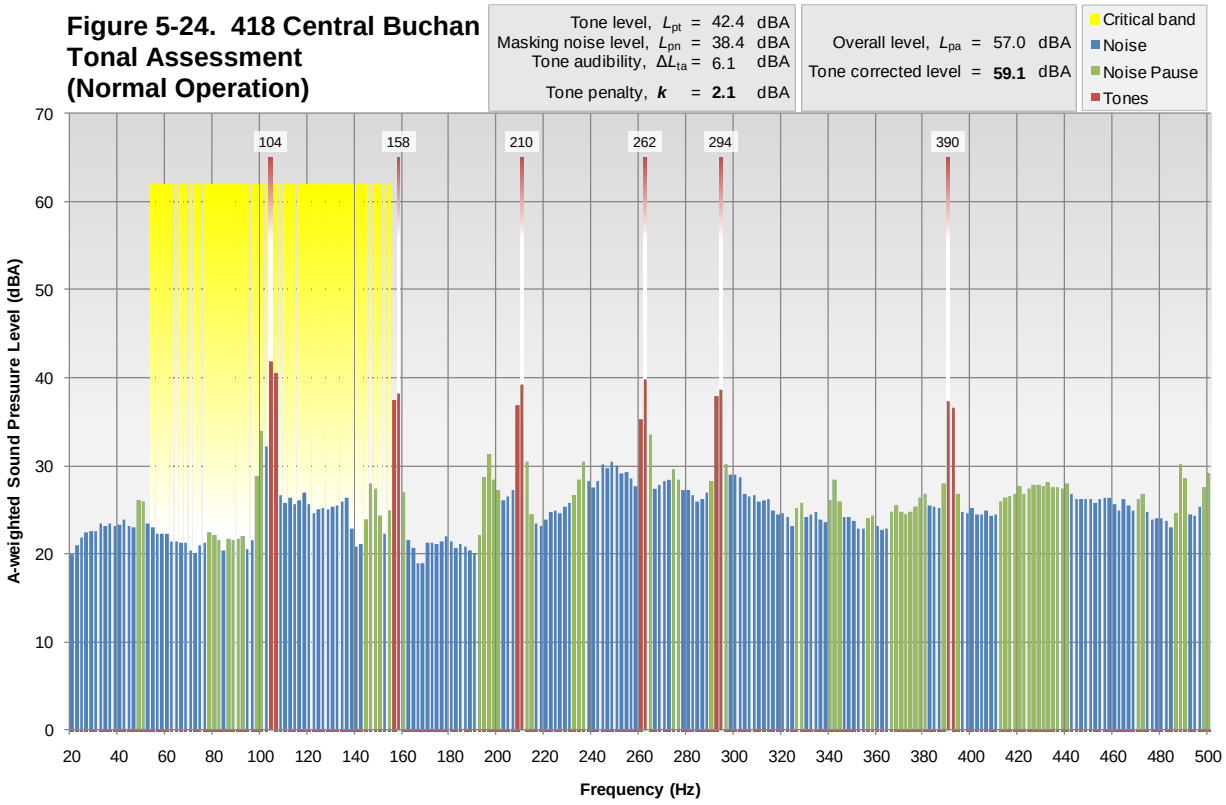
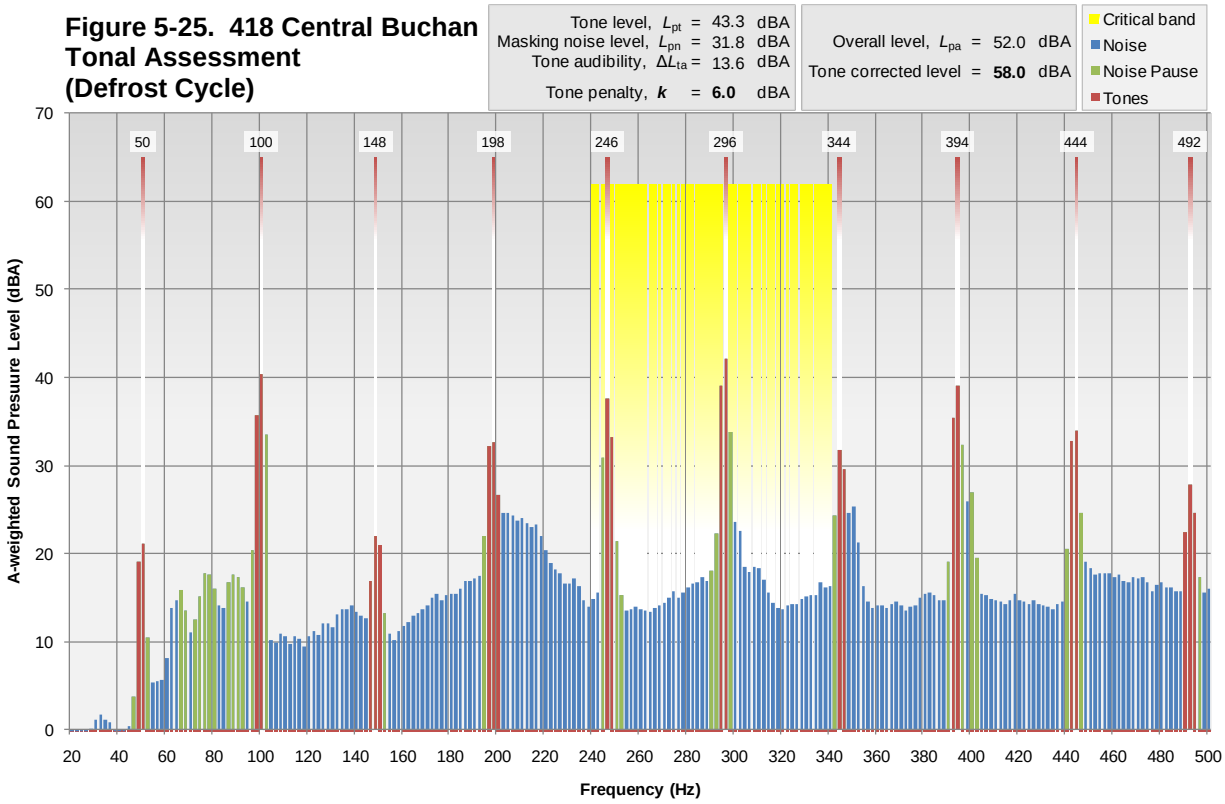


Figure 5-25. 418 Central Buchan Tonal Assessment (Defrost Cycle)



Sound Power Level calculations

5.3.19. Figure 5-8 presents a statistical analysis plot of the percentage of time that a specific sound power level would be recorded, when the ASHP is under operation. This assumes that the ASHP is located in the common mounting scenario as detailed in Section 3.42, which is not necessarily representative of the actual measured condition.

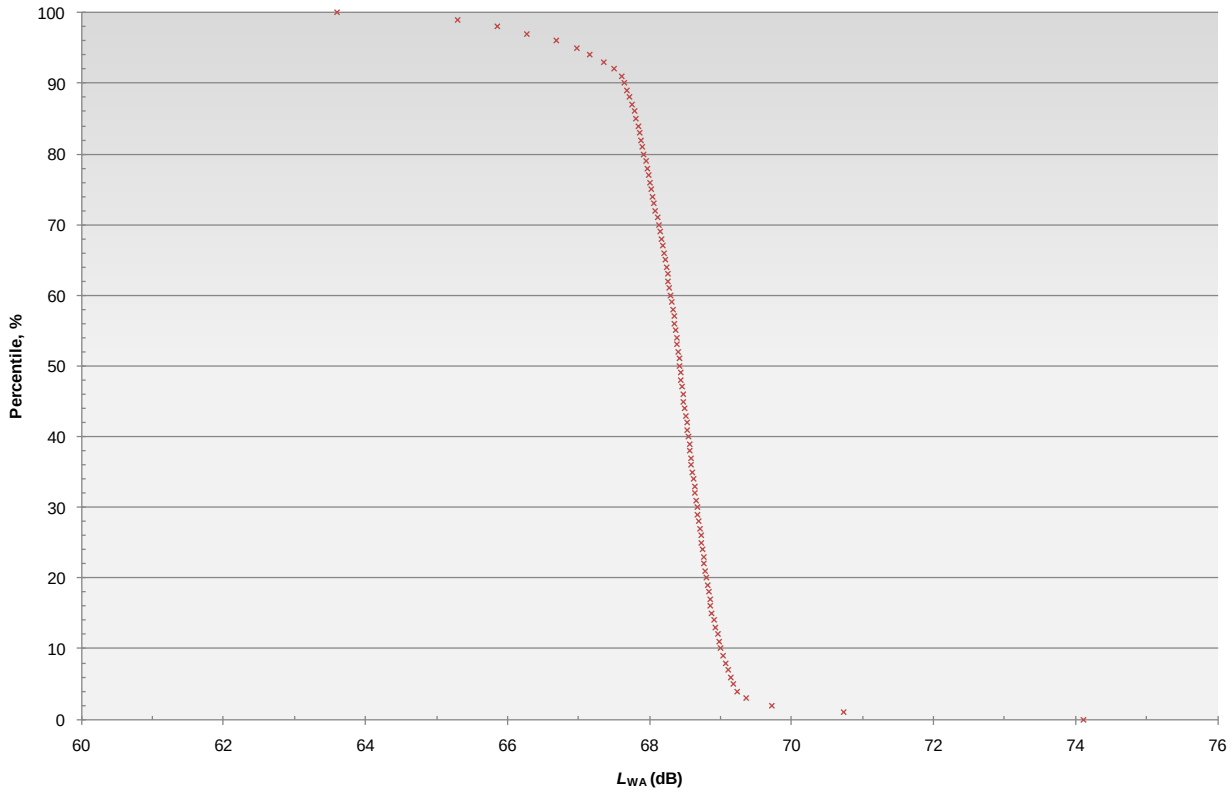


Figure 5-26. 418 Central Buchan, Sound Power Level Statistical Analysis

5.3.20. The chart indicates that noise from the ASHP during operation will have a 90% certainty of being within around 1 dB of $\boldsymbol{L_{WA}}$ **68 dB.**

5.3.21. Use of Equation 1 leads to an estimation that noise levels from the unit operating normally would drop to L_{Aeq} 42 dB at a distance separation of approximately **11 m**. If a tonal penalty were to be included, then this distance would rise to around **14 m**.

Discussion

5.3.22. Whilst the manufacturer has not provided us with detailed information on the fan and compressor speeds, analysis of the ASHP noise data suggests that the fan speed was 790 rpm, and included four fan blades. The fan configuration corresponds with a blade passing frequency of 53 Hz, with second, third and fourth harmonics at 104, 158 and 210 Hz respectively. The compressor was of a scroll type with an unknown speed. Analysis of the defrost cycle frequency

spectrum suggests however that the primary tone is at around 50Hz, which corresponds with a rotational speed of 3000 rpm, typical for this type of compressor. Harmonics of this tone are seen at multiple frequencies in the spectrum, as displayed in the FFT analysis charts for the defrost cycle.

5.3.23. During normal operation, the fan contributes a greater amount of noise than the compressor, although tonal content provided by the compressor is audible.

5.4 *422 Fraserburgh (Original ASHP)*

Site description

5.4.1. The property is located in a rural area off a quiet road. The ASHP is located to the side of the brick built single story detached property. The unit is seated on concrete paving slab footings.

5.4.2. This section details the results for the original ASHP that was subsequently replaced, the results of which will be presented separately.

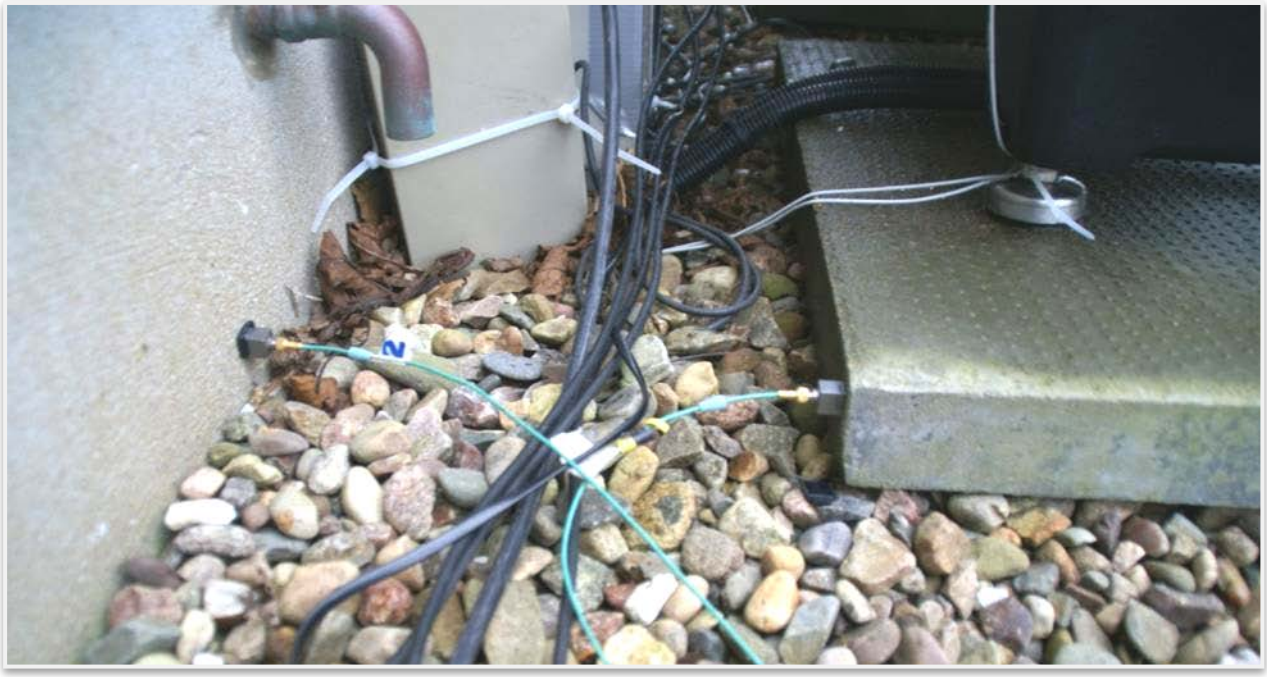
5.4.3. Subjectively the unit appeared to be operating normally with no audible rattle, resonance or fault.

Equipment set up

5.4.4. The 9 Channel PULSE system was used at this site.

5.4.5. The ASHP was located on reflective ground, and in front of a reflective wall.

5.4.6. Accelerometers were fixed to the footings and to the wall surface immediately behind the unit, as shown in Picture 5-10. The accelerometers were fixed to the surfaces using cyanoacrylate cement.



Picture 5-10. 422 Fraserburgh (Original), Footing and Wall-mounted Accelerometers

5.4.7. The microphones were mounted on heavy-duty tripods as shown in Picture 5-11 and Picture 5-12. All microphones were positioned 1 m from the ASHP casing.

Picture 5-11. 422 Fraserburgh, Original ASHP and Microphone Arrangement

Picture 5-12. 422 Fraserburgh, Original ASHP and Microphone Arrangement

Measurement Results

5.4.8. The results given by the energy measurements were found to be erroneous for the per-minute logging. The logging data has therefore been used from the alternative per-five-minute logging system.

5.4.9. Figure 5-27 presents the $L_{Aeq(1min)}$ measured noise levels at the microphone 1m in front of the unit set against time, along with the per-five-minute logged ASHP power consumption.

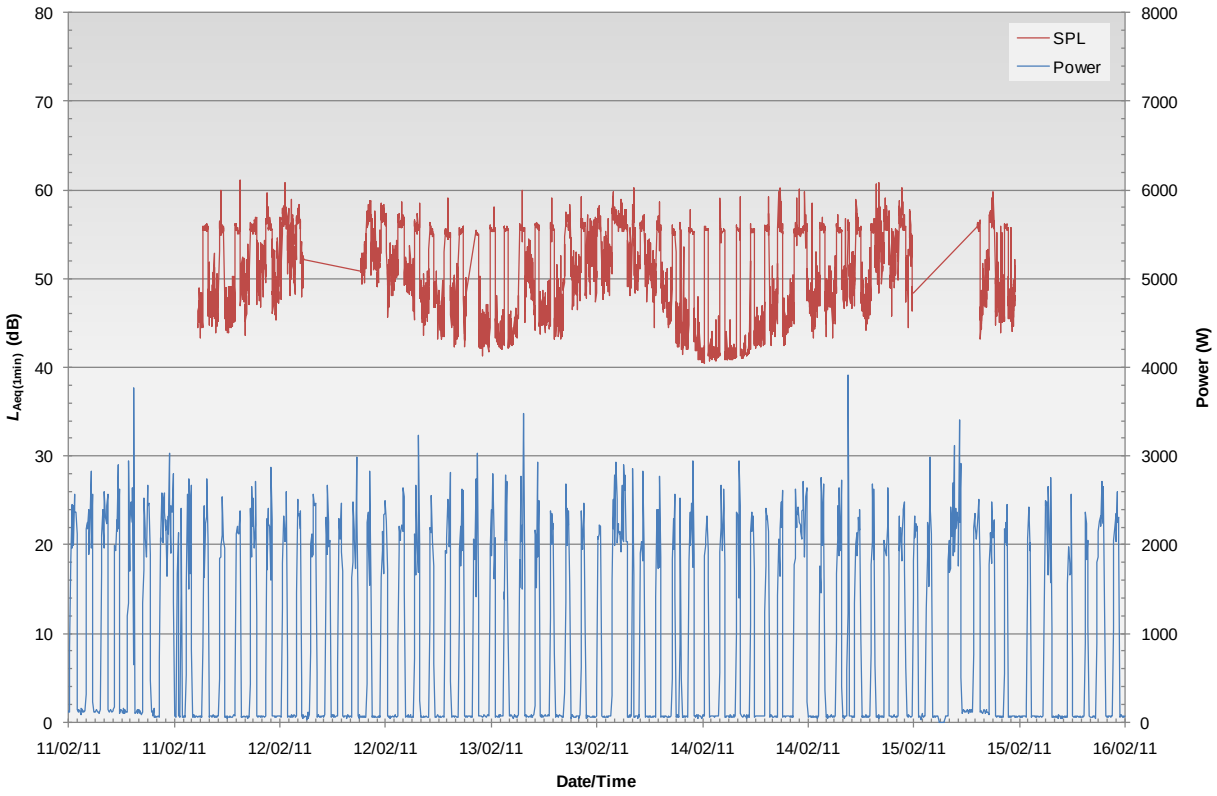


Figure 5-27. 422 Fraserburgh (Original ASHP), Sound Pressure Level and Power Consumption vs Time

5.4.10. The PULSE system stopped recording on two occasions and had to be reset.

5.4.11. The data highlights that the ASHP is cycling on and off approximately every two hours, consistently throughout the day and night-time periods. Throughout the measurement period, the ASHP was operational for approximately 29% of the time.

5.4.12. The trace clearly shows the increase in measured noise level during periods when the ASHP is operating.

Measurement Analysis

5.4.13. Figure 5-28 presents a scatter diagram showing the noise levels against the power consumption, for the periods when the ASHP was operating. It is seen that the sound pressure level has no dependence on the power output of the ASHP.

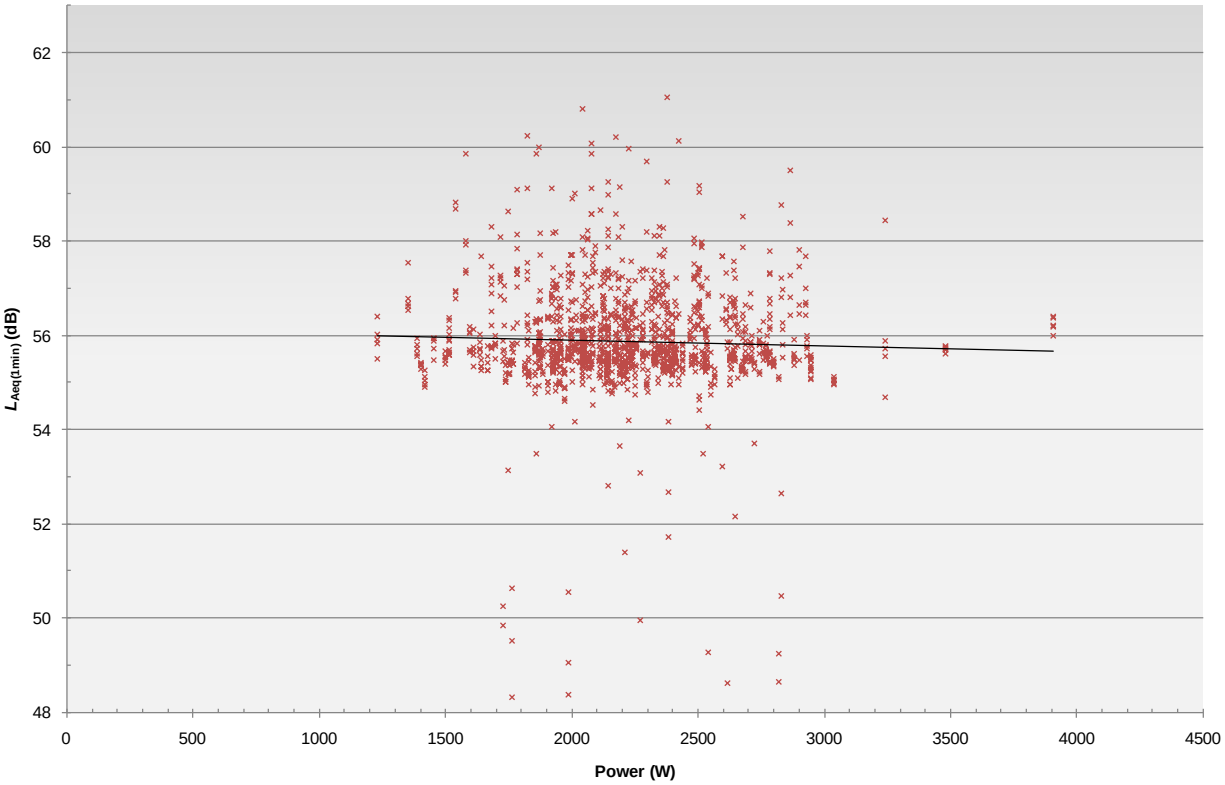


Figure 5-28. 422 Fraserburgh (Original ASHP), Sound Pressure Level vs Power Consumption

5.4.14. Figure 5-29 presents a statistical analysis plot of the percentage of time that a specific noise level would be recorded, when the ASHP is under operation. From this confidence intervals can be presented for the typical noise levels.

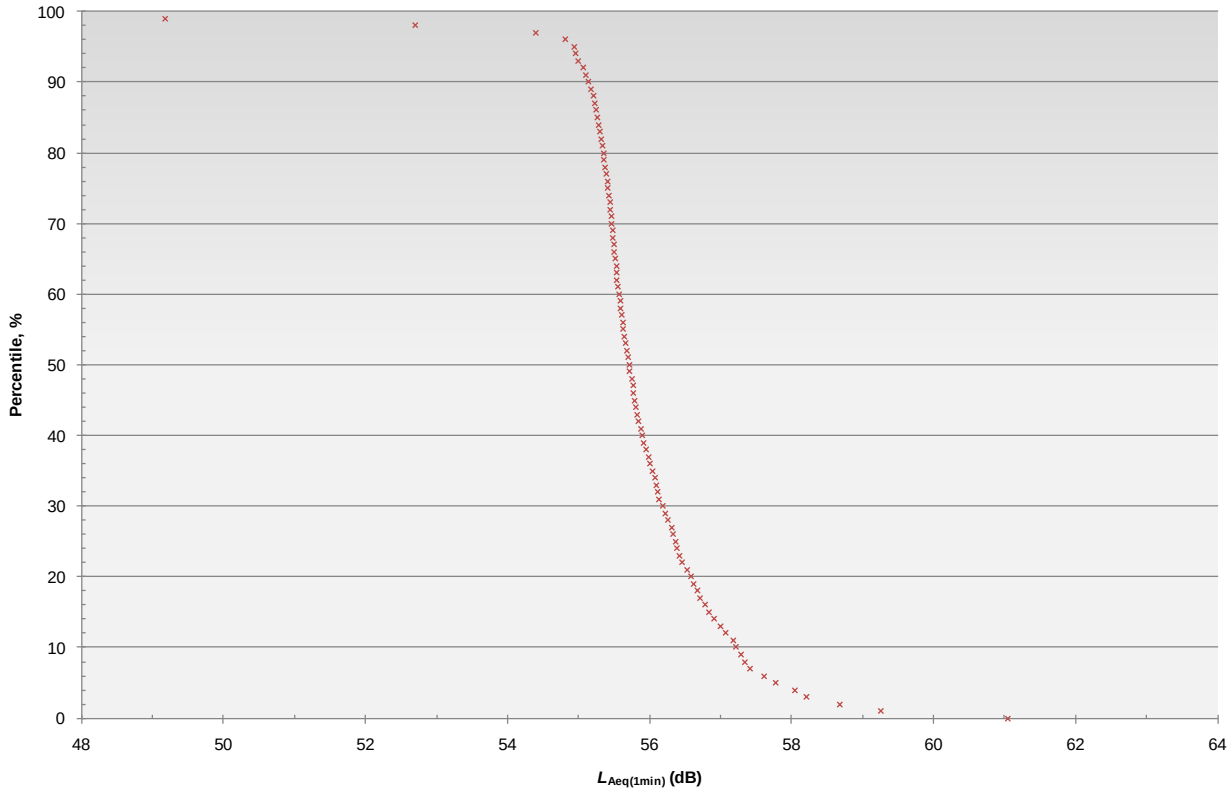


Figure 5-29. 422 Fraserburgh (Original ASHP), Sound Pressure Level Statistical Analysis

5.4.15. The chart indicates that noise from the ASHP during operation will have a 90% certainty of being within around 1.5 dB of $L_{Aeq(1min)}$ **56 dB**. The corresponding total ASHP noise dose over the whole assessment period is calculated as $L_{Aeq(1week)}$ 51 dB.

Defrost Cycle

5.4.16. Analysis of the measurements revealed that defrost cycles are part of the ASHP operation. During these periods, which can last for 3 to 4 minutes, the compressor is operating in reverse, without the fan. The average sound pressure level during a typical defrost cycle is around $L_{Aeq(1min)}$ **54 dB**.

Directivity

5.4.17. Table 5-4 shows the directivity in noise emissions from the unit by comparing the noise levels at the different microphones, for a typical period of ASHP operation.

Table 5-4: Directivity Analysis of the ASHP Noise Emissions $L_{Aeq(1min)}$ dB 422 Fraserburgh (Original ASHP), normal operation

Microphone Location	Front	Left	Right	Above
Typical Microphone Level	56	54	56	52
Change from front microphone	-	-2	0	-4

5.4.18. It is seen that the ASHP exhibits a slight directivity, such that noise is greater in line with the fan, and on the side nearest the compressor (i.e. the right hand side for this ASHP).

Frequency analysis

5.4.19. For the frequency analysis, a Fast Fourier Transform (FFT) of the signal was performed, averaged over a representative one minute period at a frequency resolution of 2 Hz. The resulting frequency spectrum for the ASHP operating under normal conditions is given in Figure 5-30, with that for the defrost cycle presented in Figure 5-31.

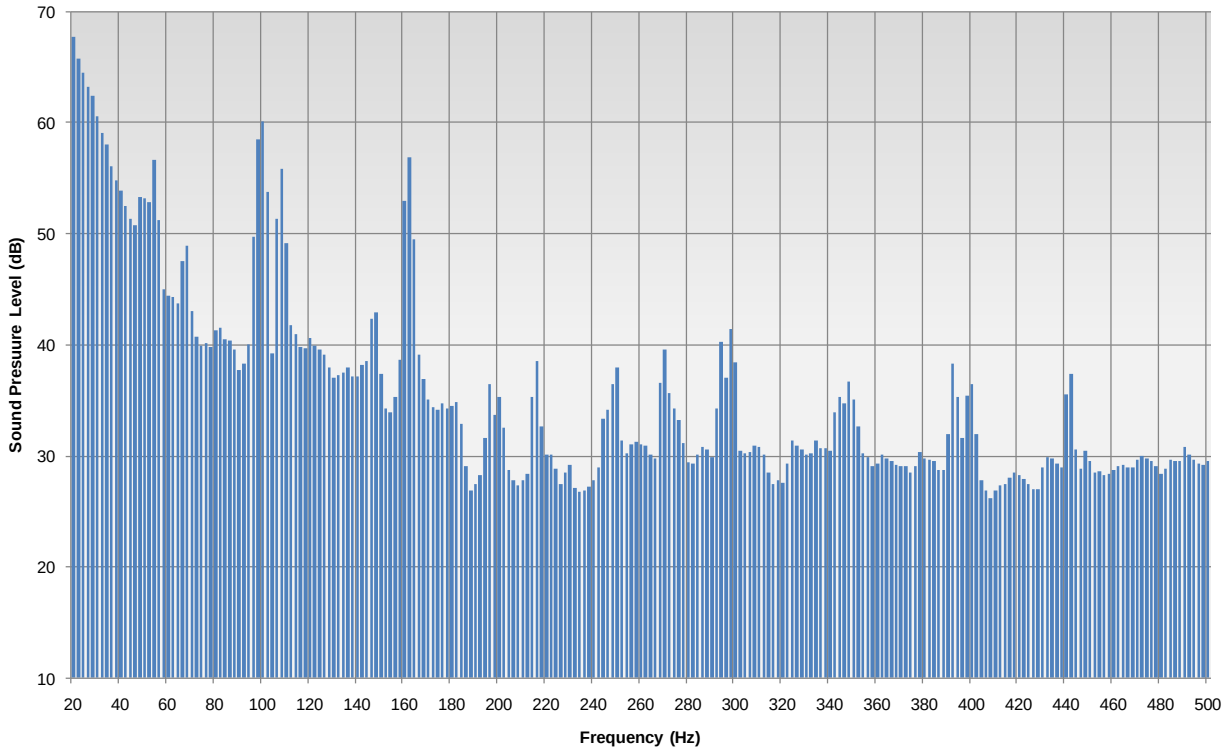


Figure 5-30. 422 Fraserburgh (Original ASHP), Sound Pressure Level Spectrum (Normal Operation)

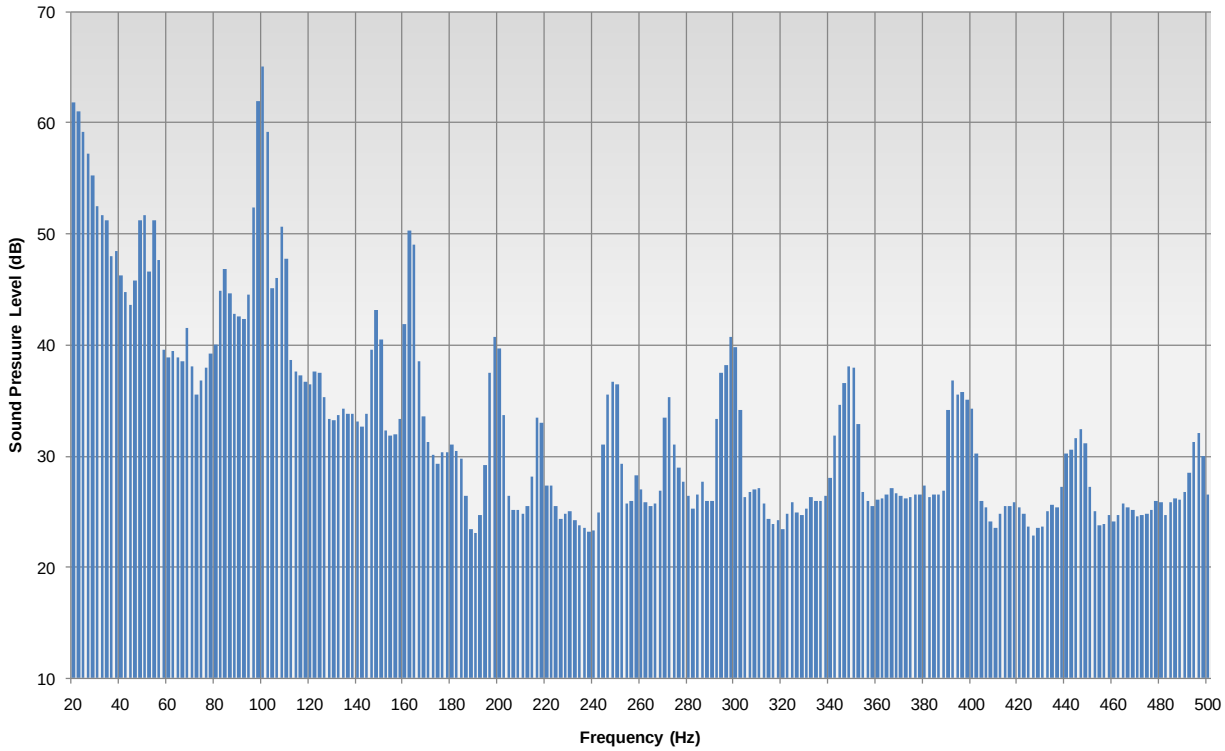
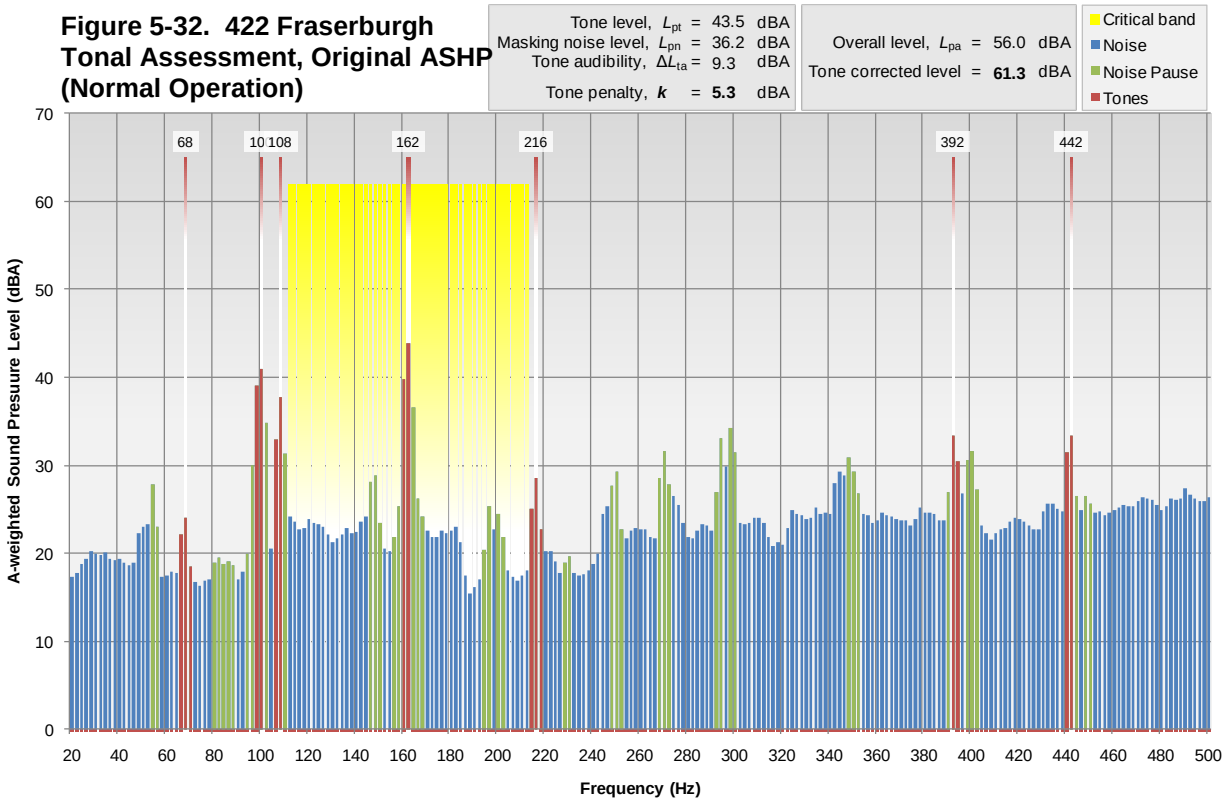


Figure 5-31. 418 Fraserburgh (Original ASHP), Sound Pressure Level Spectrum (Defrost Cycle)

5.4.20. Tonal analysis of the frequency spectra shown in Figure 5-30 and Figure 5-31 has been undertaken in accordance with the Joint Nordic Method (v2). The resulting tonal assessments are presented in Figure 5-31 and Figure 5-32, showing that the tones identified within the spectrum for normal operation would lead to a **5 dB tonal penalty**. During the defrost cycle, the tonal assessment indicates that a **6 dB tonal penalty** would be appropriate.

Figure 5-32. 422 Fraserburgh Tonal Assessment, Original ASHP (Normal Operation)



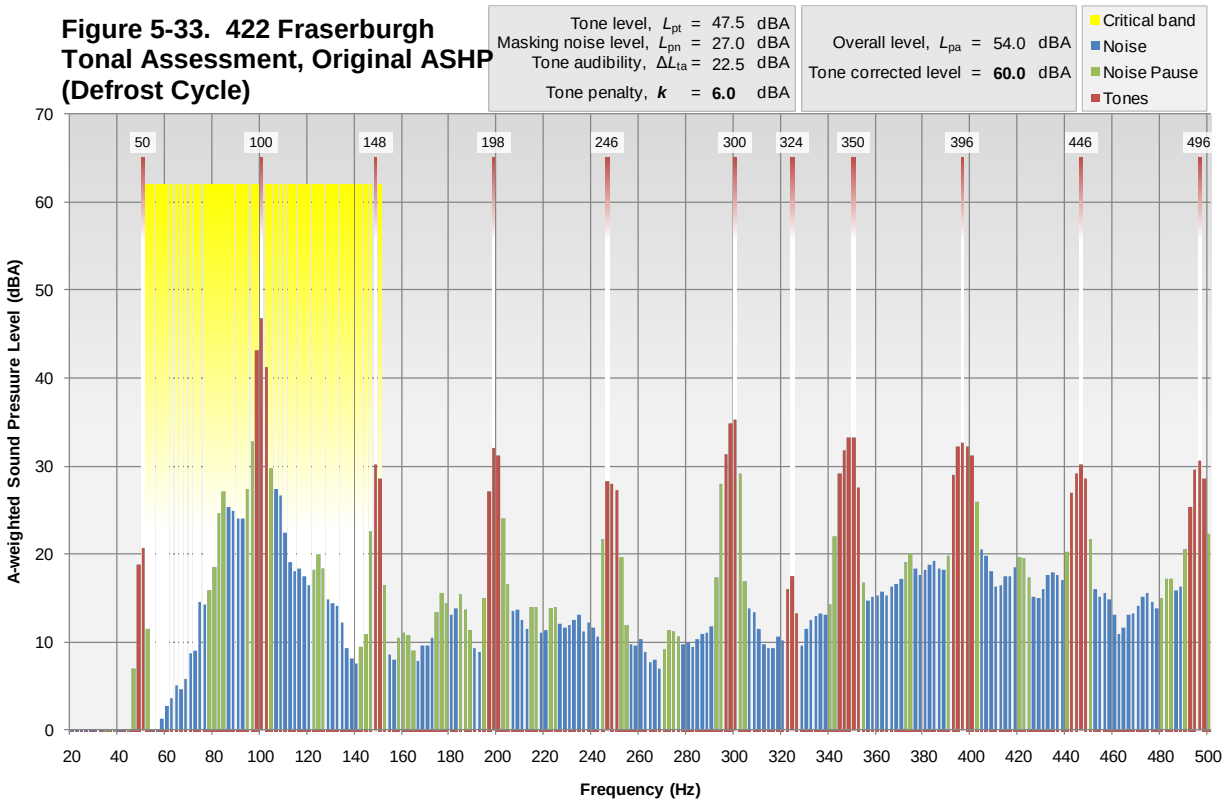


Figure 5-33. 422 Fraserburgh Tonal Assessment, Original ASHP (Defrost Cycle)

Sound Power Level calculations

5.4.21. Figure 5-34 presents a statistical analysis plot of the percentage of time that a specific sound power level would be recorded, when the ASHP is under operation.

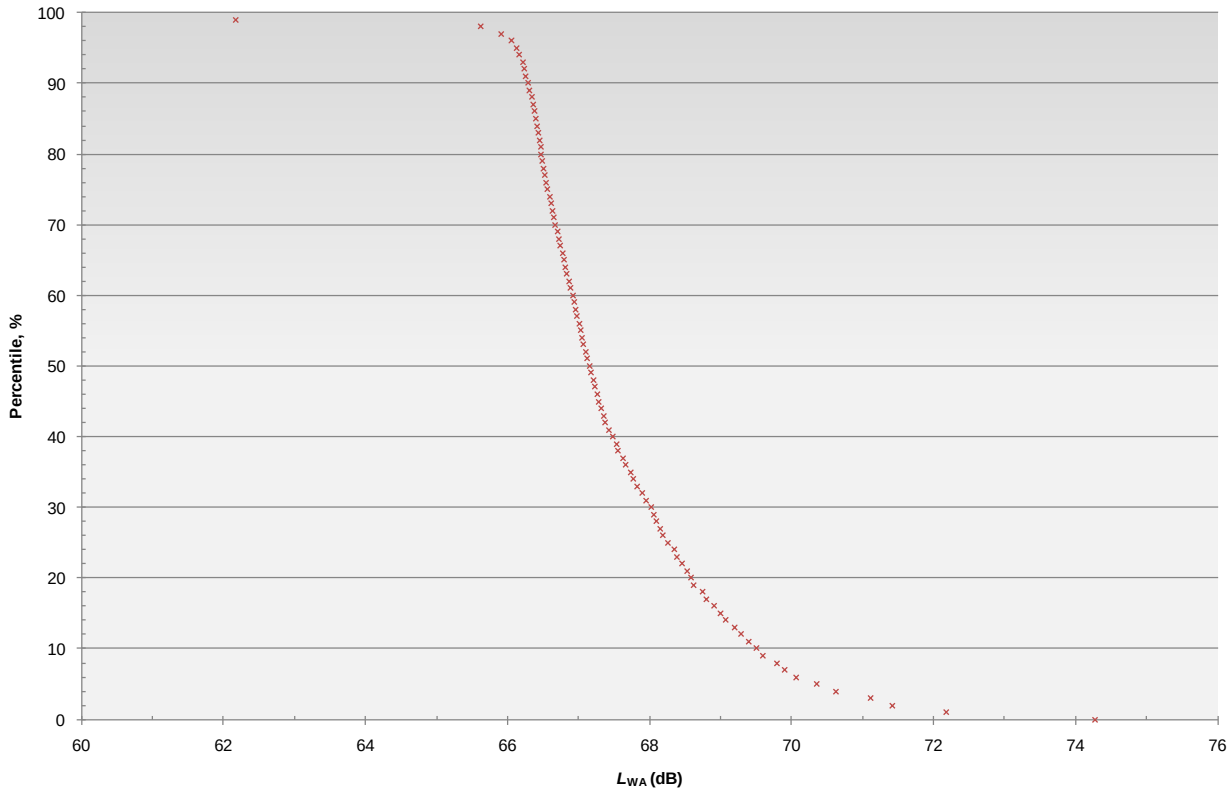


Figure 5-34. 422 Fraserburgh (Original ASHP), Sound Power Level Statistical Analysis

5.4.22. The chart indicates that noise from the ASHP during operation will have a 90% certainty of being within around 2 dB of $\boldsymbol{L_{WA}}$ **67 dB.**

5.4.23. Use of Equation 1 leads to an estimation that noise levels from the unit operating normally would drop to L_{Aeq} 42 dB at a distance separation of approximately **10 m**. If a tonal penalty were to be included, then this distance would rise to around **18 m**. This assumes that the ASHP is located in the common mounting scenario as detailed in Section 3.42, which is not necessarily representative of the actual measured condition.

Vibration

5.4.24. An FFT analysis of the vibration levels recorded for normal operation of the ASHP is shown in Figure 5-35. The overall weighted peak vibration level at the wall surface was 0.0035 ms^{-2}, significantly below the average perception threshold for whole-body vibration.

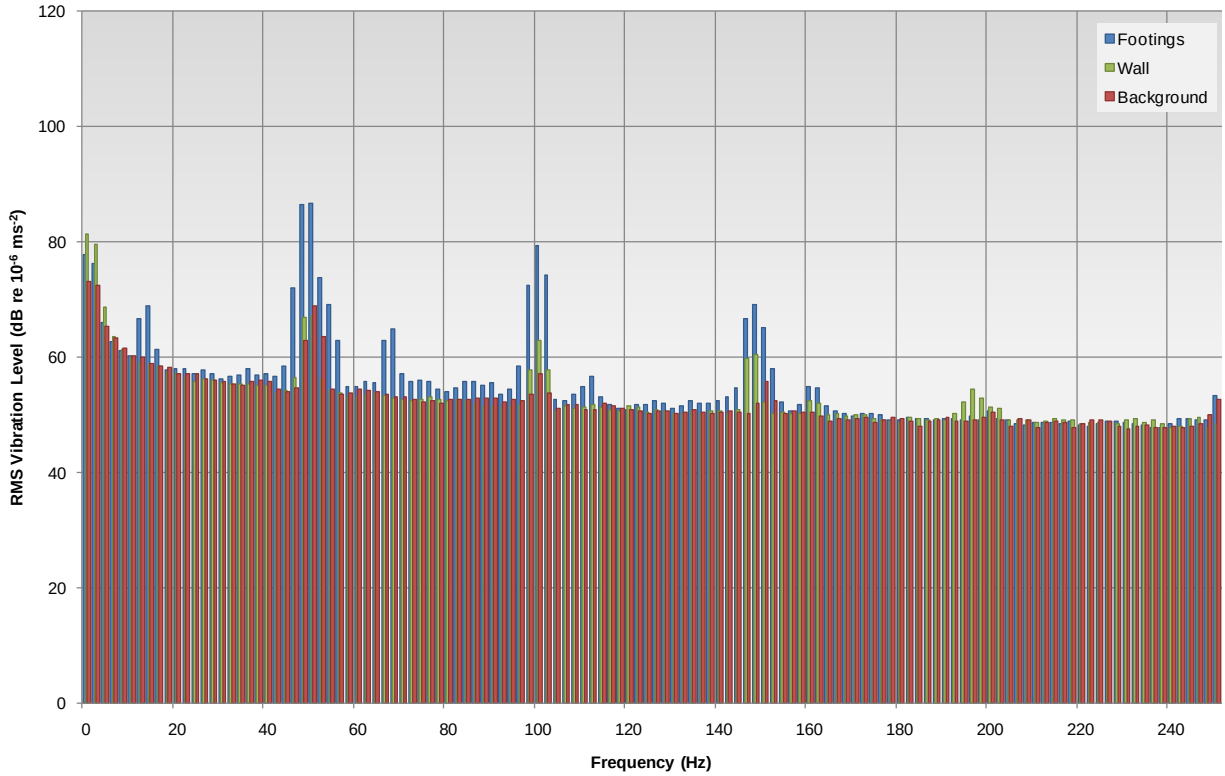


Figure 5-35. 422 Fraserburgh (Original ASHP), Vibration Levels

Discussion

5.4.25. Whilst the manufacturer has not provided us with detailed information on the fan and compressor speeds, inspection of the results and experience of similar units suggest that the fan speed was around 810 rpm, and included four fan blades. This fan configuration corresponds with a blade passing frequency of 54 Hz, with second and third harmonics at 108 and 162 Hz respectively. These effects are seen prominently in the frequency spectrum for normal operation. The compressor was of a scroll type with an unknown speed. Analysis of the defrost cycle frequency spectrum suggests however that the primary tone is at around 50Hz, which corresponds with a rotational speed of 3000 rpm, typical for this type of compressor. Harmonics of this tone are seen at multiple frequencies in the spectrum.

5.4.26. During normal operation, the fan contributes a greater amount of noise than the compressor, although the tonal content provided by compressor is audible.

5.4.27. The vibration data shows that the compressor contributes greatest to the vibration emissions, with a small amount of vibration caused by the fan.

5.5 *422 Fraserburgh, Aberdeenshire (Replacement ASHP)*

Site description

5.5.1. The site is identical to that detailed above.

5.5.2. This section details the results for the replacement ASHP.

5.5.3. Subjectively the unit appeared to be operating normally with no audible rattle, resonance or fault.

Equipment set up

5.5.4. The 5 Channel PULSE system was used at this site.

5.5.5. The ASHP was located on reflective ground, and in front of a reflective wall.

5.5.6. An accelerometer was fixed to the casing of the ASHP, as shown in Picture 5-13. The accelerometer was fixed to the surface using cyanoacrylate cement.

Picture 5-13. 422 Fraserburgh (Replacement), Casing-mounted Accelerometer

5.5.7. The microphones were mounted on heavy-duty tripods as shown in Picture 5-14. All microphones were positioned 1 m from the ASHP casing.

Picture 5-14. 422 Fraserburgh, Replacement ASHP and Microphone Arrangement

Measurement Results

5.5.8. Figure 5-36 presents the $L_{Aeq(1min)}$ measured noise levels at the microphone 1m in front of the unit set against time, along with the ASHP power consumption.

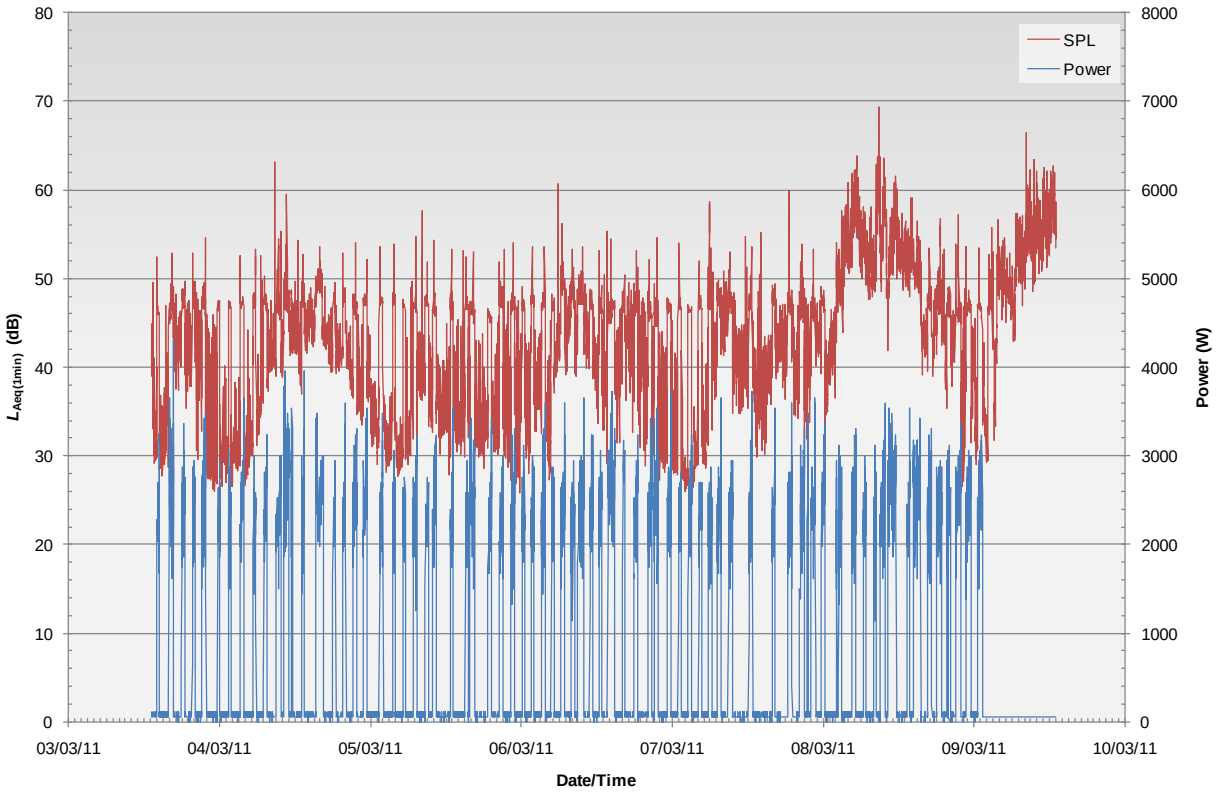


Figure 5-36. 422 Fraserburgh (Replacement), SPL and Power Consumption vs Time

5.5.9. The data highlights that the ASHP is cycling on and off approximately every two and a half hours, consistently throughout the day and night-time periods. Throughout the measurement period, the ASHP was operational for approximately 30% of the time.

5.5.10. The trace clearly shows the increase in measured noise level during periods when the ASHP is operating.

5.5.11. Due to high winds on the 8th and 9th March, these periods have been excluded from the analysis.

Measurement Analysis

5.5.12. Figure 5-37 presents a scatter diagram showing the noise levels against the power consumption, for the periods when the ASHP was operating. It is seen that the sound pressure level has no dependence on the power output of the ASHP.

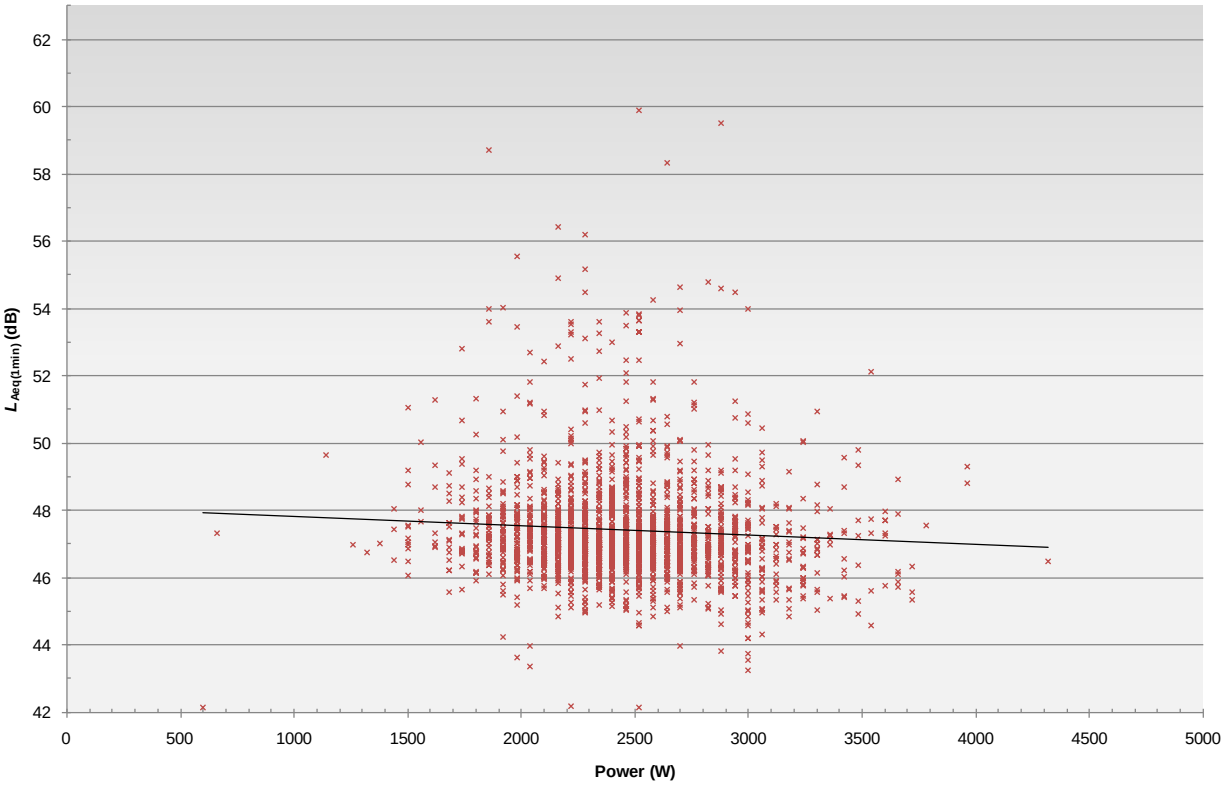


Figure 5-37. 422 Fraserburgh (Replacement), SPL vs Power Consumption

5.5.13. Figure 5-38 presents a statistical analysis plot of the percentage of time that a specific noise level would be recorded, when the ASHP is under operation. From this confidence intervals can be presented for the typical noise levels.

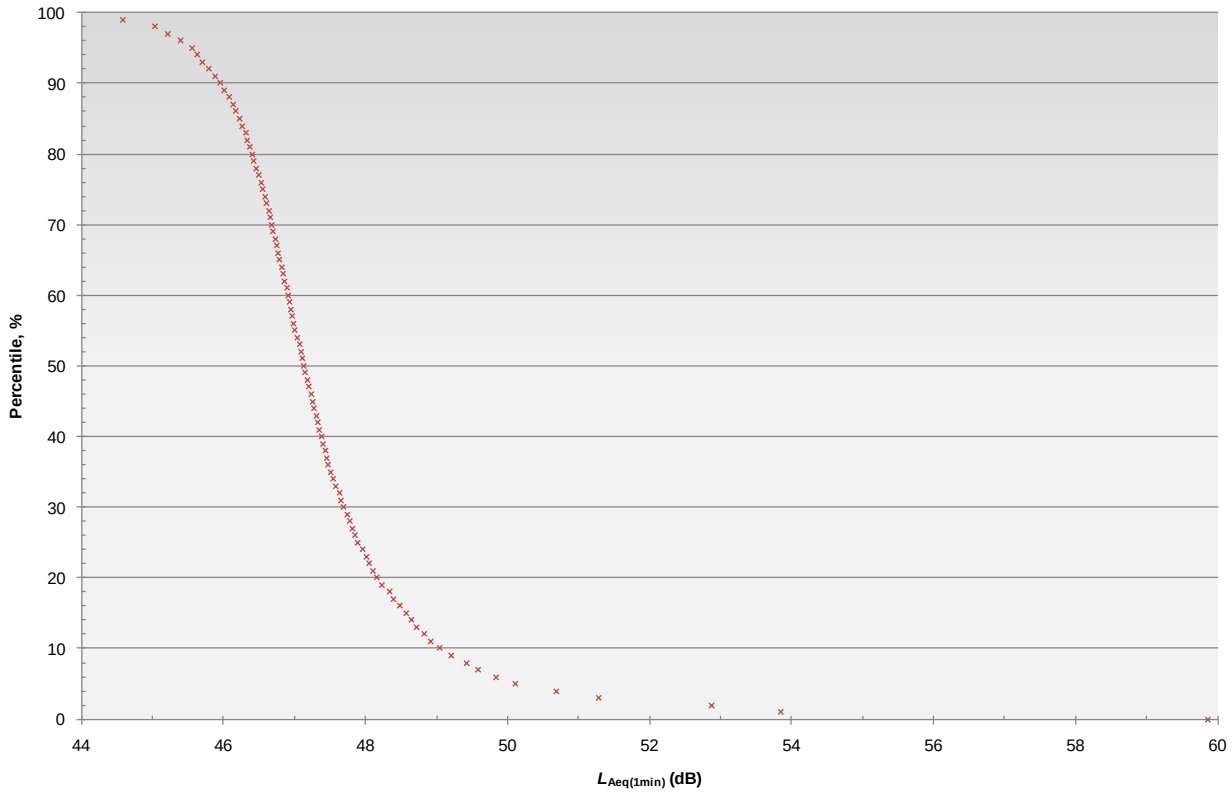


Figure 5-38. 422 Fraserburgh (Replacement), Sound Pressure Level Statistical Analysis

5.5.14. The chart indicates that noise from the ASHP during operation will have a 90% certainty of being within around 2 dB of $\boldsymbol{L_{Aeq(1min)}}$ **47 dB**. The corresponding total ASHP noise dose over the whole assessment period is calculated as $L_{Aeq(1week)}$ 42 dB.

Defrost Cycle

5.5.15. Analysis of the measurements revealed that defrost cycles are part of the ASHP operation. During these periods, which can last for 1 to 2 minutes, the compressor is operating in reverse, without the fan. The average sound pressure level during a typical defrost cycle is around $\boldsymbol{L_{Aeq(1min)}}$ **50 dB**.

Directivity

5.5.16. Table 5-5 shows the directivity in noise emissions from the unit by comparing the noise levels at the different microphones, for a typical period of ASHP operation.

Table 5-5: Directivity Analysis of the ASHP Noise Emissions $L_{Aeq(1min)}$ dB 422 Fraserburgh (Replacement), normal operation

Microphone Location	Front	Left	Right	Above
Typical Microphone Level	47	44	45	45
Change from front microphone	-	-3	-2	-2

5.5.17. It is seen that the ASHP exhibits a slight directivity, such that noise is greater in line with the fan.

Frequency analysis

5.5.18. For the frequency analysis, a Fast Fourier Transform (FFT) of the signal was performed, averaged over a representative one minute period at a frequency resolution of 2 Hz. The resulting frequency spectrum for the ASHP operating under normal conditions is given in Figure 5-39, with that for the defrost cycle presented in Figure 5-40.

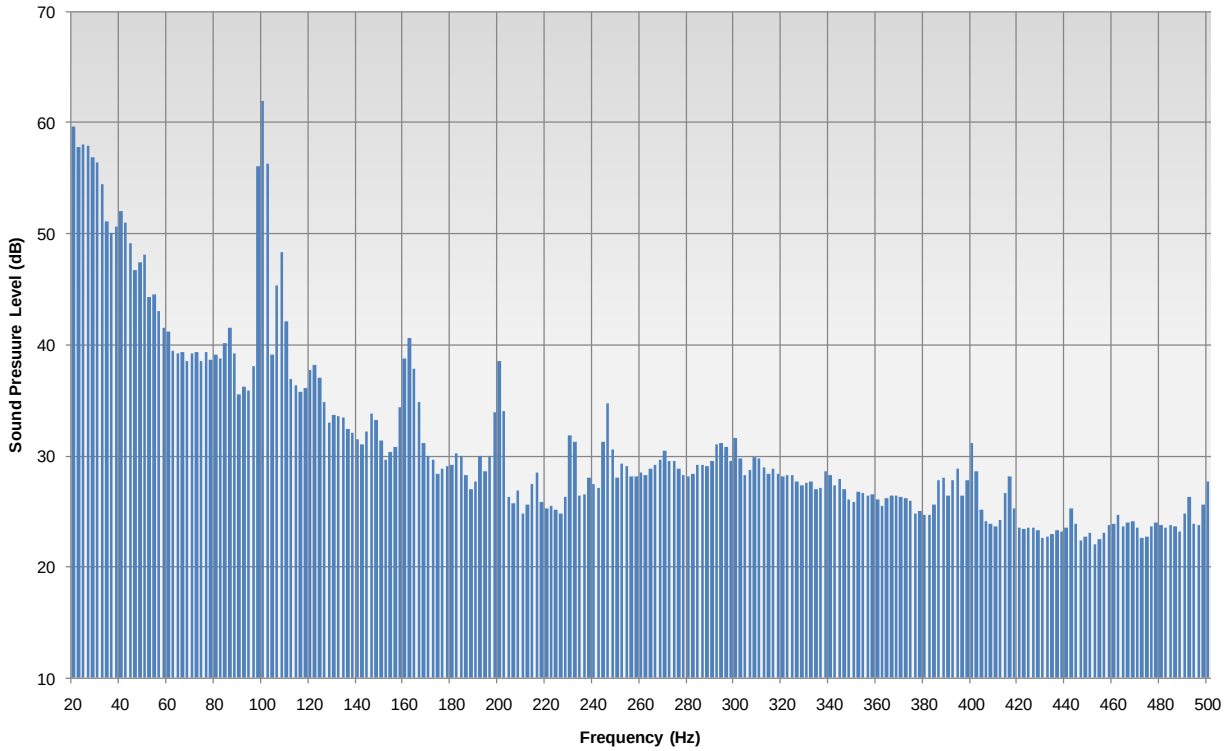


Figure 5-39. 422 Fraserburgh (Replacement), SPL Spectrum (Normal Operation)

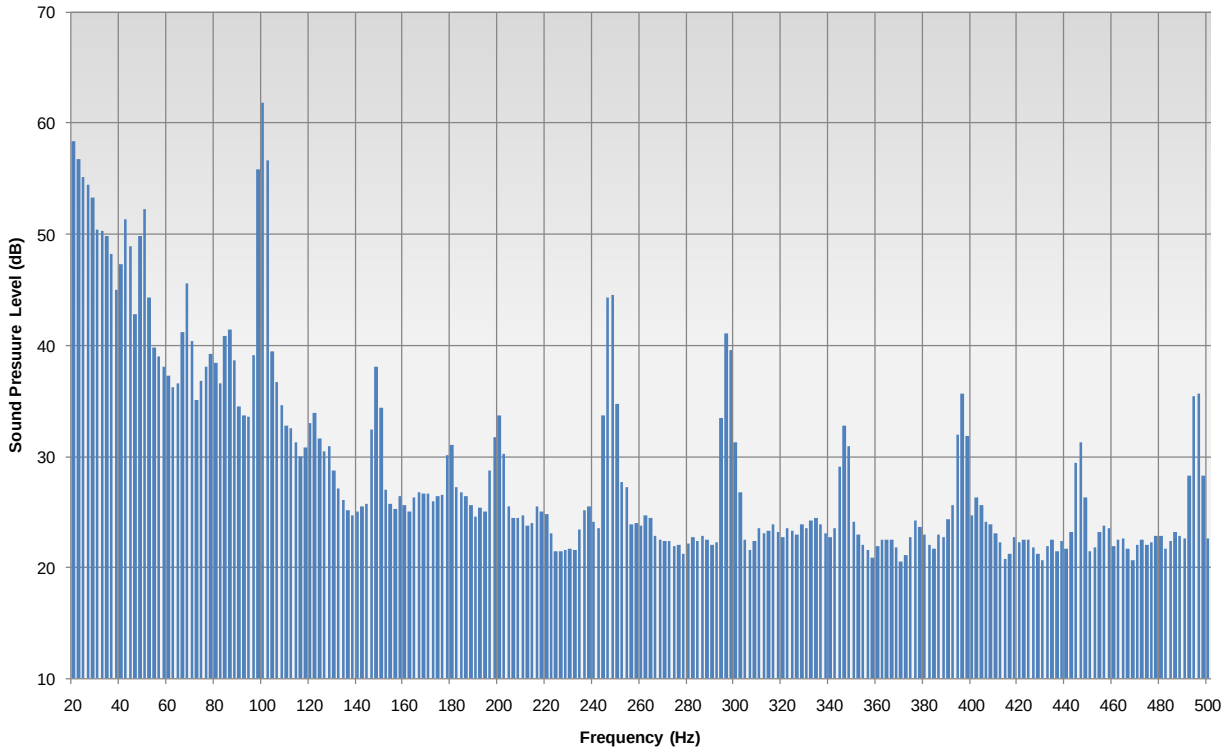
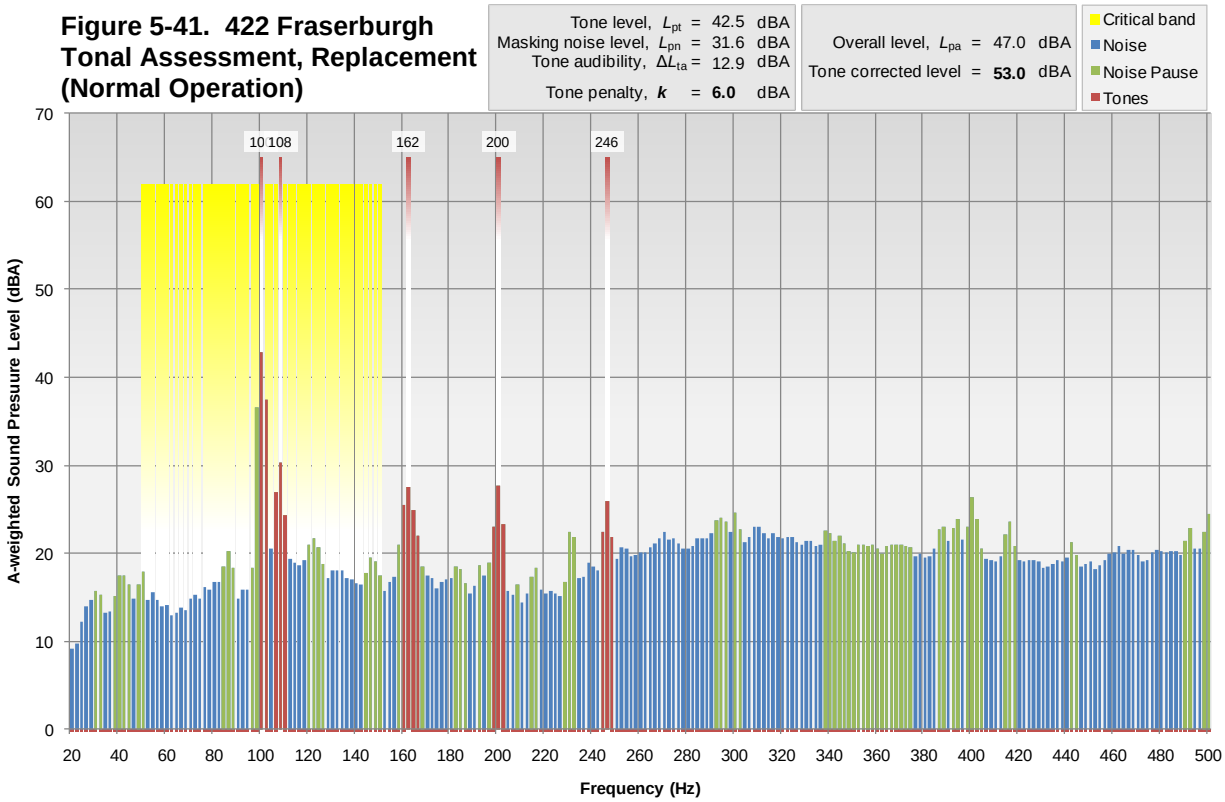


Figure 5-40. 418 Fraserburgh (Replacement), SPL Spectrum (Defrost Cycle)

5.5.19. Tonal analysis of the frequency spectra shown in Figure 5-39 and Figure 5-40 has been undertaken in accordance with the Joint Nordic Method (v2). The resulting tonal assessments are presented in Figure 5-40 and Figure 5-41, showing that the tones identified within the spectrum for normal operation would lead to a **6 dB tonal penalty**. During the defrost cycle, the tonal assessment indicates that a **6 dB tonal penalty** would also be appropriate.

Figure 5-41. 422 Fraserburgh Tonal Assessment, Replacement (Normal Operation)



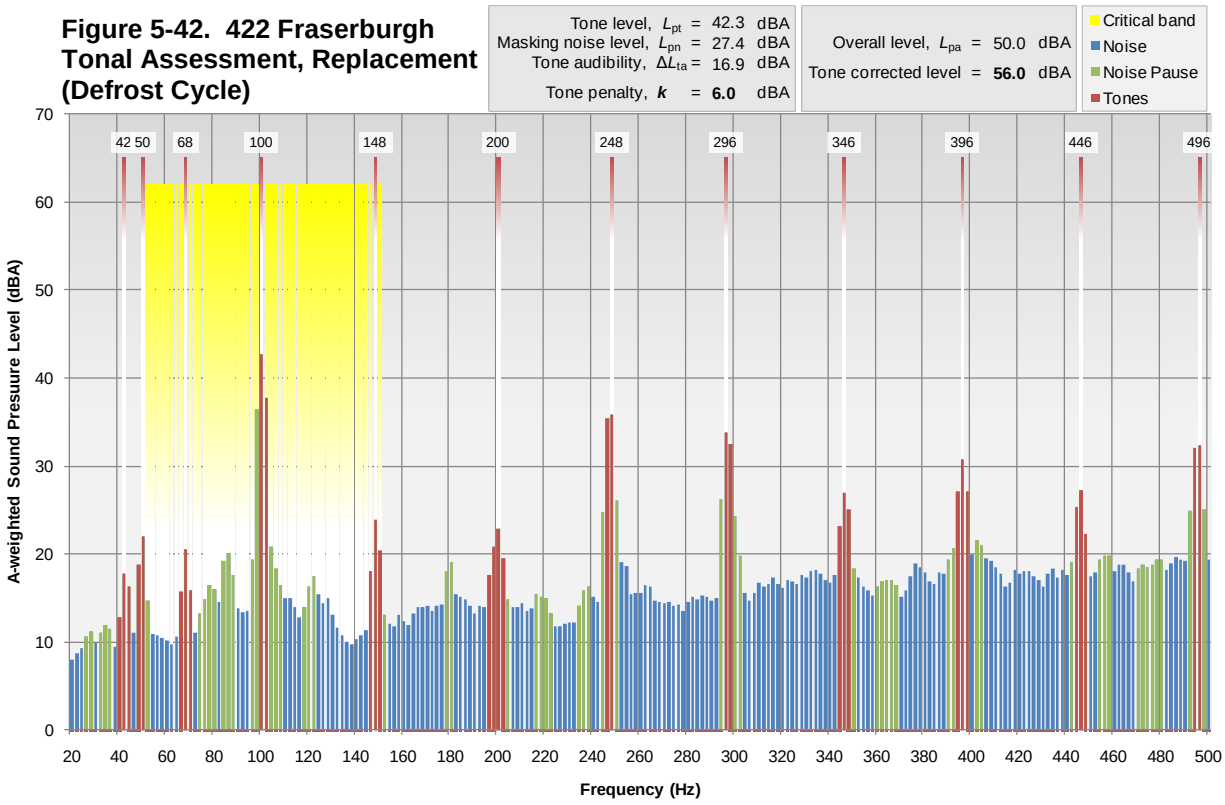


Figure 5-42. 422 Fraserburgh Tonal Assessment, Replacement (Defrost Cycle)

Sound Power Level calculations

5.5.20. Figure 5-43 presents a statistical analysis plot of the percentage of time that a specific sound power level would be recorded, when the ASHP is under operation.

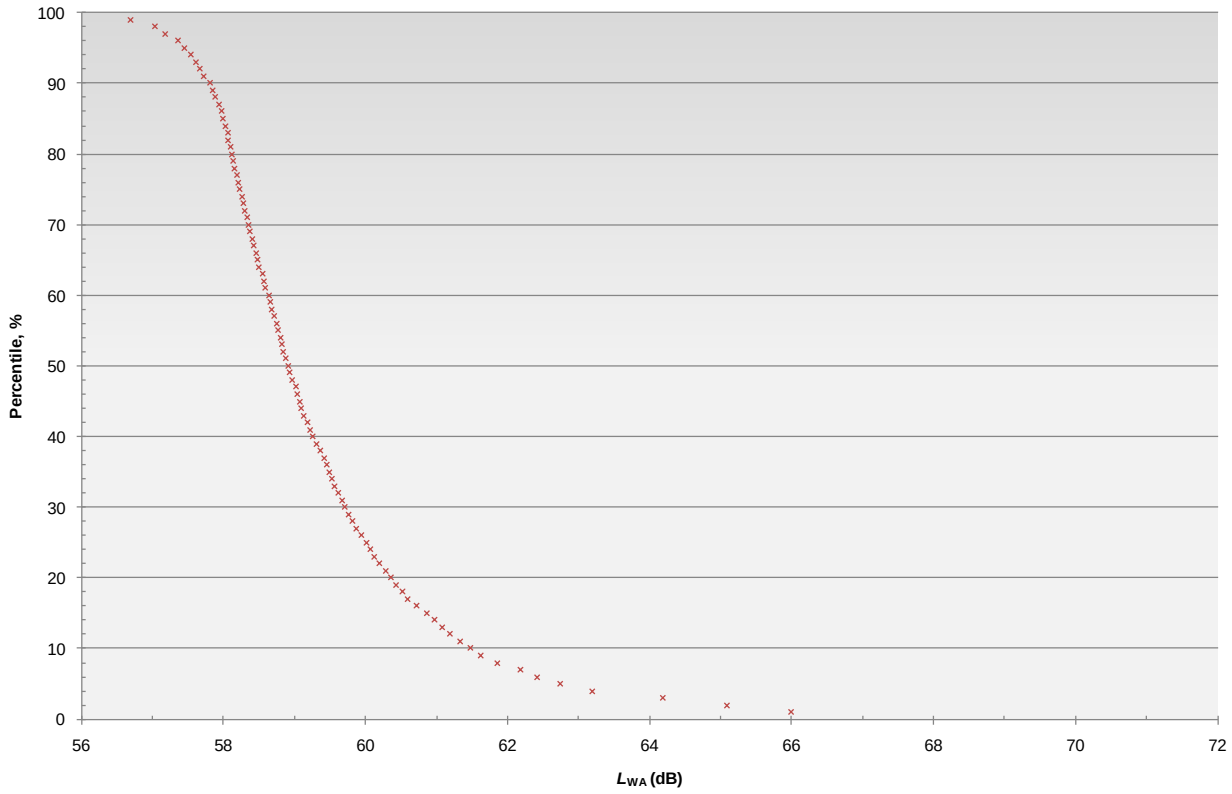


Figure 5-43. 422 Fraserburgh (Replacement), Sound Power Level Statistical Analysis

5.5.21. The chart indicates that noise from the ASHP during operation will have a 90% certainty of being within around 2 dB of L_{WA} **59 dB.**

5.5.22. Use of Equation 1 leads to an estimation that noise levels from the unit operating normally would drop to L_{Aeq} 42 dB at a distance separation of approximately **4 m**. If a tonal penalty were to be included, then this distance would rise to around **8 m**. This assumes that the ASHP is located in the common mounting scenario as detailed in Section 3.42, which is not necessarily representative of the actual measured condition.

Vibration

5.5.23. An FFT analysis of the vibration levels recorded for normal operation of the ASHP is shown in Figure 5-44. The peaks in the background spectrum at 100 and 200 Hz are deemed to be due to an electrical component within the ASHP.

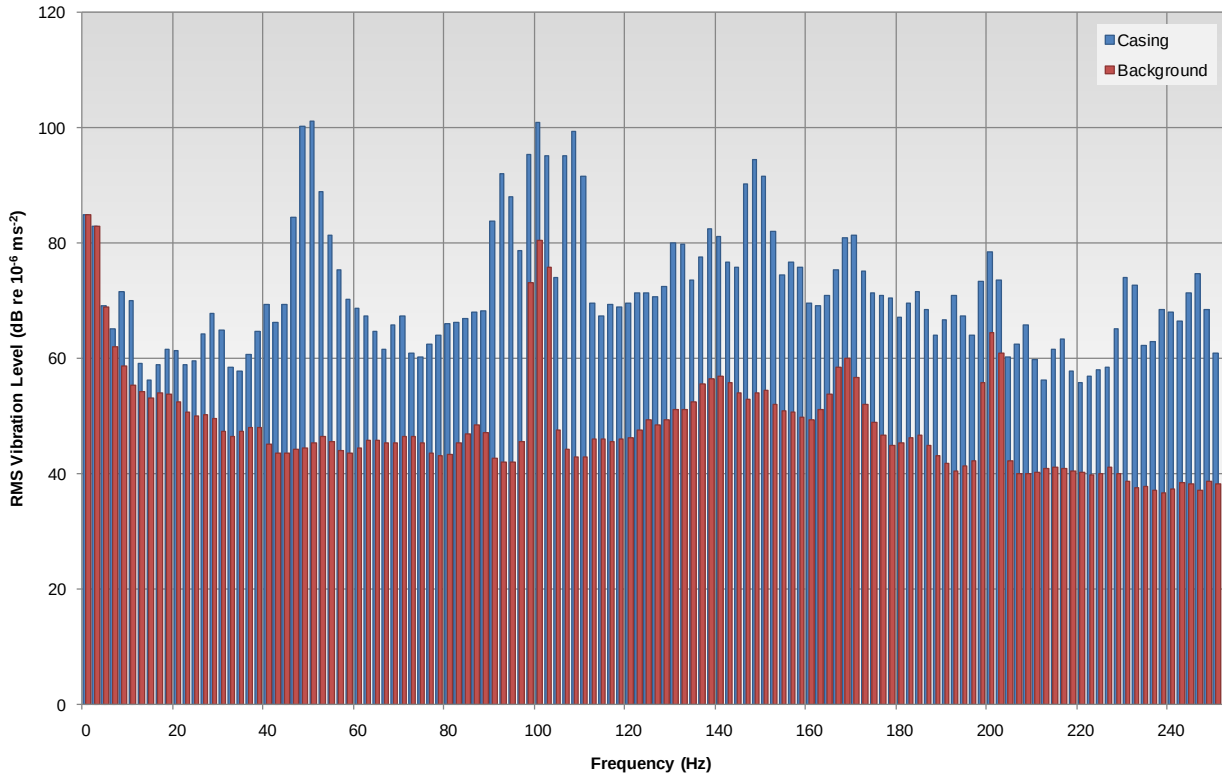


Figure 5-44. 422 Fraserburgh (Replacement), Vibration Levels

Discussion

5.5.24. Whilst the manufacturer has not provided us with detailed information on the fan and compressor speeds, inspection of the results and experience of similar units suggest that the fan speed was around 810 rpm, and included four fan blades. This fan configuration corresponds with a blade passing frequency of 54 Hz, with second and third harmonics at 108 and 162 Hz respectively. These effects are seen in the frequency spectrum for normal operation. The compressor was of a scroll type with an unknown speed. Analysis of the defrost cycle frequency spectrum suggests however that the primary tone is at around 50Hz, which corresponds with a rotational speed of 3000 rpm, typical for this type of compressor. Harmonics of this tone are seen at multiple frequencies in the spectrum.

5.5.25. During normal operation, the compressor contributes a greater amount of noise than the fan, and also provides the majority of the tonal content.

5.5.26. This replacement 6.0 kW ASHP measured 9 dB quieter than the initial 8.0 kW ASHP. The manufacturer's data suggested a reduction in noise by 7 dB would have been achievable.

5.5.27. The vibration data shows that both the compressor and fan contribute to the vibration emissions.

5.6 *443 Cheshire West*

Site description

5.6.1. The property is located in a small village off a quiet road. The ASHP is located to the rear of the brick built single story semi-detached property. The unit is mounted onto the wall surface, supported from a metal frame fixed to the brickwork. Vibration isolation couplings were used between the unit and the framework.

5.6.2. Subjectively the unit appeared to be operating normally with no audible rattle, resonance or fault.

Equipment set up

5.6.3. The 9 Channel PULSE system was used at this site.

5.6.4. The unit was mounted above a mixed ground surface of soil and paving slabs.

5.6.5. Accelerometers were fixed to the unit casing and to the wall surface immediately behind the unit. The accelerometers were fixed to the surfaces using cyanoacrylate cement.

5.6.6. The microphones were mounted on a temporary scaffolding framework as shown in Picture 5-15 and Picture 5-16. All microphones were positioned 1 m from the ASHP casing.

Picture 5-15. 443 Cheshire West, ASHP and Microphone Arrangement

Picture 5-16. 443 Cheshire West, ASHP and Microphone Arrangement

Measurement Results

5.6.7. Figure 5-45 presents the $L_{Aeq(1min)}$ measured noise levels at the microphone 1m in front of the unit set against time, along with the per-minute logged ASHP power consumption.

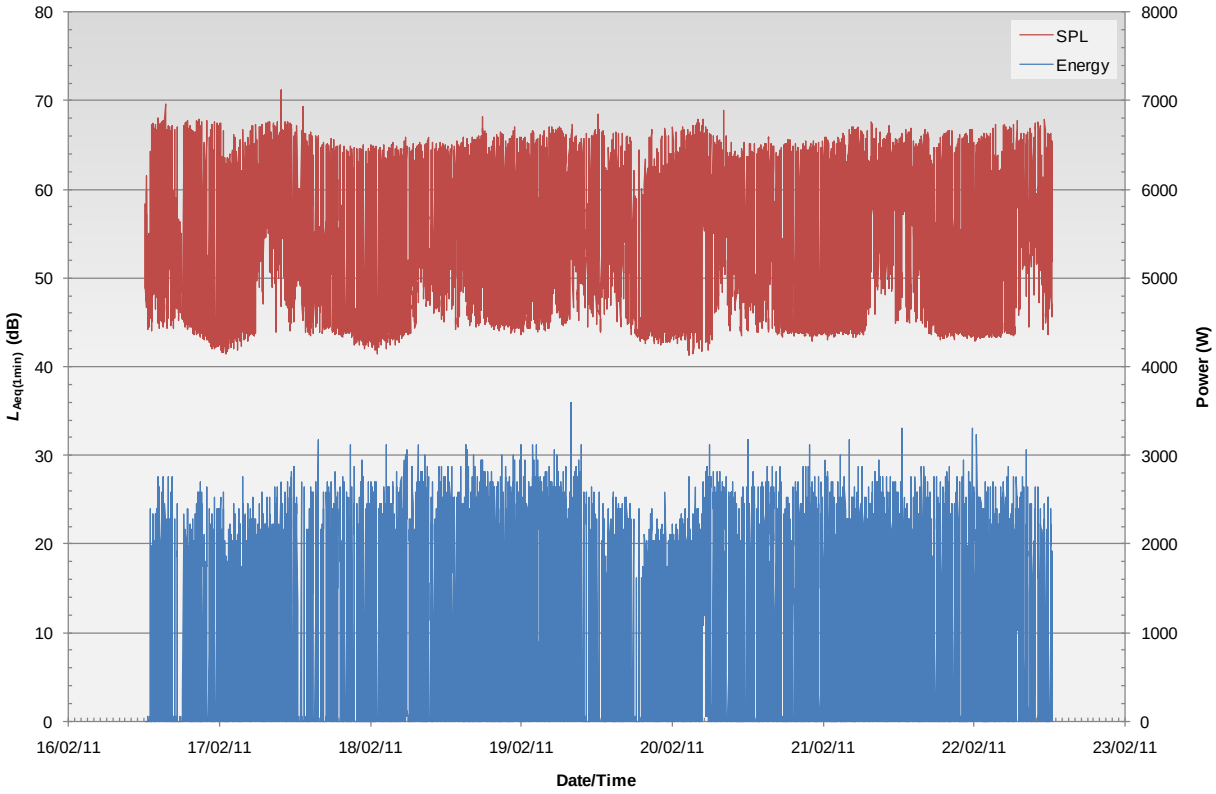


Figure 5-45. 443 Cheshire West, Sound Pressure Level and Power Consumption vs Time

5.6.8. The chart highlights that the ASHP is cycling on and off very frequently, approximately every twenty minutes, throughout the day and night time periods. When the unit is operational, it is on for approximately four minutes. Throughout the measurement period, the ASHP was operational for approximately 22% of the time.

5.6.9. The data shows an increase in measured noise level during periods when the ASHP is operating.

Measurement Analysis

5.6.10. Figure 5-2 presents a scatter diagram showing the noise levels against the power consumption, for the periods when the ASHP was operating. The chart trend line indicates a slight increase in noise level with ASHP power level, although the fit is not conclusive, with a regression coefficient (r^2) of 23%.

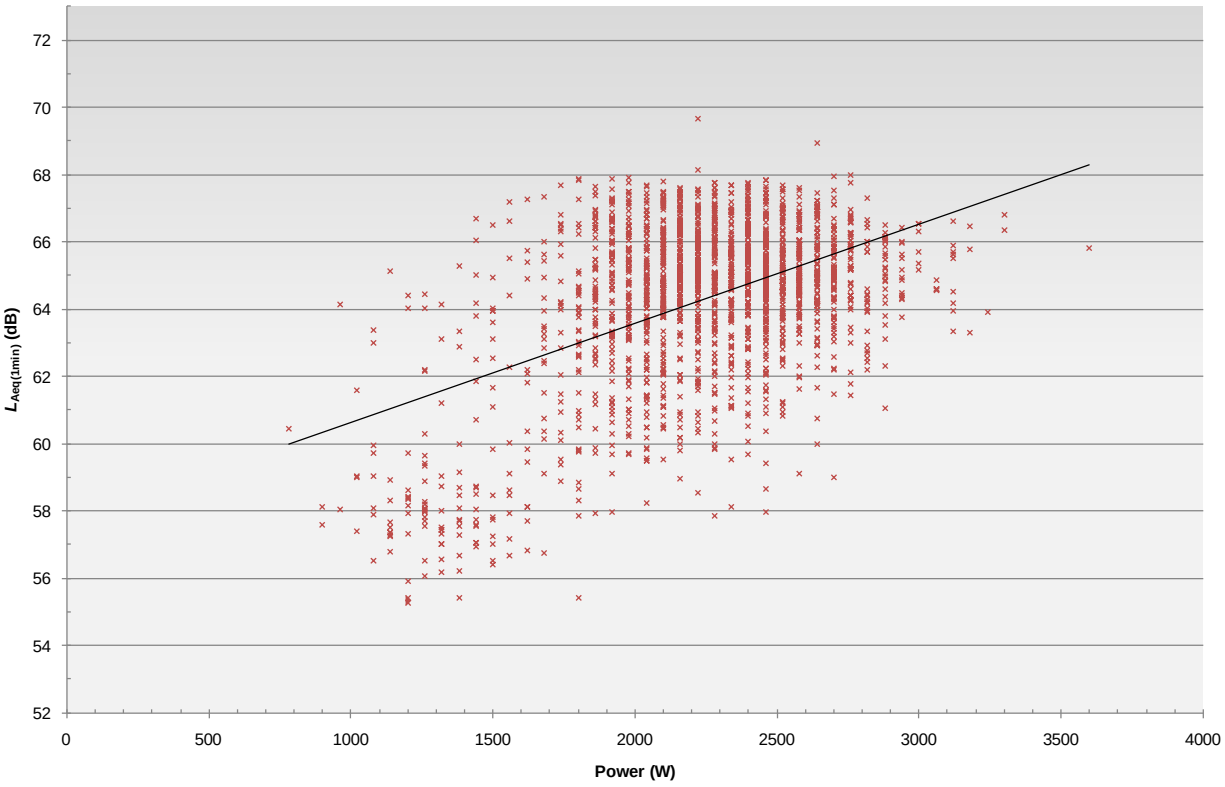


Figure 5-46. 443 Cheshire West, Sound Pressure Level vs Power Consumption

5.6.11. Figure 5-47 presents a statistical analysis plot of the percentage of time that a specific noise level would be recorded, when the ASHP is under operation. From this confidence intervals can be presented for the typical noise levels.

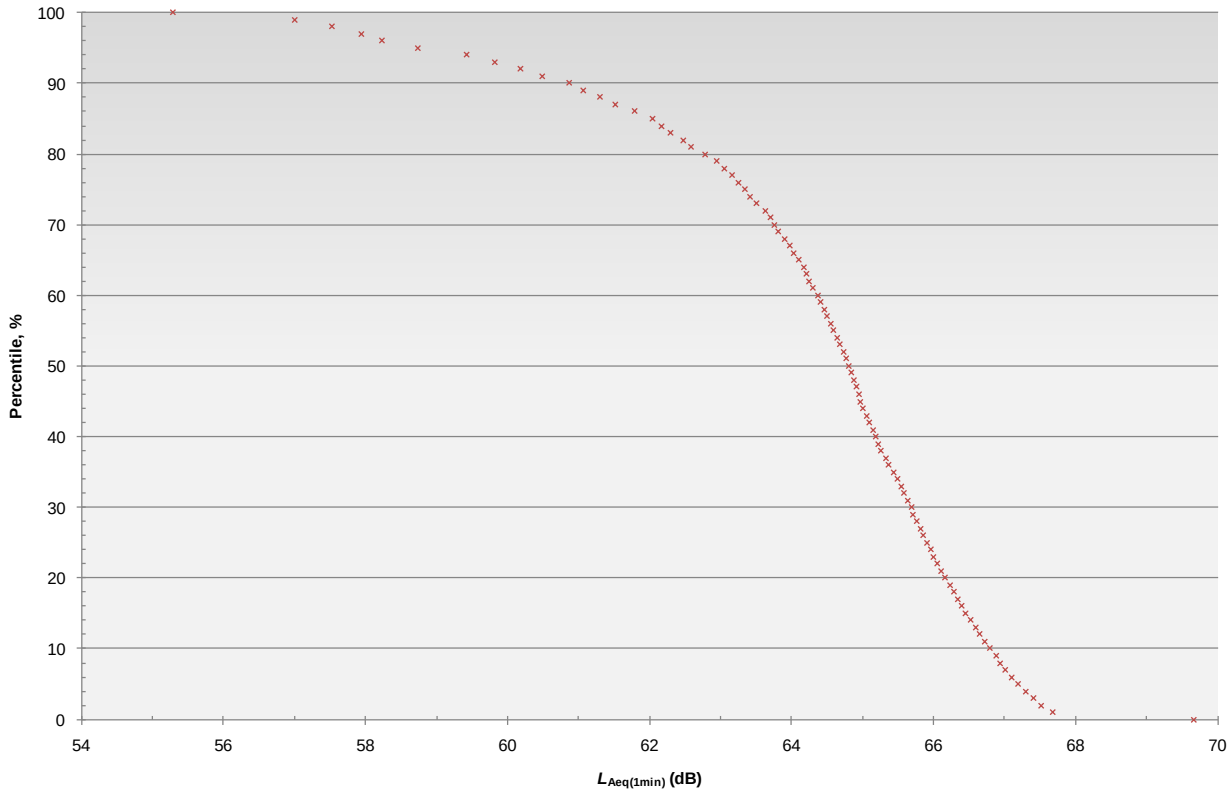


Figure 5-47. 443 Cheshire West, Sound Pressure Level Statistical Analysis

5.6.12. The chart indicates that noise from the ASHP during operation will have a 90% certainty of being within around 4 dB of $\boldsymbol{L_{Aeq(1min)}}$ **64 dB**. The corresponding total ASHP noise dose over the whole assessment period is calculated as $L_{Aeq(1week)}$ 58 dB.

Defrost Cycle

5.6.13. Analysis of the measurements revealed that defrost cycles are part of the ASHP operation. During these periods, which can last for 2 to 3 minutes, the compressor is operating in reverse, without the fan. The average sound pressure level during a typical defrost cycle is around $\boldsymbol{L_{Aeq(1min)}}$ **57 dB**.

Directivity

5.6.14. Table 5-6 shows the directivity in noise emissions from the unit by comparing the noise levels at the different microphones, for a typical period of ASHP operation.

Table 5-6: Directivity Analysis of the ASHP Noise Emissions $L_{Aeq(1min)}$ dB 443 Cheshire West, normal operation

Microphone Location	Front	Left	Right	Above
Typical Microphone Level	64	63	62	59
Change from front microphone	-	-1	-2	-5

5.6.15. It is seen that the ASHP exhibits a slight directivity, such that noise is greatest in line with the fan, whilst there is a reduction in noise above the ASHP.

Frequency analysis

5.6.16. For the frequency analysis, a Fast Fourier Transform (FFT) of the signal was performed, averaged over a representative one minute period at a frequency resolution of 2 Hz. The resulting frequency spectrum for the ASHP operating under normal conditions is given in Figure 5-48, with that for the defrost cycle given in Figure 5-49.

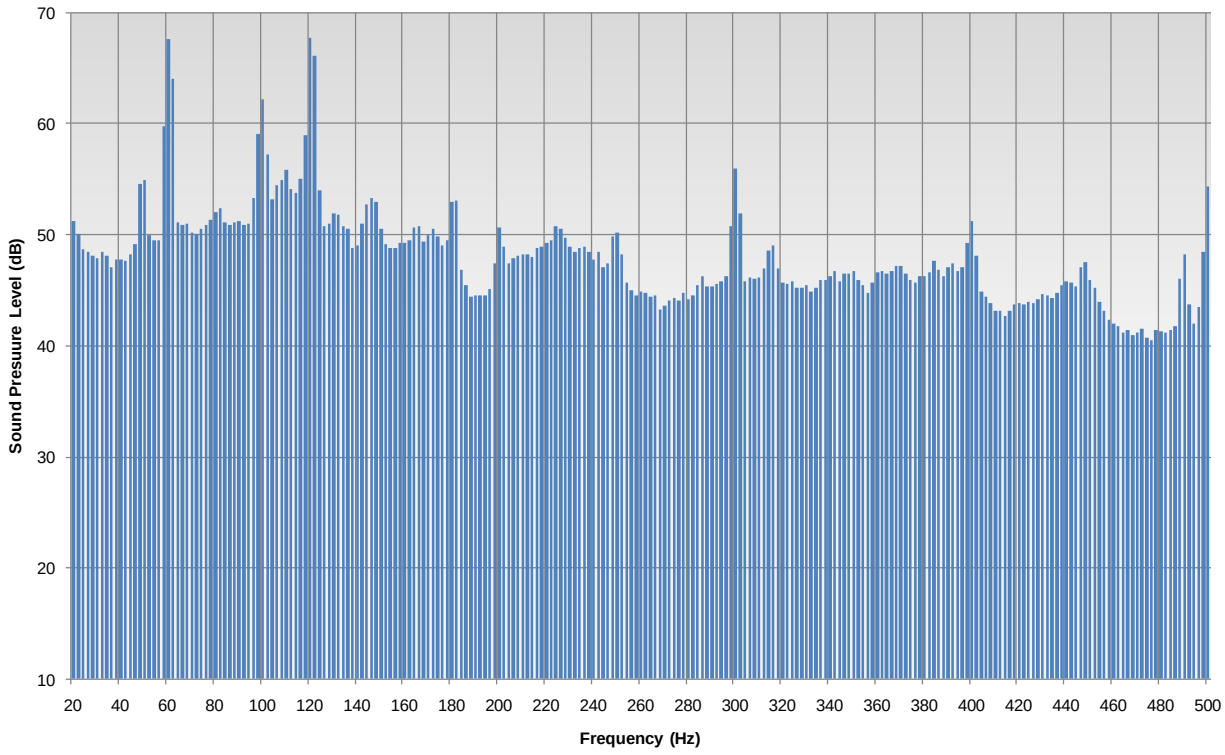


Figure 5-48. 443 Cheshire West, Sound Pressure Level Frequency Spectrum (Normal Operation)

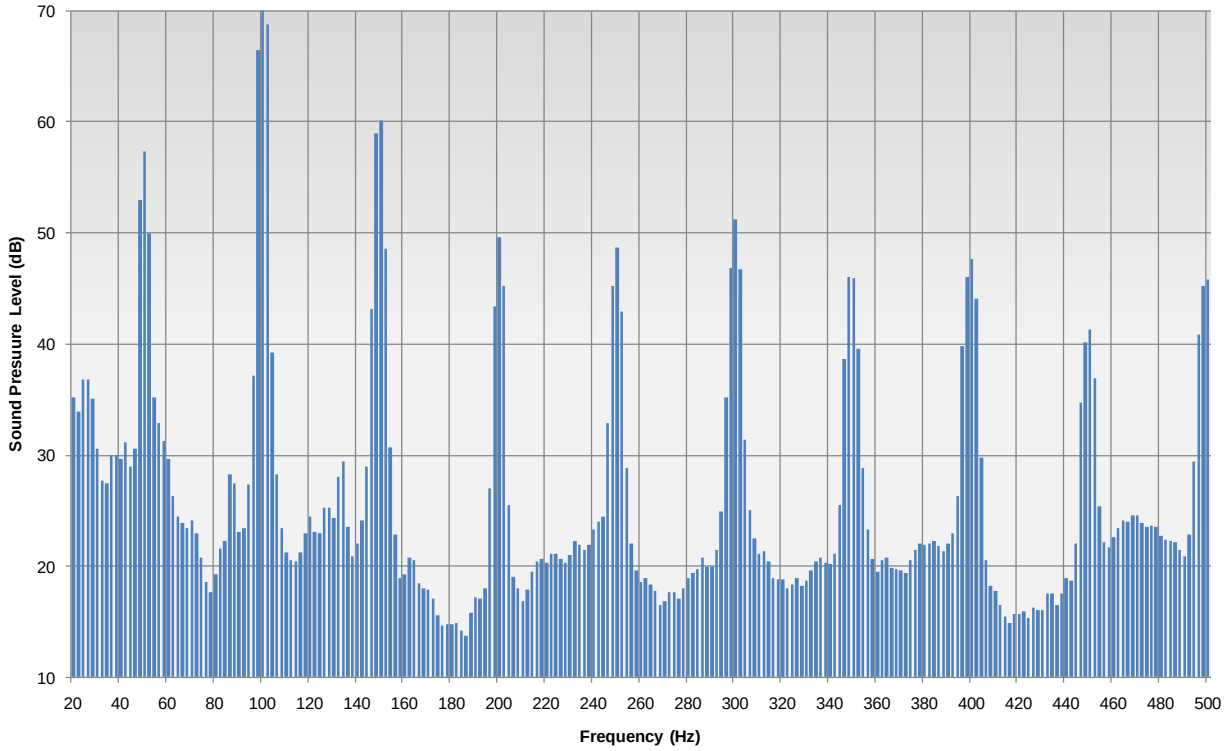


Figure 5-49. 443 Cheshire West, Sound Pressure Level Frequency Spectrum (Defrost cycle)

5.6.17. Tonal analysis of the frequency spectra shown in Figure 5-48 and Figure 5-49 has been undertaken in accordance with the Joint Nordic Method (v2). The resulting tonal assessments are presented in Figure 5-49 and Figure 5-50, showing that the tones identified within the spectrum would lead to a **4 dB tonal penalty** for normal operation and a **6 dB tonal penalty** for the defrost cycle.

Figure 5-50. 443 Cheshire West Tonal Assessment (Normal Operation)

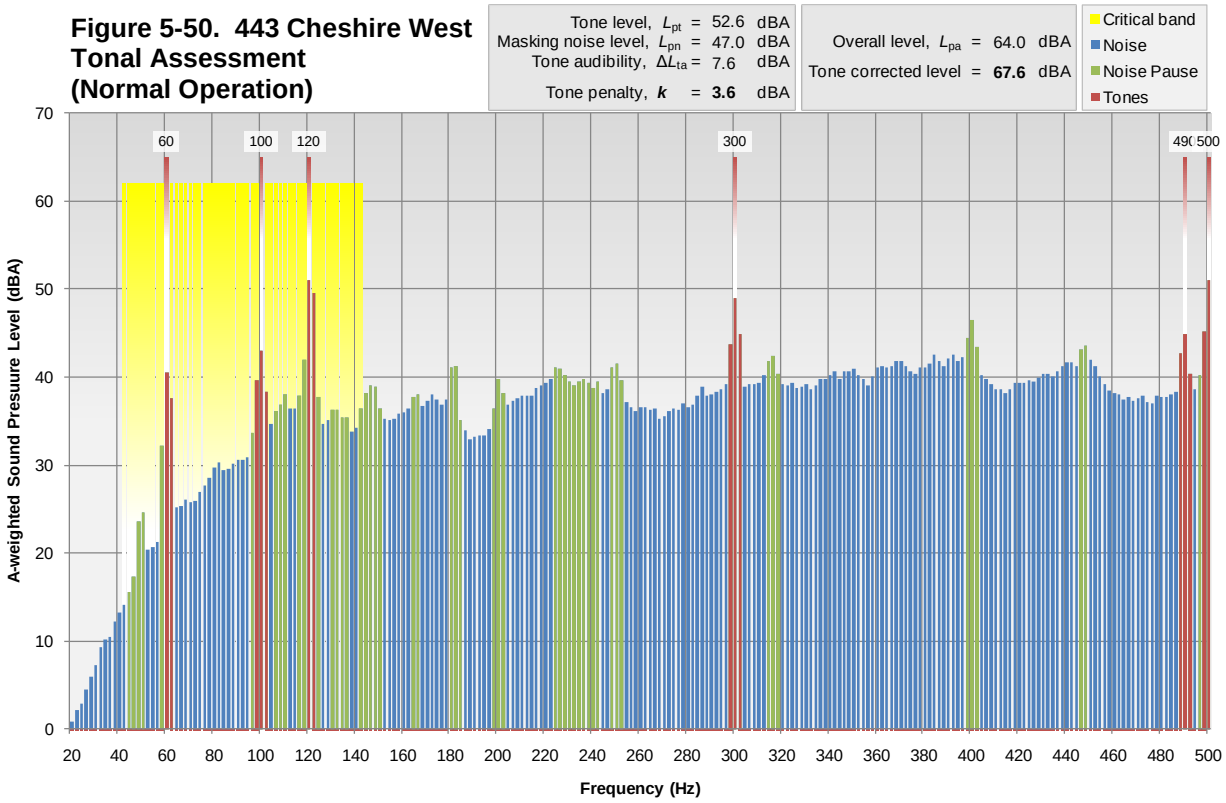
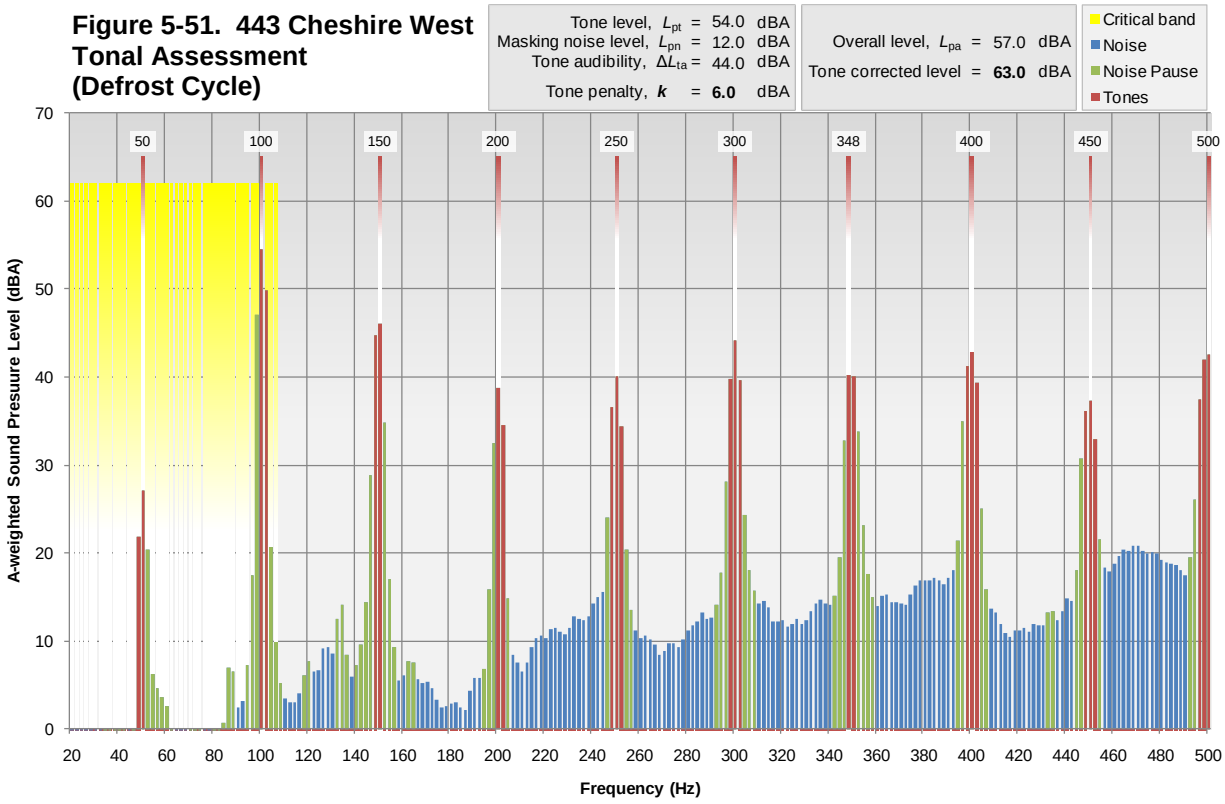


Figure 5-51. 443 Cheshire West Tonal Assessment (Defrost Cycle)



Sound Power Level calculations

5.6.18. Figure 5-8 presents a statistical analysis plot of the percentage of time that a specific sound power level would be recorded, when the ASHP is under operation.

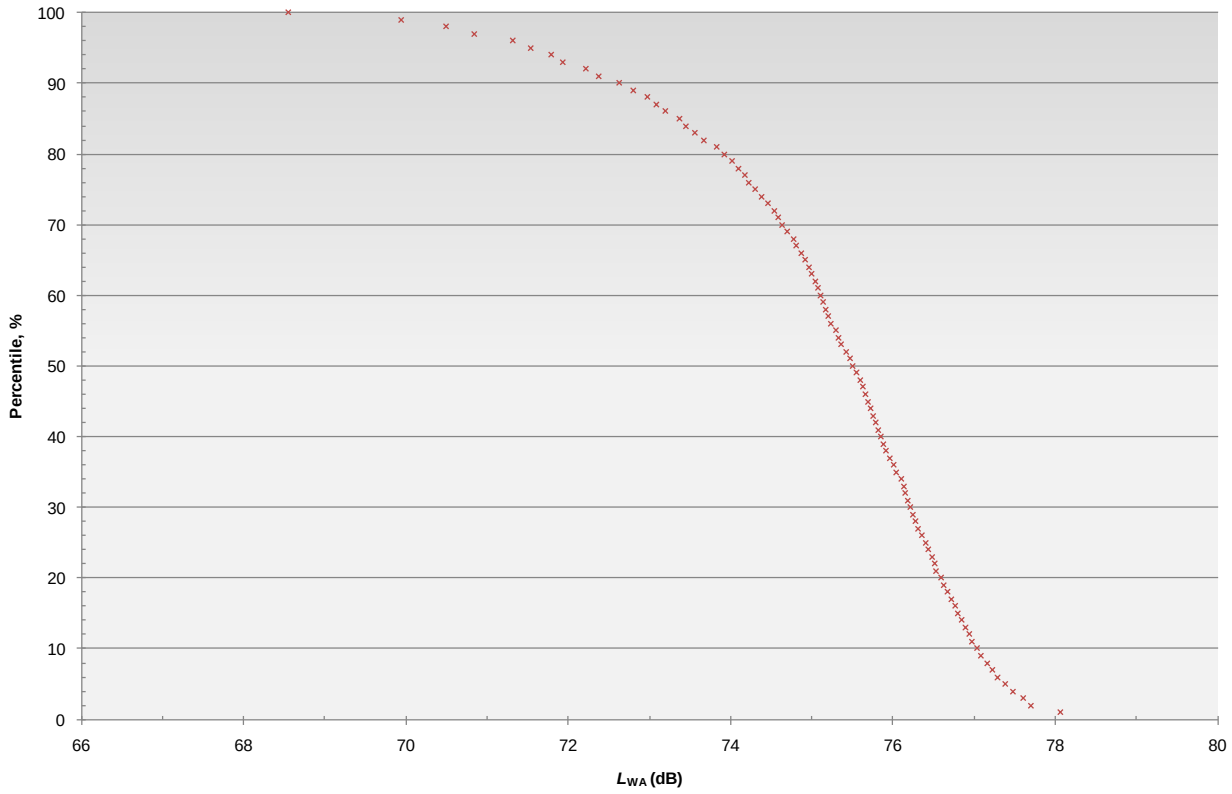


Figure 5-52. 443 Cheshire West, Sound Power Level Statistical Analysis

5.6.19. The chart indicates that noise from the ASHP during operation will have a 90% certainty of being within around 3 dB of $\boldsymbol{L_{WA}}$ **76 dB.**

5.6.20. Use of Equation 1 leads to an estimation that noise levels from the unit operating normally would drop to L_{Aeq} 42 dB at a distance separation of approximately **28 m**. If a tonal penalty were to be included, then this distance would rise to around **45 m**. This assumes that the ASHP is located in the common mounting scenario as detailed in Section 3.42, which is not necessarily representative of the actual measured condition.

Vibration

5.6.21. An FFT analysis of the vibration levels recorded for normal operation of the ASHP is shown in Figure 5-53. The overall weighted peak vibration level at the wall surface was 0.017 ms^{-2}, just above the average perception threshold for whole-body vibration.

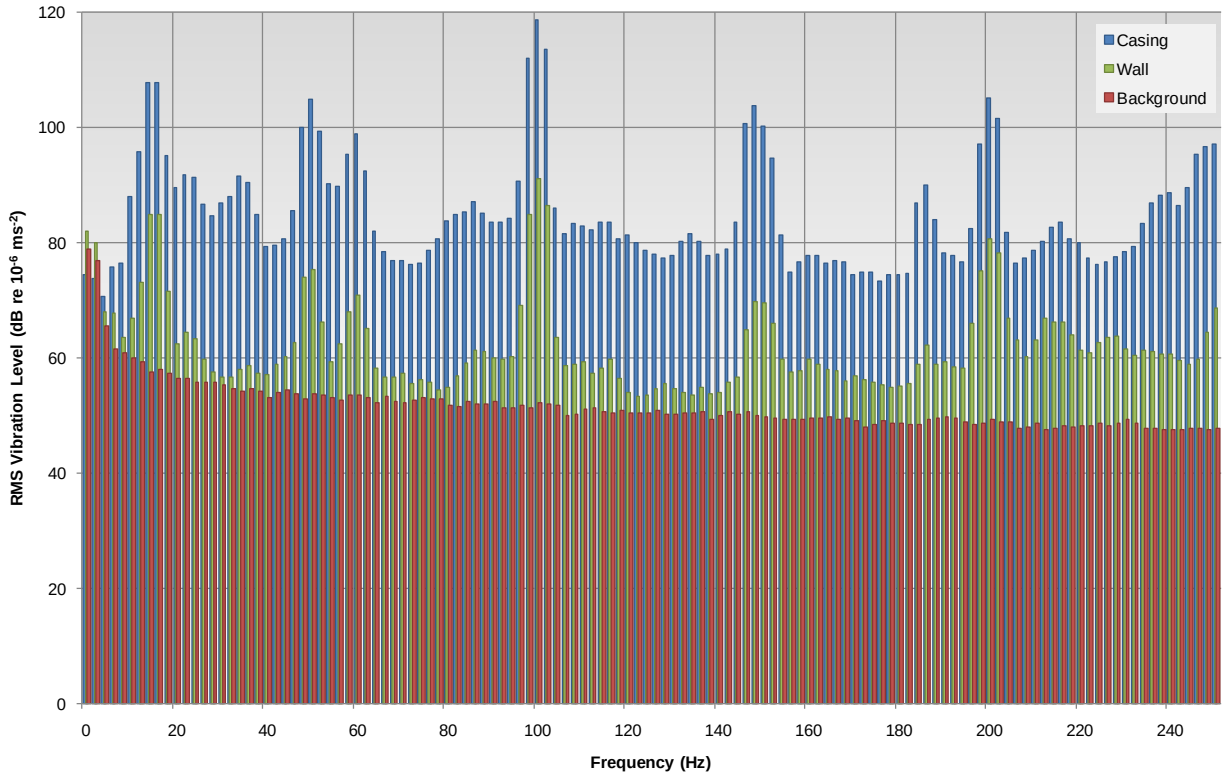


Figure 5-53. 443 Cheshire West, Vibration Levels

Discussion

5.6.22. The manufacturer has stated that the fan for ASHP rotates at a nominal speed of 903 rpm, with a compressor speed of 2900 rpm. With four fan blades, the blade passing frequency is around 60 Hz, with harmonics around 120 and 180 Hz. These are identified in the frequency spectrum for normal operation. The compressor speed corresponds to a frequency of around 50 Hz, with harmonics observed throughout the frequency range.

5.6.23. During normal operation, the fan provides a greater amount of noise than the compressor, although some tonal content from the compressor is audible.

5.6.24. The vibration data shows that both the compressor and fan contribute to the vibration levels, and there is good vibration attenuation between the casing and wall surface, due to the presence of the isolation mounts. It should be noted that the vibration level around 100 Hz is likely to cause some structure-borne noise to the inhabitants of the property.

5.7 *474 West Berkshire (Site 1)*

Site description

5.7.1. The property is located in a rural village off a quiet road. The ASHP is located to the rear of a modern brick built two story semi-detached property. The unit is seated on concrete footings, in front of the property wall.

5.7.2. Subjectively the unit appeared to be operating normally with no audible rattle, resonance or fault.

Equipment set up

5.7.3. The 5 Channel PULSE system was used at this site.

5.7.4. The ASHP was located on hard, reflective ground, with a fence panel situated close by, to the right of the unit.

5.7.5. An accelerometer was fixed to the unit casing, as shown in Picture 5-17, using cyanoacrylate cement.

Picture 5-17. 474 West Berkshire (Site 1), Casing-mounted Accelerometer

5.7.6. Three microphones were used, two mounted on scaffolding and one mounted on a tripod as shown in Picture 5-18. All microphones were positioned 1 m from the ASHP casing, with the exception of the position to the right of the ASHP, which was situated slightly closer (60 cm) due to the presence of a walkway.

Picture 5-18. 474 West Berkshire (Site 1), ASHP and Microphone Arrangement

Measurement Results

5.7.7. Figure 5-54 presents the $L_{Aeq(1min)}$ measured noise levels at the microphone 1m in front of the unit set against time, along with the per-minute logged ASHP power consumption.

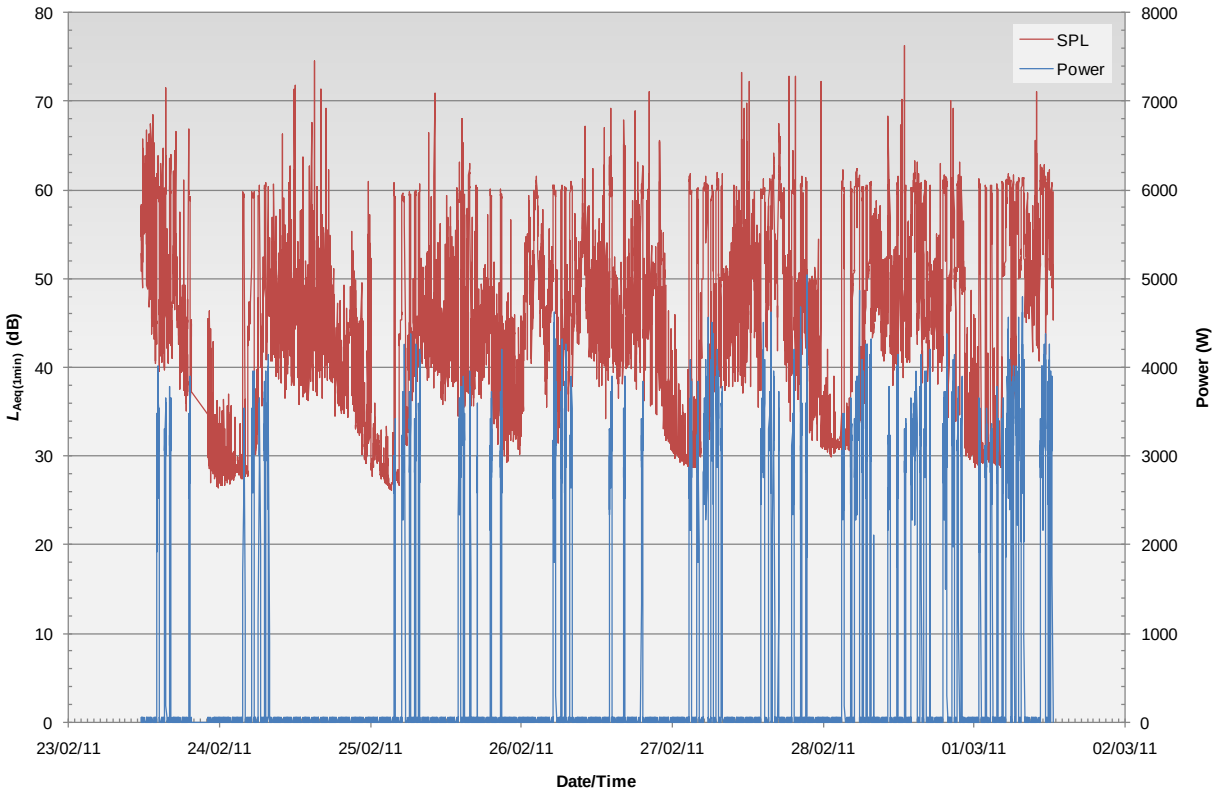


Figure 5-54. 474 West Berkshire (Site 1), Sound Pressure Level and Power Consumption vs Time

5.7.8. The chart highlights that the ASHP operates mainly over a morning period and an afternoon period. During these periods, the ASHP cycles on and off every hour or so; when the ASHP is operating, it does so for periods of 10-20 minutes. Throughout the measurement period, the ASHP was operating for approximately 15% of the time.

5.7.9. The trace shows an increase in measured noise level during periods when the ASHP is operating.

Measurement Analysis

5.7.10. Figure 5-55 presents a scatter diagram showing the noise levels against the power consumption, for the periods when the ASHP was operating. The chart trend line indicates a slight increase in noise level with ASHP power level, although the fit is not conclusive, with a regression coefficient (r^2) of just 4%.

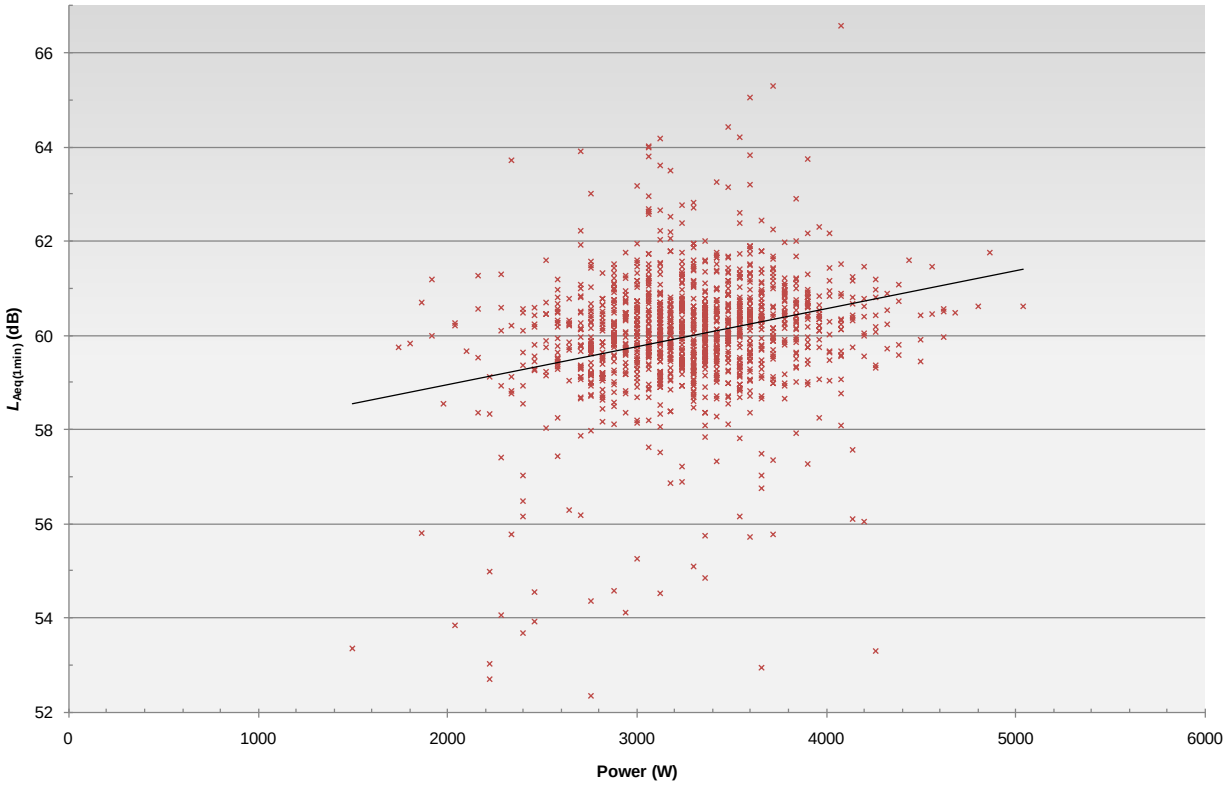


Figure 5-55. 474 West Berkshire (Site 1), Sound Pressure Level vs Power Consumption

5.7.11. Figure 5-56 presents a statistical analysis plot of the percentage of time that a specific noise level would be recorded, when the ASHP is under operation. From this confidence intervals can be presented for the typical noise levels.

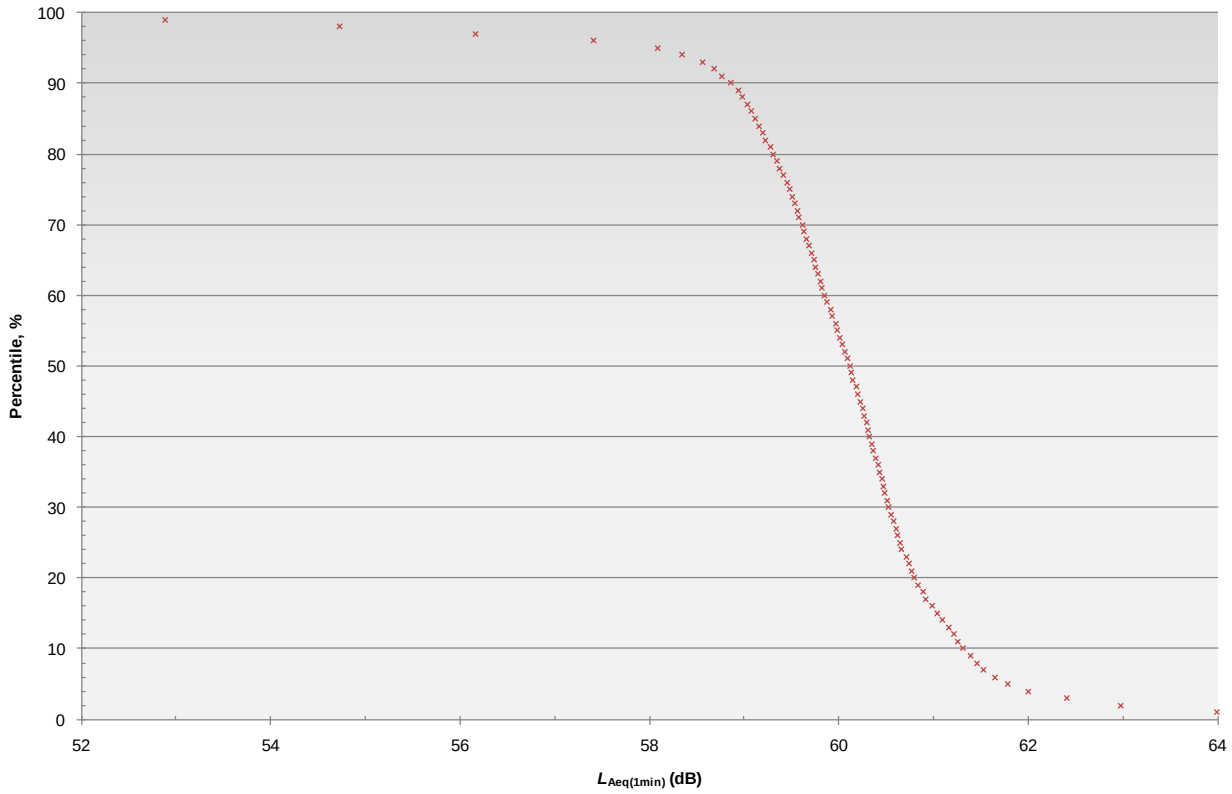


Figure 5-56. 474 West Berkshire (Site 1), Sound Pressure Level Statistical Analysis

5.7.12. The chart indicates that noise from the ASHP during operation will have a 90% certainty of being within around 2 dB of $L_{Aeq(1min)}$ **60 dB**. The corresponding total ASHP noise dose over the whole assessment period is calculated as $L_{Aeq(1week)}$ 52 dB.

Defrost Cycle

5.7.13. Analysis of the measurements revealed that defrost cycles are part of the ASHP operation. During these periods, which can last for 1 to 2 minutes, the compressor is operating in reverse, without the fan. The average sound pressure level during a typical defrost cycle is around $L_{Aeq(1min)}$ **51 dB**.

Directivity

5.7.14. Table 5-7 shows the directivity in noise emissions from the unit by comparing the noise levels at the different microphones, for a typical period of ASHP operation.

Table 5-7: Directivity Analysis of the ASHP Noise Emissions $L_{Aeq(1min)}$ dB 474 West Berkshire (Site 1), normal operation

Microphone Location	Front	Left	Above
Typical Microphone Level	60	61	58
Change from front microphone	-	+1	-2

5.7.15. It is seen that the ASHP is not significantly directional, which is likely to be due to the nearby acoustically reflective surfaces.

Frequency analysis

5.7.16. For the frequency analysis, a Fast Fourier Transform (FFT) of the signal was performed, averaged over a representative one minute period at a frequency resolution of 2 Hz. The resulting frequency spectrum for the ASHP operating under normal conditions is given in Figure 5-57, with that for the defrost cycle presented in Figure 5-58.

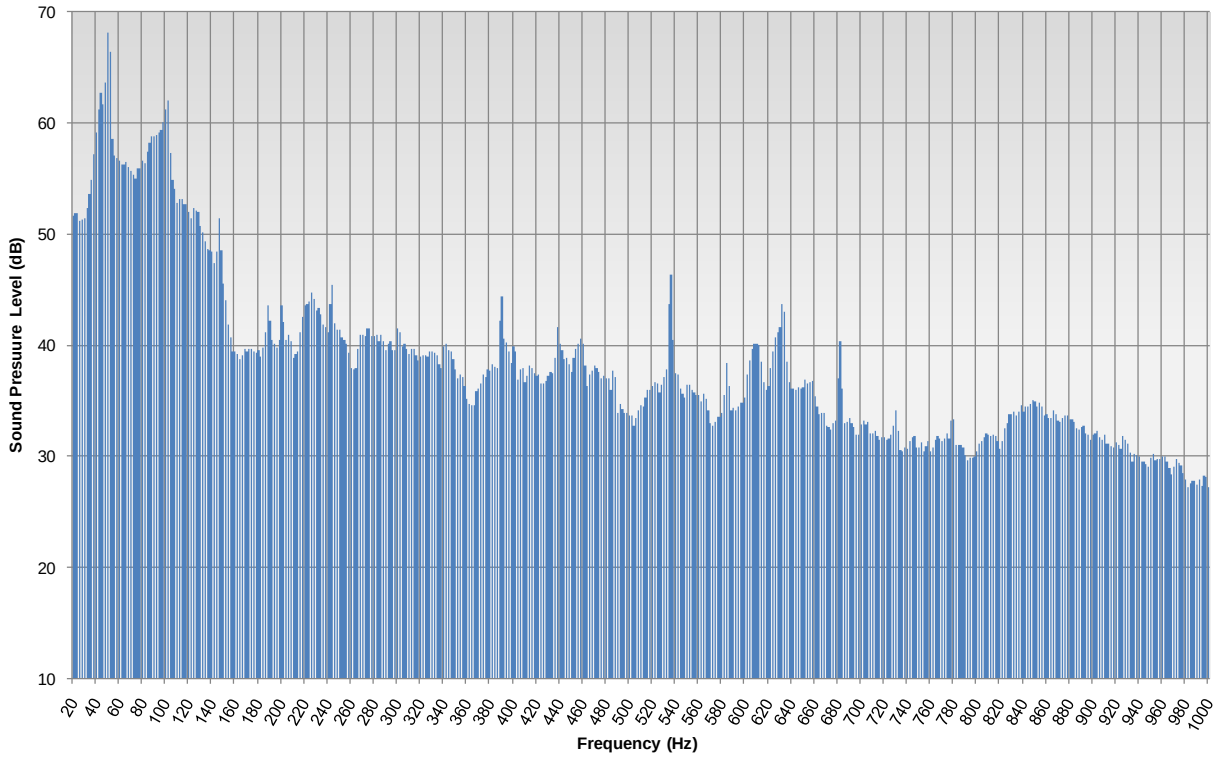


Figure 5-57. 474 West Berkshire (Site 1), SPL Spectrum (Normal Operation)

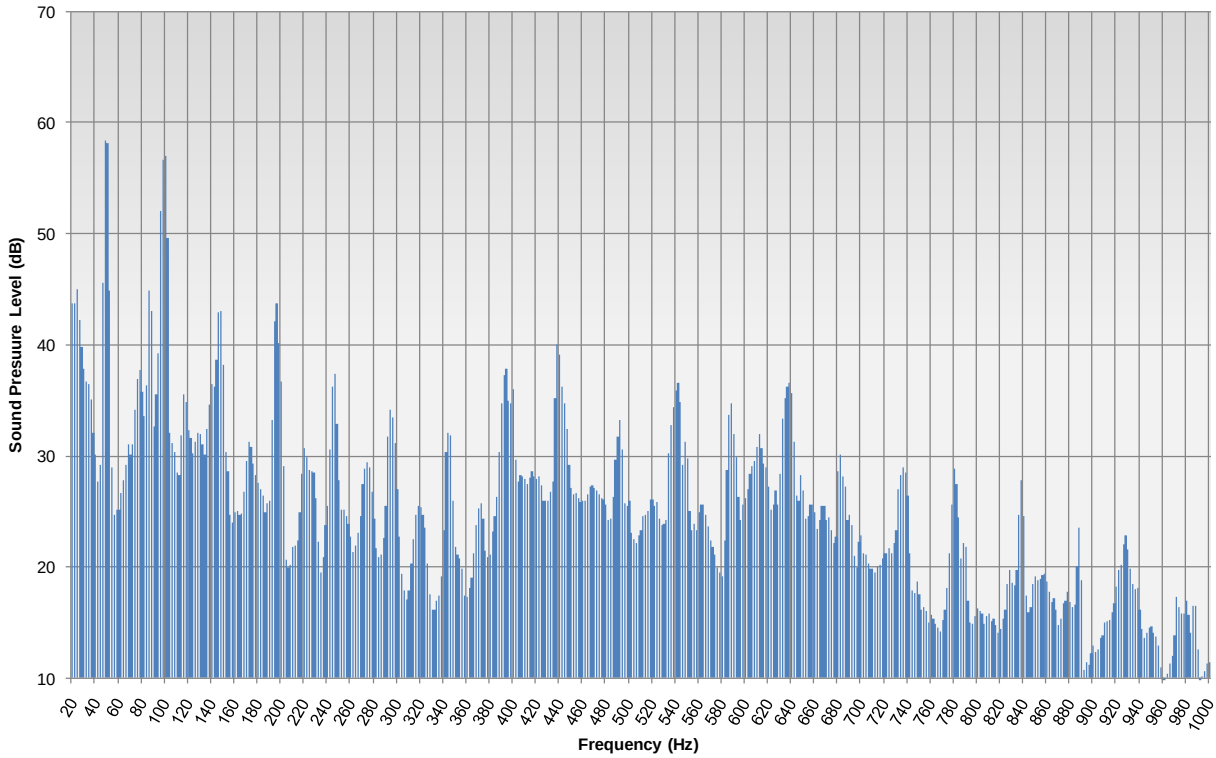


Figure 5-58. 474 West Berkshire (Site 1), SPL Spectrum (Defrost Cycle)

5.7.17. Tonal analysis of the frequency spectra shown in Figure 5-57 and Figure 5-58 has been undertaken in accordance with the Joint Nordic Method (v2). The resulting tonal assessments are presented in Figure 5-58 and Figure 5-59, showing that the tones identified within the spectrum for normal operation would lead to a **0 dB tonal penalty**. During the defrost cycle, the tonal assessment indicates that a **6 dB tonal penalty** would be appropriate.

Figure 5-59. 474 West Berkshire Tonal Assessment (Normal Operation)

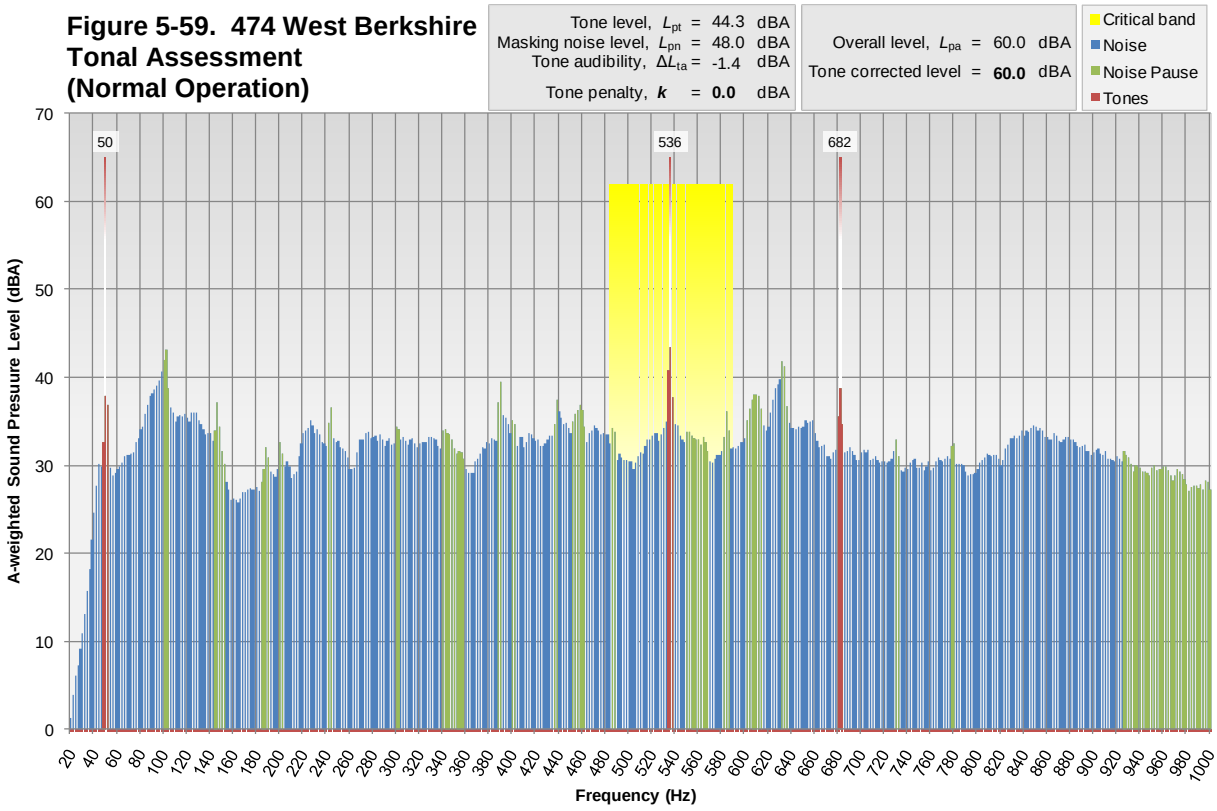
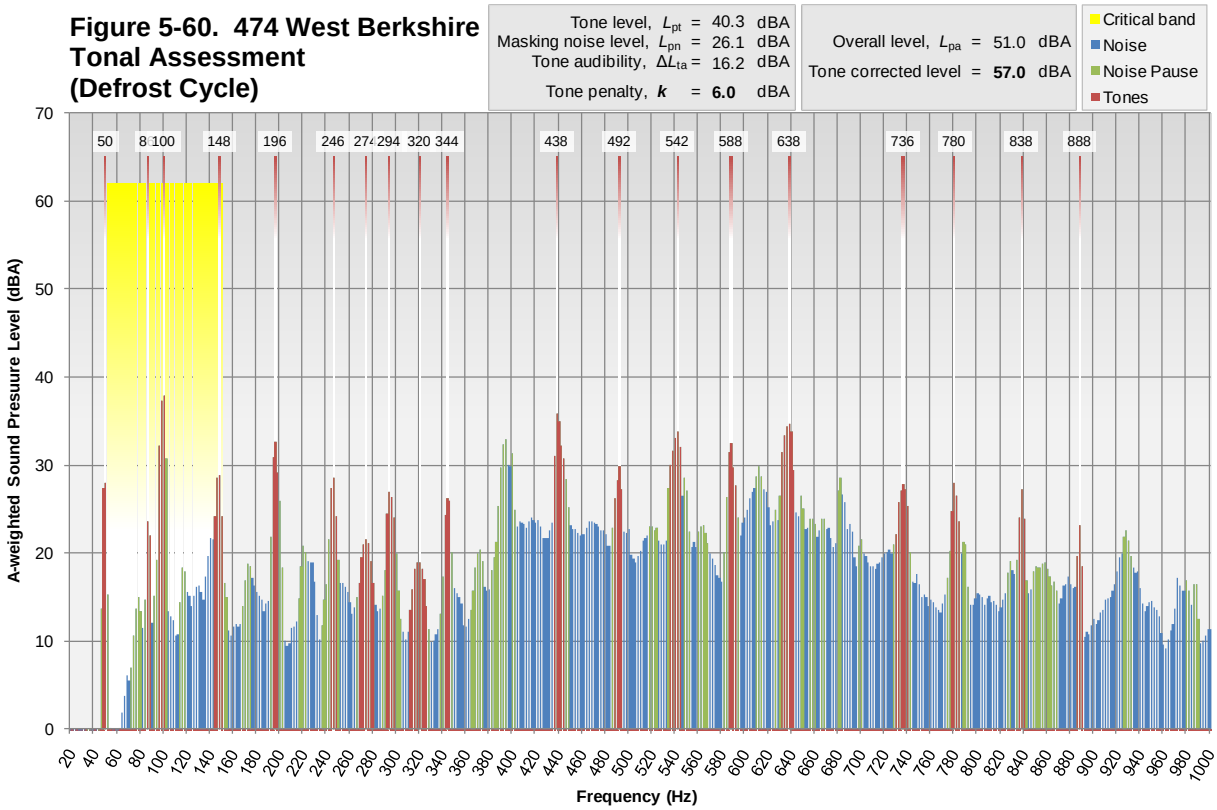


Figure 5-60. 474 West Berkshire Tonal Assessment (Defrost Cycle)



Sound Power Level calculations

5.7.18. Figure 5-61 presents a statistical analysis plot of the percentage of time that a specific sound power level would be recorded, when the ASHP is under operation.

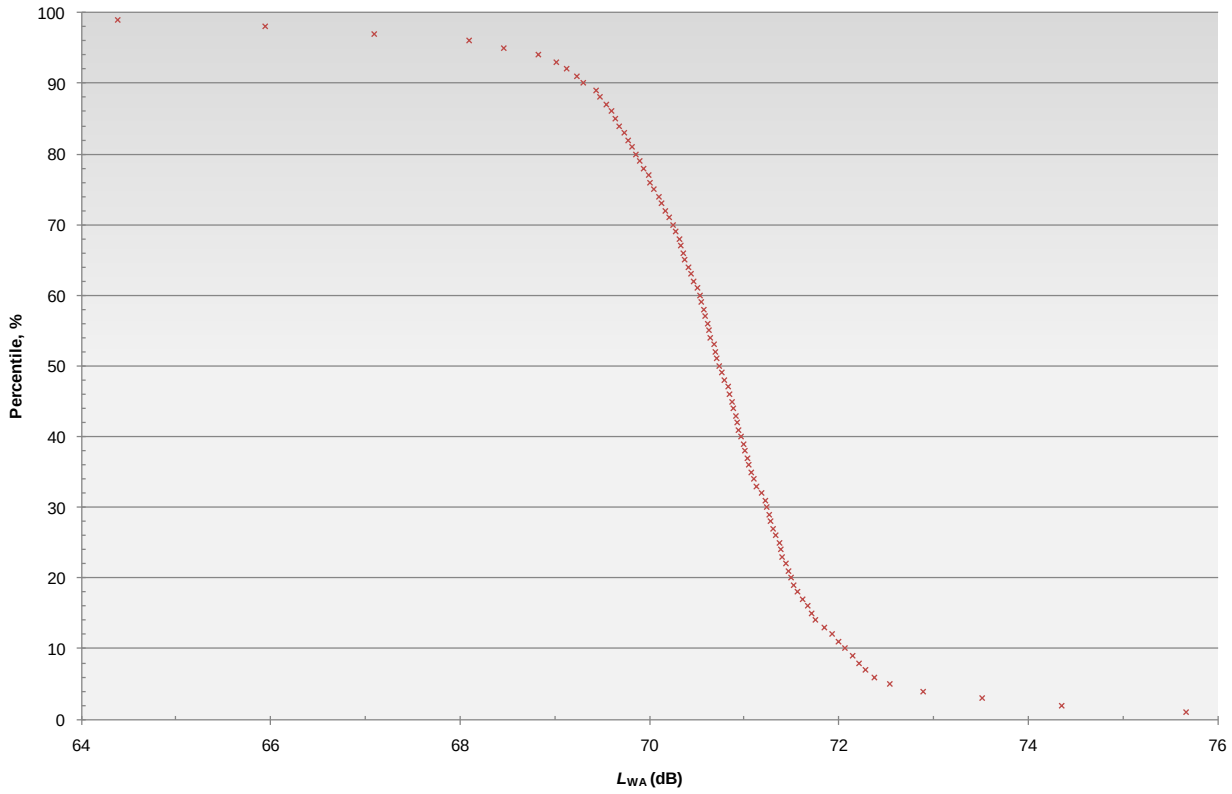


Figure 5-61. 474 West Berkshire (Site 1), Sound Power Level Statistical Analysis

5.7.19. The chart indicates that noise from the ASHP during operation will have a 90% certainty of being within around 2 dB of $\boldsymbol{L_{WA}}$ **71 dB.**

5.7.20. Use of Equation 1 leads to an estimation that noise levels from the unit operating normally would drop to L_{Aeq} 42 dB at a distance separation of approximately **16 m**. This assumes that the ASHP is located in the common mounting scenario as detailed in Section 3.42, which is not necessarily representative of the actual measured condition.

Vibration

5.7.21. An FFT analysis of the vibration levels recorded for normal operation of the ASHP is shown in Figure 5-62. The peaks in the background spectrum at 100 and 200 Hz are deemed to be due to an electrical component within the ASHP.

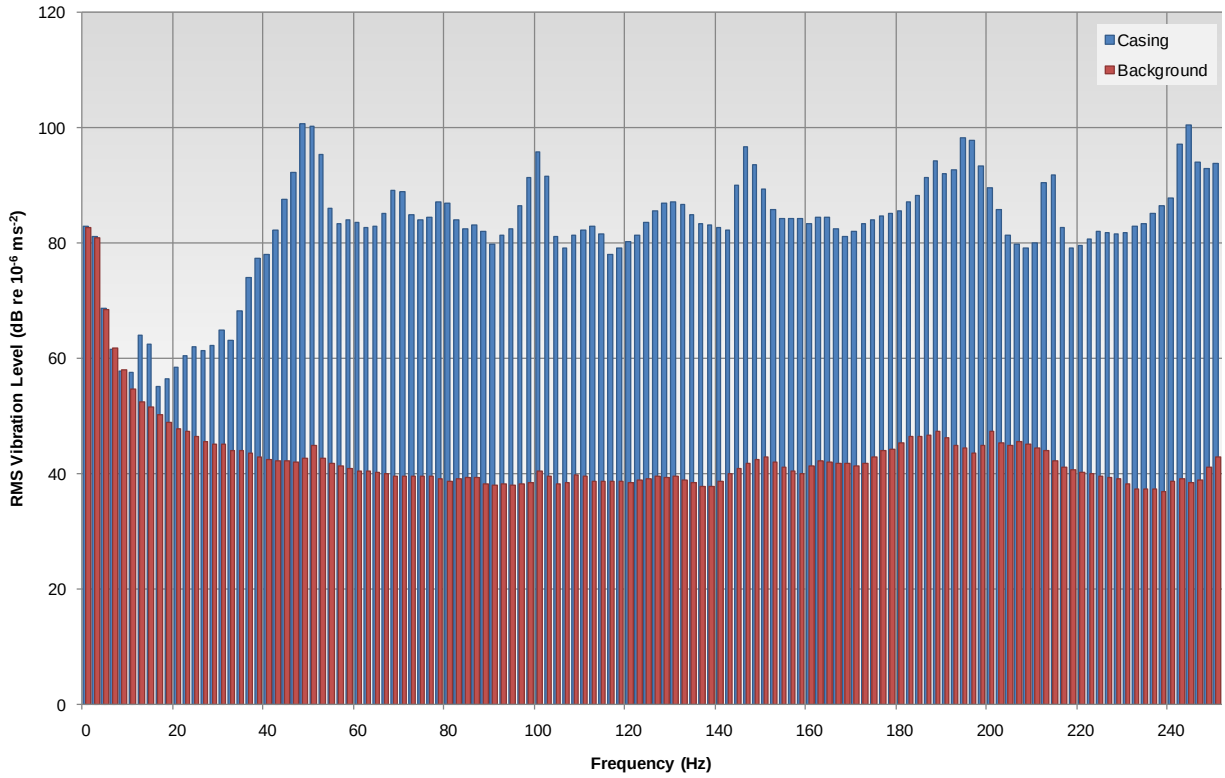


Figure 5-62. 474 West Berkshire (Site 1), Vibration Levels

Discussion

5.7.22. The manufacturer has indicated that the speed rating of the fan is nominally 770 rpm, and the compressor speed is 2850 rpm. With four fan blades, the passing frequency would correspond to around 51 Hz, with upper harmonics around 102 and 153 Hz. These are seen in the frequency spectrum results of normal operation. The compressor speed corresponds with a rotation frequency of around 48 Hz, upper harmonics are clearly visible in the defrost cycle frequency spectrum.

5.7.23. During normal operation, the fan contributes a greater amount of noise than the compressor, although tonal content provided by the compressor is audible.

5.7.24. The vibration data shows that both the compressor and fan contribute to the vibration emissions.

5.8 *475 West Berkshire (Site 2)*

Site description

5.8.1. The property is located in a small village off a quiet road. The ASHP is located to the rear of the brick built two story end of terrace property. The unit is mounted onto concrete paving slab footings.

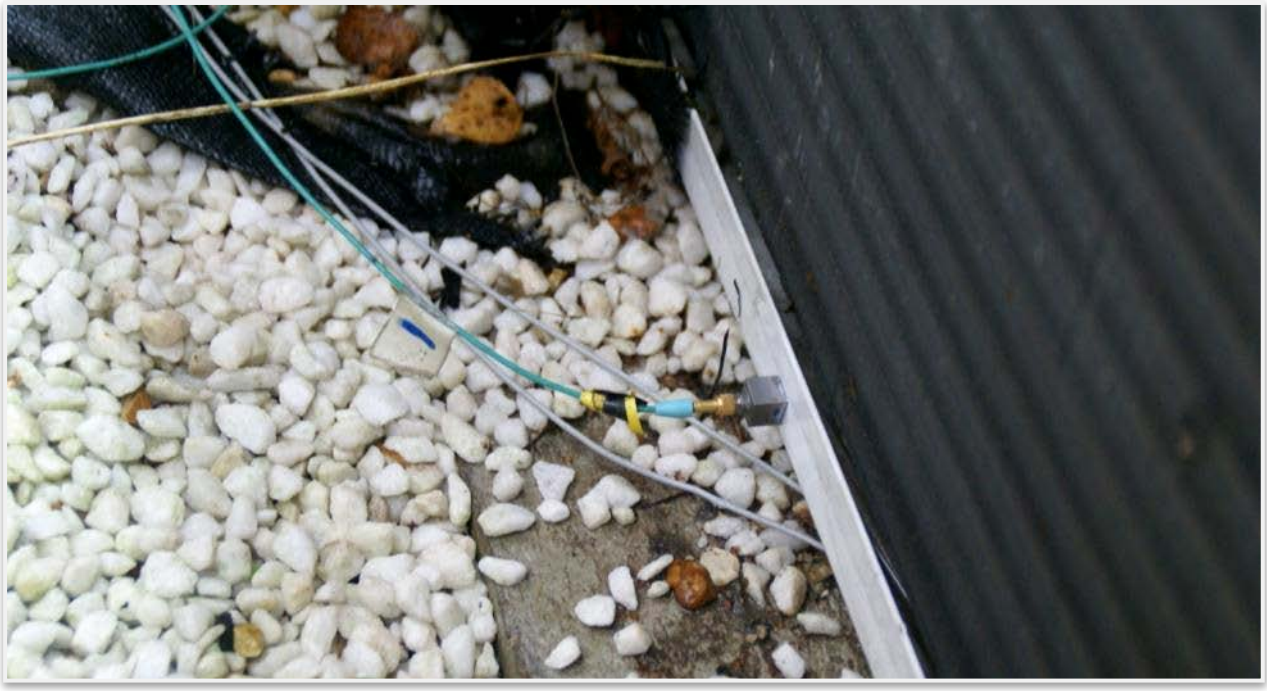
5.8.2. Subjectively the unit appeared to be operating normally although a prominent rattle was heard at times.

Equipment set up

5.8.3. The 9 Channel PULSE system was used at this site.

5.8.4. The unit was mounted above a mixed ground surface of soil, gravel and paving slabs. A garden storage unit was located to the right of the unit, preventing the installation of a microphone to the right of the ASHP. A fence was located to the left of the unit, which limited the distance at which the microphone could be placed at this location.

5.8.5. Accelerometers were fixed to the unit casing and to the wall surface immediately behind the unit as shown in Picture 5-19 and Picture 5-20. The accelerometers were fixed to the surfaces using cyanoacrylate cement.



Picture 5-19. 475 West Berkshire (Site 2), Casing-mounted Accelerometer

Picture 5-20. 475 West Berkshire (Site 2), Wall-mounted Accelerometer

5.8.6. The microphones were mounted on tripods as shown in Picture 5-21. All microphones were positioned 1 m from the ASHP casing, with the exception of the microphone to the left, which had a separation of 60 cm.

Picture 5-21. 475 West Berkshire (Site 2), ASHP and Microphone Arrangement

Measurement Results

5.8.7. Figure 5-63 presents the $L_{Aeq(1min)}$ measured noise levels at the microphone 1m in front of the unit set against time, along with the per-minute logged ASHP power consumption.

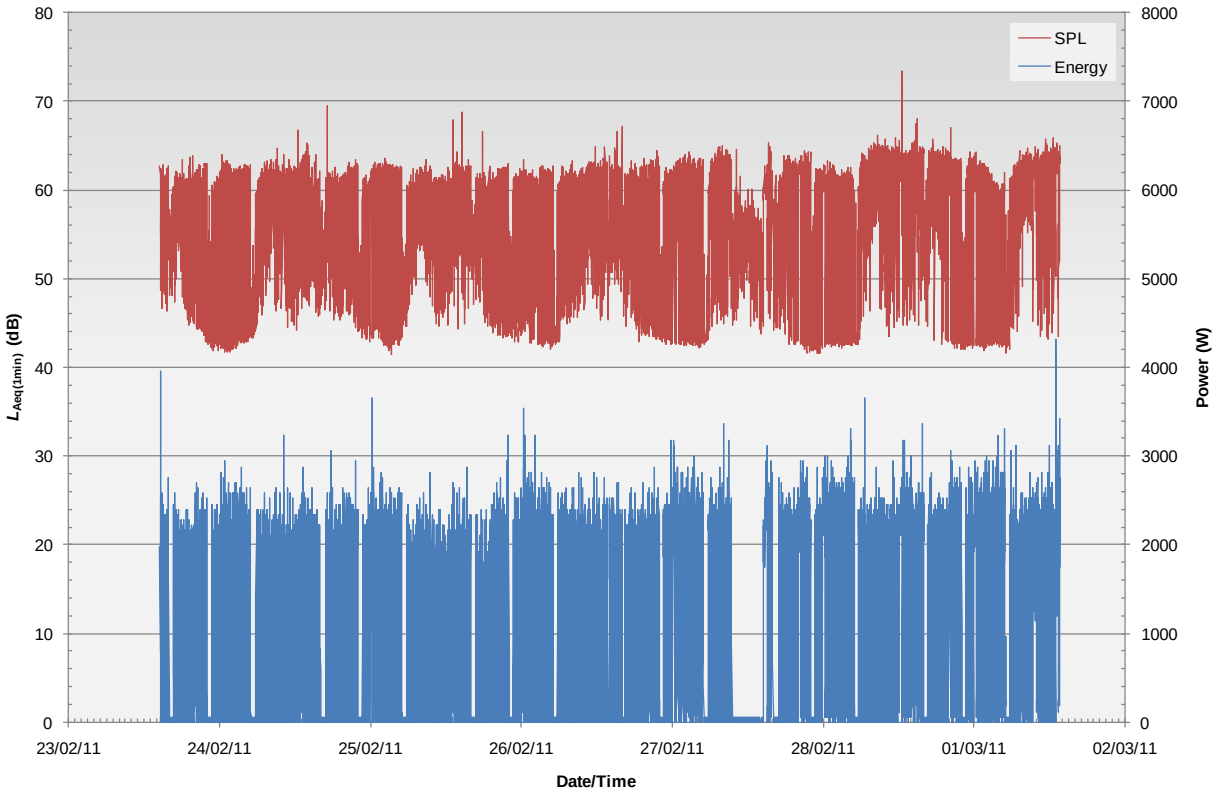


Figure 5-63. 475 West Berkshire (Site 2), Sound Pressure Level and Power Consumption vs Time

5.8.8. The chart highlights that the ASHP is cycling on and off very frequently, approximately every ten minutes, throughout the day and night time periods. When the unit is operational, it is usually on for approximately three to four minutes. Throughout the measurement period, the ASHP was operational for approximately 33% of the time.

5.8.9. The data shows an increase in measured noise level during periods when the ASHP is operating.

Measurement Analysis

5.8.10. Figure 5-64 presents a scatter diagram showing the noise levels against the power consumption, for the periods when the ASHP was operating. The chart shows no apparent link between power and noise level.

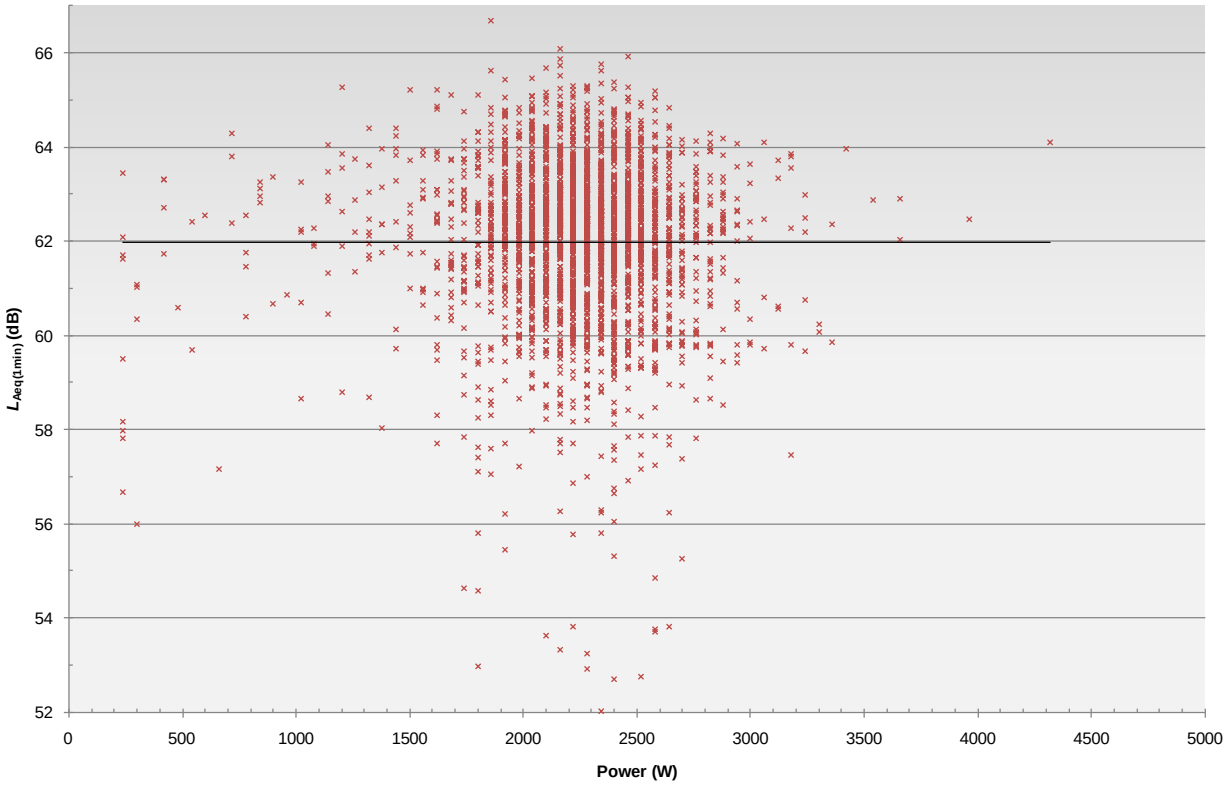


Figure 5-64. 475 West Berkshire (Site 2), Sound Pressure Level vs Power Consumption

5.8.11. Figure 5-65 presents a statistical analysis plot of the percentage of time that a specific noise level would be recorded, when the ASHP is under operation. From this confidence intervals can be presented for the typical noise levels.

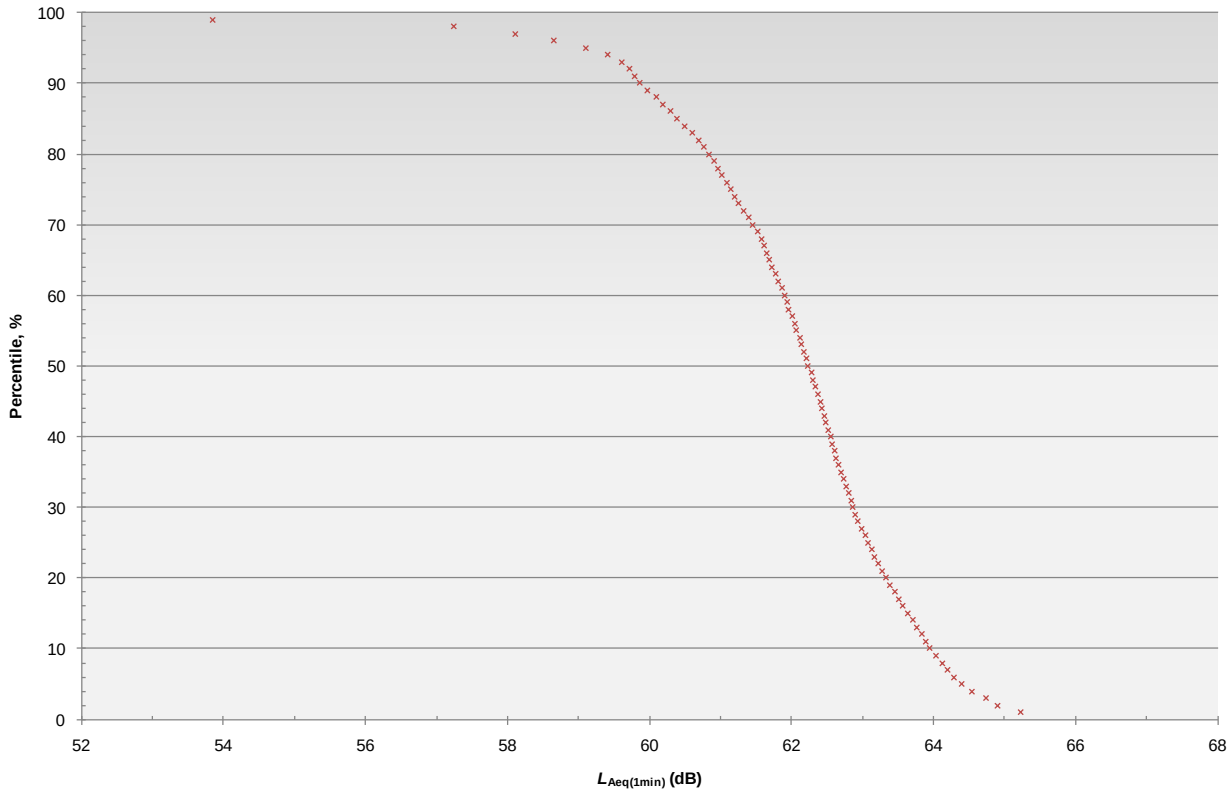


Figure 5-65. 475 West Berkshire (Site 2), Sound Pressure Level Statistical Analysis

5.8.12. The chart indicates that noise from the ASHP during operation will have a 90% certainty of being within around 3 dB of $\boldsymbol{L_{Aeq(1min)}}$ **62 dB**. The corresponding total ASHP noise dose over the whole assessment period is calculated as $L_{Aeq(1week)}$ 57 dB.

Defrost Cycle

5.8.13. Analysis of the measurements revealed that defrost cycles are part of the ASHP operation. During these periods, which can last for 2 to 3 minutes, the compressor is operating in reverse, without the fan. The average sound pressure level during a typical defrost cycle is around $\boldsymbol{L_{Aeq(1min)}}$ **63 dB**.

Directivity

5.8.14. Table 5-8 shows the directivity in noise emissions from the unit by comparing the noise levels at the different microphones, for a typical period of ASHP operation.

Table 5-8: Directivity Analysis of the ASHP Noise Emissions $L_{Aeq(1min)}$ dB 475 West Berkshire (Site 2), normal operation

Microphone Location	Front	Left	Above
Typical Microphone Level	62	62	62
Change from front microphone	-	0	0

5.8.15. It is seen that the ASHP does not exhibit significant directivity, which is likely to be due in part to the acoustically reflective nature of the nearby fence and garden storage unit.