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CONNAH'S QUAY POWER STATION: IMPACT ASSESSMENT OF OUTLET ATTENUATOR REMOVAL ON U3 AND U4 COOLING TOWERS

prepared for

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SUMMARY

A comprehensive assessment of the potential noise impact of removal of Cooling Tower outlet attenuators has been completed. A variety of off-site measurements were completed at residential locations overnight when residual noise levels were at a minimum. They involved the switching of individual Cooling Tower fans on and off to quantify their overall L_{Aeq} and tonal contribution at key residential receptors. There are already some cells without outlet attenuators. These included U4B2 and U4B5 which are some of the closest cells to residential locations and therefore represent useful examples of future possible scenarios.

Although apparent in FFT spectra, the characteristic 370Hz tone from gear meshing of the Cooling Tower gearboxes did not attract a tonal penalty during the operation of Unit 2, Unit 3 and Unit 4 fans (exc. U4B1 which has defective gearbox mounts), even overnight.

It has been found that the operation of U4B2, U4B5 and U4A5 fans (which already have outlet attenuators removed) does not give rise to significant overall L_{Aeq} or tonal levels at residential locations - implying that further attenuators on Unit 3 or Unit 4 cells could be removed (thereby allowing repair and return to service) without causing an adverse increase in noise.

ISO 9613/2 based noise modelling results have been used to examine the sensitivity to various scenarios. The model suggests that, relative to January/February 2016 levels, overall L_{Aeq} noise levels from the site in the event that all four units are in operation would increase by between 2.4 to 3.0dB across the nearest residential receptors if all Unit 3 and U4 outlet attenuators were removed. By making a variety of assumptions regarding the magnitude of current and future tonal noise (including the assumption of reduced tonal levels due to maintenance permitted by more ready access) from individual cells it is estimated that tonal level might increase by 4dB relative to the current base-line levels. If this were to be accurate then the site's tonal signature would be similar to that which has prevailed during faulty U4B1 fan operation – and which has not resulted in any public complaint.

Although there is broad agreement between the model predictions and measured levels and the ambient noise climate is dominated by traffic, there is uncertainty associated with the variability of the source emission, modelling assumptions and background noise level.

From an impact perspective, a 3.0dB increase in overall broad band L_{Aeq} noise from the site is slight in the context of an the prevailing background noise climate that is dominated by road noise from the A548 dual carriageway and intermittent noise from the nearby Crewe to Holyhead main line railway. Instead it is the presence of a prominent tone in the community which has the greater potential to attract public attention (reflected in the BS 4142 0 to 6dB rating penalty). Nevertheless, the measurement and modelling data does support the incremental removal of further outlet attenuators from Unit 3 and/or Unit 4 cells.

Prepared by **Approved for publication**

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1 INTRODUCTION

At the request of Connah's Quay Power Station, Uniper Technologies has undertaken noise investigations into the current noise emissions and impacts from the plant's Cooling Towers (CT) with a view to assessing whether further outlet attenuators can be removed permanently from the towers to allow future repair and maintenance of failed fans and gearboxes.

The study has involved a variety of on- and off-site noise monitoring exercises in the middle of the night to quantify the specific individual noise contributions from CT cells and then sensitivity tests using the existing noise model for the site. Taken together, the measurements and modelling have been used to estimate the potential noise level from the site for outlet attenuator removal.

2 HISTORY

Originally the Cooling Towers (CTs) were supplied with sound attenuators in the wet inlet, dry inlet and outlet parts of the tower cell. Since this time the outlet attenuators have gradually corroded and become a safety hazard and a significant hindrance to maintenance of the CT fan and gearbox.

In response to this issue the power station management proposed a modification to Unit (U1) and Unit 2 (U2) CTs which included the removal of the outlet attenuators.

In 2008, an EON study showed that the modification would result in only modest increases in overall noise level at key residential receptor locations. In the context of the existing noise climate, the number of residential locations affected and the benefit to the plant efficiency, improved plant maintenance and reduced pluming, the increase in noise level was considered to have low significance. The Environment Agency approved the proposed modification and the plant has been running with no outlet attenuators in U1 and U2.

Since this time, Units 3 (U3) and 4 (U4) CTs have continued to operate but have experienced component failures and repairs have been hindered by the presence of the outlet attenuators which are typically so corroded that they cannot be safely reinstalled.

2.1 Historic Compliance of the Site

The noise impact of the site has been assessed annually in accordance with the requirements of BS 4142 at key residential receptor locations. See Figure 1 which shows a map of the site and the key noise sensitive receptors. Further details are provided in Table 1.

As the key noise sensitive receptors are subject to considerable traffic noise, the assessment of the plant has typically focussed on assessing the noise impact in the night time period when the plant noise might be most quantifiable. The most recent assessment took place in January 2016 and showed that for the typically circumstances that prevailed at the time of the survey the impact from the plant was less than the noise level predicted as part of the 2008 modifications, see Table 2. However, historically the assessment of impacts have been variable, see Table 3 showing history of differences between rating and background level at the key noise sensitive receptors.

It can be seen that Woodfield Railway Cottages, Kelsterton Farm and Rockcliffe Cottages are the receptors which experience the greatest impact from the site. Where the rating level is relatively high this has been due to the plant's specific noise being rated 5dB higher due to

having a prominent tonal character overnight. In 2014 this was caused by the Purge Pond Cooling Towers (PPCT) and this aspect of the power station's noise signature has been improved by only operating the No 1 PPCT and improved maintenance.

Although, historically, the BS4142 assessment has predicted relatively large differences between the rating levels for the plant at the two nearest residential receptors, it is understood that no public noise complaints have been received in the last 7 years. This probably reflects the context of the ambient noise climate – i.e. intermittent noise of a much higher L_{Aeq} level from traffic movements on nearby roads 24 hours a day and rail movements to a lesser extent

3 CURRENT STATUS OF COOLING TOWERS

The location of the main cooling towers is shown in the annotated site map in Figure 2. Each unit has an individual bank of 10 cooling tower cells, see schematic diagram showing the labelling convention (A1 to A5 and B1 to B5).

The main sources of noise from the cooling tower (from bottom to top) are as follows:

- Broadband (white noise) Water droplet impact noise from Wet stage inlet to CT pond.
- Broadband fan and tonal gearbox noise from Dry stage inlet.
- Tonal gearbox noise from outlet diffuser structure.
- Broadband fan and tonal gearbox noise from outlet.

See Figure 3 which shows a schematic diagram of a generic hybrid CT cell.

As mentioned previously, U1 and 2 CT Cells have no outlet attenuators and U3 and U4 CT cells typically have the original fans and original outlet attenuators. At the time this assessment was completed, of the U3 and U4 cells under consideration 9 fans were out of service due to failures (U3A1, U3A2, U3A3, U3A4, U3B2 and U4A1, U4A4, U4A5 and U4B3). U3A4, U3A5, U4A5, U4B2 and U4B5 have previous had their outlet attenuators removed. See Table 4 which shows the attenuator and operation state of the forty individual cells.

4 ASSESSMENT APPROACH

4.1 General Principles

A worst case scenario for noise impact is obviously all four units operating overnight (when the ambient noise level is reduced) and during the summer (when local residents might have their bedroom windows open). However, recent energy markets and demands have meant that very rarely are all available units on-load at the same time and have typically not be operating overnight.

Therefore, although subsequent assessments are based on on-load operation of all four units this is truly a worst case scenario for assessing the impact and ordinarily the plant activity would be less, generating less noise and having a lower impact at off—site residential locations. It is not feasible to model all the possible scenario – suffice to say that the BS4142 impact assessments undertaken in recent years (Table 3) have shown that the impact from the plant has been low during day and evening periods due to the elevated traffic noise.

4.2 Information Gathering

To assess the potential impact from future removal of outlet attenuators the following measurements and modelling has been completed.

- Measurement of overall dBA and tonal noise at residential locations overnight.
- Measurement of specific components from Units Tower or individual cells at residential locations overnight by switching fans on and off.
- Measurement of internal and external noise levels of CT fans to quantify the current general noise emission from each cell.
- Modelling of original, current and future noise emissions from outlet, dry stage inlet and wet stage inlet for every 10 cells for each of the four Units.

Due to its proximity to the residential locations and there being unobscured line of sight, U4 cells have the greatest impact at the noise sensitive receptors. Fortuitously there are 2 operational cells on U4 CT which are currently operating without outlet attenuators (U4B2 and U4B5). Quantifying the individual noise contributions from these un-attenuated cells can be used to infer the likely noise from other cells if their outlet attenuators were removed. Due to U4B5 being closer to the community than any other cell, other factors being equal it would be expected that that the specific noise from any other cell at residential location would naturally be less due to being further away or screened.

4.3 Noise Modelling

The noise model for this study is based around an existing model which was previously used in the 2008 study. It has been updated with the current state of the various noise sources on the 40 CT cells (i.e. incorporating the EA approved changes to U1 and U2 fans and Dry Stage inlet attenuator modifications on all four units). See Figure 4 which shows a 3D image of the noise model and how the cooling towers are represented. The model was developed within the IMMI 2010 noise mapping program and predictions are based on the ISO 9613/2 methodology, assuming downwind propagation 70% RH and 15°C ambient conditions, with sound sources specified with octave band spectra.

4.4 Noise Measurements

Precision sound level meters were used meeting the requirements of BS EN 60651 and 60804 Type 1 or BS EN 61672 Class 1. All measurement apparatus used are maintained in calibration by regular certification, with an accredited laboratory, to BS 7580-1. Each set of measurements was preceded and followed by a calibration check using the sound level meter's acoustic calibrator. No significant drift in meter response was detected during the exercise. Calibration certificates for the equipment used in the survey are given in Figure 2.

Typically the meter was configured to measure 1/3rd octave band L_{Aeq}, L_{A10}, L_{A90} and L_{A99} levels. However, additional narrow band Fast Fourier Transform (FFT) measurements were also made to quantify the magnitude of any tones (800 lines, 0-1250Hz, Hanning Window). To be most representative of the noise climate, ordinarily environmental noise measurements should be 15 min in duration overnight. However, during the times when individual plant were being switched on and off the measurements were typically shorter in duration and, where possible, were taken when transient ambient noise sources were absent. This approach of collecting

short-term measurements meant that the maximum amount of data was collected during the exercise due to measurements being made at various locations and whilst the plant was in various different states.

The recent calibration certificates for the equipment used in the measurements are shown in Figure 5.

5 OFF-SITE MEASUREMENT SURVEYS

The background sound climate at the key residential receptors is dominated by the road noise from the A548 dual carriageway and intermittent noise from the nearby Crewe to Holyhead main line railway. Ordinarily the power station only becomes a discernible contributor to the noise level in the late evening and overnight. To minimise the interference from residual noise sources such as traffic the measurements have concentrated on quantifying the plant's noise overnight, where possible.

5.1 5-6th January 2016

Details of the overnight measurements to quantify the individual plant contributions the nearest noise sensitive receptors are given in Appendix A. The key findings from these measurements that inform the assessment of potential impact from possible removal of further outlet attenuators on U3 and U4 are summarised below.

Even overnight the L_{Aeq} levels in the community are still subject to transient contributions from traffic movements which restrict its usefulness as a measure of the specific noise level from the plant. As the power station noise is relatively steady, changes in L_{A90} arising from the staged switching on and off of U2 and U4 cells have been used to estimate the specific noise levels from each Units CTs.

	Rockcliffe Cottages	**Woodfield Railway Cottages**	**Kelsterton Farm**
U2 CTs (Estimate 1)	39	40.5	36.6
U2 CTs (Estimate 2)	---	41.3	28.8
U3 CTs	<37	<40	<37
U4 CTs	---	36	38.3

This data is used in conjunction with predicted levels in Section 7.3, as a basic check on the validity of the ISO 9613/2 noise model to confirm the models suitability for use in estimating changes in noise levels arising from future outlet attenuator removal.

The analysis of magnitude and audibility of 370Hz tones that occurred off-site during 5-6th January 2016 survey shows:

- Unit 2 cells were not responsible for discernible levels of 370Hz tonal noise at any community location.

- U3 cells were not responsible for audible levels of 370Hz tonal noise at any community location.

- U4 cells are responsible for levels of 370Hz tonal noise at Kelsterton Farm and Woodfield Railway cottages that would attract a tonal penalty. However this was primarily due to U4B1 fan and the other fans (including U4B2 and U4B5 with no outlet attenuators) would appear not to have a significant effect at residential location.

5.2 25-26th January 2016

To check the observations from the 5-6th January 2016 surveys and improve the robustness of any assessment, a further measurement exercise was undertaken overnight on 25-26th January 2016. Details of the overnight measurements to quantify the individual plant contributions the nearest noise sensitive receptors are given in Appendix B. The key findings from these measurements that inform the assessment of potential impact from possible removal of further outlet attenuators on U3 and U4 are summarised below.

The current configuration of U4 fans (including U4B2 and U4B5 with outlet attenuators removed removed) had a relatively minor contribution to overall L_{Aeq} levels at Woodfield Railway Cottages - providing empirical evidence that further removal of outlet attenuators on other U3 or U4 cells would not be expected to increase the site's overall L_{Aeq} footprint significantly. [Note: based purely on simple decibel addition of one or more sources to an existing level – however see Section 7 for more comprehensive model sensitivity and scenario analysis].

- The 370Hz tone level apparent in the spectrum from U2 and U3 fans was sufficiently low level to be indiscernible.

- Pairs of U4 fans (U4B2/U4B5 and U4A2/U4A3) caused subtle increases in 370Hz tonal levels at Woodfield Railway Cottages that were within the range of measurement uncertainty.

Specific tonal contributions from unit blocks of CTs and individual cells are combined with other measurements in the following section.

5.3 Summary of Off-site Tonal Level Estimates

A summary of estimates of 370Hz tones from the three off-site surveys when fans which switched on and off in an attempt to reveal their specific contribution at key receptors is provided below.

Unit CT	Specific Plant Item	Survey Date	Kelsterton Farm	Rockcliffe Cottages	Woodfield Railway cottages
U1	No Data	No Data			
U2	U2 Fans	5-6 Jan Survey 1	18dB		
U2 & U3	U2 CT and U3 CT Fans	5-6 Jan Survey 1		28dB	
	U2 CT and U3 CT Fans	25-26 Jan	24dB	23dB	24-26dB
U3	U3 Fans	6 Jan Survey 2		18dB	32dB
U4	U4B2 and U4B5 together	25-26 Jan			16-24dB
	U4 fans (including U4B1)	25-26 Jan	32dB	25dB	29dB
	U4 fans (excluding U4B1)	6 Jan Survey 2			28dB
	U4 B1	6 Jan Survey 2			40dB
	All U4	5-6 Jan Survey 1	40dB		38dB
	U4B5	5-6 Jan Survey 1			<21dB

Where comparable measurements were possible, there is variability between the results of each survey. The key noteworthy features are relative dominance of the U4B1 fans and the comparable minor tonal contributions from the remaining other fans. In fact, the only times the 370Hz tone caused the plant's spectrum to attracted a tonal penalty was when U4B1 fan was running. For all the other fan operational states the 370Hz tone may have been visible in the FFT spectrum but was not prominent.

5.4 U1 Contribution

At the time that the off-site measurements were being taken U1 was undergoing an outage and the Cooling Towers were out of service. U1 has since returned to service and a survey of the Dry Stage inlet internal levels were undertaken on 12th February. The tonal and overall noise levels have been included alongside the other unit data in Table C1. Overall, this table shows that in term of both tonal and overall noise levels, the amount of noise generated by U1 cells is very similar in magnitude to that generated by the neighbouring U2. As a consequence it is possible to infer that the noise contribution from U1 CT would be similar if not less than U2 CT levels by virtue of being further from the residential receptors and potentially screened by intervening structures.

6 U4B1 FAN IMPACT

The various on and off-site assessments have identified that the U4B1 fan is the noisiest of the cooling tower fans – and is responsible for the greatest contribution to the 370Hz tone off-site. This has been identified to the power station in UTG report in February 2016 in which recommendations made for this particular fan shut-down if not needed and should be scheduled for repair.

Connah's Quay Power Station Engineers have advised that the reason for this fan being particularly noisy is associated with a worn gearbox and anti-vibration mounts. It is understood that remedial work has been hampered by the outlet attenuators restricting access. The U4 fans without outlet attenuators (U4B2 and U4B5) have been measured to have a considerably less tonal noise impact off-site – possibly due to being in a better state of repair due to access being possible. If removal of outlet attenuators are allowed in the future then it will be possible for maintenance to be more readily undertaken, assuring a better integrity of fan/gearbox and preventing a fan/cell from generating tonal noise levels as high as those detected from U4B1 in this study.

For the purpose of assessing the future impact from the CT plant in its current configuration scenarios where outlet attenuators are removed, it has been assumed that U4B1 fan emission is equivalent to other U3 and U4 fans.

7 MODIFICATION SCENARIO PREDICTIONS

The plant noise model developed for the 2008 exercise has been updated with the current configuration of CTs and has been used to estimate the likely noise levels that might occur after removal of further outlet attenuators.

7.1 Scenario Results

Seven scenarios, A to G, have been identified. A is a theoretical scenario representing the CT configuration following the 2008 agreed modifications (40 fans on) and Scenario B represents

the current Jan/Feb 2016 configuration with some U3&U4 outlet attenuators removed and some fans not available. Scenarios C to G are theoretical options of removing outlet attenuators on combinations of U3 and U4 cells. See overall L_{Aeq} dB specific noise level predictions for the various scenarios to the key residential receptors in Table 5.

Note: Although the model includes representations of basic topography, it is considered that the attenuation associated with the presence of the elevated A548 dual-carriageway between the site and 102 Kelsterton Road is not well characterised by the model. As a result, the barrier attenuation provided by the road is believed to be underestimated and hence the overall and Cooling Tower plant noise level predictions are over-estimates. At the other three locations the presence of the A548 doesn't overly obscure line of sight of the plant sources and topographic effects are not an issue.

This table shows that Kelsterton Farm and Woodfield Railway Cottages are sensitive to changes on the CTs, which is supported by subjective observations and the reason why surveys have concentrate at these locations. It is estimated that if all four units were run with the CT cell configurations as of Jan/Feb 2016 (Scenario B), the L_{Aeq} noise level from the site would be between -0.4 and 0.3dB higher than the level predicted by theoretical post-2008 configuration (Scenario A). The reduction due to non-operation of some U3 and U4 cells is offset by the increase in noise level from those small number of cells which have had already had their outlet attenuators removed.

Scenario C results suggest that removal of outlet attenuators from the currently unavailable U3 cells and their subsequent return to service without attenuators would result in noise level increase less than 1.4dB at all locations. Scenario D results suggest that removal of outlet attenuators from the currently unavailable U4 cells and their subsequent return to service without attenuators would result in noise level increase less than 1.6dB at all locations

Scenario E results suggest that removal of outlet attenuators from all ten U3 cells but keeping U4 in its current state would result in noise level increase between 0.9 and 1.9dB across residential locations. If outlet attenuators were removed from all twenty U3 and U4 cells and all fans returned to service (Scenario G) then, relative to theoretical 2008 levels, an increase in overall L_{Aeq} level at receptors of 2.4 to 3.0dB is estimated.

7.2 Single Cell Modifications

Whilst Table 5 shows the model estimates for some possible scenarios of outlet attenuator removal, it is considered worthwhile to provide detail of each cells specific contribution at the key residential receptors. Table 6 shows specific noise levels from individual cells, from A&B groups of 5 cells and from Unit blocks of 10 cells at four key residential receptors.

The data is presented for the theoretical Post-2008 (Scenario A) state of all U3 and U4 cell having outlet attenuators and the theoretical situation (Scenario G) of removal of all outlet attenuators from U3 and U4 cells. This data can be used to estimate the noise level impact from any proposed removal of outlet attenuators that is not precisely covered by the one of the C to G scenarios. The scenarios are defined in Table 5.

Example Sensitivity Calculation:

If U4B3 (not available to run in January 2016 due to collapsed attenuators and damaged blades) was to have its outlet attenuators removed permanently to facilitate repairs undertaken, then the specific noise level from that cell is estimated to be 31.2dBA at Kelsterton Farm. Table 5 shows that for all four generating units being on-load the overall noise level from the current

configuration of plant (Scenario B) is 41.7dBA. Therefore it is estimated that although the removal of outlet attenuators on U4B3 would increase its noise contribution from 26.5dBA to 31.2dBA this is sufficiently below the noise level from the rest of the plant that there would be virtually no change in the plant noise level at Kelsterton Farm.

i.e. 41.7dBA – 26.5dBA + 31.2dBA = 41.9dBA (i.e. a change of only 0.2dB).

7.3 Model Validation

The sound power level assumptions in the model are based on a combination of historic measurements, manufacturers data, attenuator estimates and do not take into account any inter-cell variability. Whilst there is good confidence in the amount of noise radiated by each cells Wet Stage Inlet, the amount of noise radiated by the Dry Stage inlet and Cell outlet is less certain. This can be seen in the range of overall L_{Aeq} levels measured across the CTs within the Dry Stage Inlet corridor (being a coarse indicator of the amount of noise radiated by the Dry Stage Inlet and the Outlet). With the exclusion of U4B1 data, the overall L_{Aeq} values range from 74-78dBA and the 370Hz tonal level from 67 to 76dB across the operational U3 and U4 cells. It is not feasible to reflect all aspects of the inter-cell variability in actual noise emissions within the noise model; therefore the results should be treated as basic estimates of likely changes that might occur on average. In reality the actual change in noise level could be higher or lower than predicted depending upon the particular state of the fan/gearbox compared to the assumed sound power level in the model. The predicted level and subsequent change also depends upon how accurately the rest of the plant noise is characterised.

With this in mind it is appropriate to consider how well the model results align with actual measurements that were collected during cell shutdowns in January 2016. Table 7 shows the individual cell contributions which make up Scenario B (i.e. the plant operational state that occurred in Jan/Feb 2016 in which some U3 and U4 fans are out-of-service and some U3 and U4 outlet attenuators removed).

A comparison between estimated measured and modelled Jan/Feb 2016 (Scenario B) noise levels for Unit CTs is given in Table 8.

In terms of Jan/Feb 2016 levels, the cooling tower noise model aligns with specific noise levels estimates (derived from changes in measured levels when plant were switched on/off)to within approximately 2dB at the receptors which received the greatest plant noise contribution. There is some variability between Units, but typically the noise model predictions are less than the empirical estimates of each unit's CT contribution. It should be noted that it was necessary to base the empirical estimates on changes in L_{A90} levels - which have their own uncertainty.

7.4 Tonal Predictions

There is no rigorous method for predicting tonal noise increases arising from attenuator removal as the ISO 9613/2 prediction methodology used to estimate the overall L_{Aeq} levels explicitly states that it is only applicable for broadband noise sources. Nevertheless, to be able to estimate the possible increases in tonal levels that might arise it is necessary to utilise the noise model predictions of attenuation to 400Hz one-third octave band noise that occur to the 370Hz as it propagates out from each cell to the receptors. Various assumptions regarding the current and future configuration have had to be made, including the tuning of the results to agree with measured January levels. The results of this sensitivity analysis for Scenarios B to G (representing progressive removal of outlet attenuators on U3 and U4 cell) are shown in Table 9.

The increases in tonal level estimates are compared to Scenario B (a representation of all four units CTs in their Jan/Feb 2016 configuration with some individual fans unavailable and some outlet attenuators removed).

Increases in tonal noise level up to 4dB are predicted if all outlet attenuators are removed (provided the fan and gearboxes are maintained/monitored/repaired as necessary and are consistent with existing cells without attenuators – U4B2 and U4B5).

The presence of a prominent tonal character in an industrial noise signature is known to attract public attention – reflected in BS4142 rating penalty of 0 to 6dB, therefore this is an important aspect of understanding the impact and significance of any change. Tonal levels of around 38dB are estimated at Woodfield Railway Cottages and Kelsterton Farm - if all U3 and U4 attenuators are removed and maintenance undertaken. Putting this impact into context, tonal levels from the faulty U4B1 fan of around 40dB were detected during the measurement exercise. In the middle of the night this attracted a 6dB tonal penalty based on its prominent relative to masking, therefore in comparable conditions a 38dB tonal level from a Scenario G outlet configuration might attract a 4dB penalty.

It is informative to consider that a 370Hz tonal level from the faulty U4B1 fan similar to that predicted has not given rise to public complaint. Whilst pre-existence of a condition is no defence or guarantee against a future complaint it does give some context to the prevailing noise climate and that it might actually be less likely to cause public complaint than the assessment using the worst-case scenarios assumed to date would imply.

8 DISCUSSION

If all U3 and U4 outlet attenuators are removed it is estimated that overall noise levels and tonal level at the most sensitive receptors might increase by 3dB and 4dB respectively, relative to current estimates. These estimates are based on various assumptions about source emissions, spectra and general state of fan/gearboxes and therefore should be considered to be indicative of potential outcomes. Although the site has not received any public noise complaints for the last 5 years and the ambient noise climate is dominated by traffic noise, there is sufficient uncertainty associated with the measurements and modelling that it would be inappropriate to speculate whether this magnitude of change would be acceptable. Furthermore, this analysis has been focussed on the small number of residential properties near to the site perimeter where historic data exists. The possible impact from increased overall L_{Aeq} and tonal character at more distant by more densely populated areas such as Kelsterton Road and Lane is not certain.

The potential increase in tonal noise following removal of large number of attenuator is arguably more significant that than the slight increase in broadband noise (especially in the context of the noise climate being dominated by traffic). The presence of an audible and characteristic tone in the community is more likely to attract attention and increases the likelihood of complaint (reflected in the BS 4142 0 to 6dB rating penalty) than a 3dB increase in overall noise. Whilst it is not feasible to control the broad band noise from (without introducing further outlet attenuators), it is possible to manage the tonal gearbox noise through careful maintenance and monitoring.

The measurements and analysis do suggest that, since there are already three U4 fans operating without outlet attenuators and without causing an adverse impact in the community then removal of further attenuators from selected cells should be acceptable without overly increasing the noise from the site.

9 CONCLUSIONS

The noise level from the operation of the Cooling Towers is highest at Woodfield Railway Cottages and Kelsterton and various measurements focussed on quantifying specific contributions. Observations from these measurements made whilst ambient noise levels were at a minimum are as follows:

- Although apparent in FFT spectra, the 370Hz tone from Cooling Tower gearboxes did not attract a tonal penalty during the operation of U2, U3 and U4 fans (exc. U4B1).

- The operation of U4B2, U4B5 and U4A5 fans (which already have outlet attenuators removed) does not give rise to significant overall L_{Aeq} or tonal levels at residential location – implying that further attenuators on broken U3 or U4 cells could be removed (thereby allowing repair and return to service) without causing adverse increases in noise.

ISO 9613/2 based noise modelling results have been used to examine the sensitivity to various scenarios. The model suggests that, relative to Jan/Feb 2016 levels, overall L_{Aeq} noise levels from the site during four unit operation would increase by between 2.7 to 3.0dB at the key residential receptors if all U3 and U4 outlet attenuators were removed.

By making a variety of assumptions regarding the magnitude of current and future tonal noise (assuming reduced levels due to maintenance permitted by more ready access) from individual cells it is estimated that tonal level might increase by 4dB relative to the current base-line levels. If this were to be accurate then the site's tonal signature would be similar to that which has prevailed during faulty U4B1 fan operation – and which has not resulted in any public complaint.

Although there is broad agreement between the model predictions and measured levels and the ambient noise climate is dominated by traffic, there is uncertainty associated with the variability of the source emission, modelling assumptions and background noise level. However, the measurement and modelling data does support the incremental removal of outlet attenuators from U3 and/or U4 cells.

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BS 4142:1997. Method for rating industrial noise affecting mixed residential and industrial areas.

BS 4142:2014. Methods for rating and assessing industrial and commercial sound.

GLOSSARY

dB — Decibel. Used here to represent the sound pressure level, P, expressed as twenty times the logarithm of the ratio of this pressure to a reference pressure, P_0, 20×10^{-6} N/m^2. Thus dB = $20 \times \text{Log}_{10}(P/P_0)$.

dBA — As above except that the measured sound is first subject to a frequency weighting, known as the 'A' weighting, which is designed to compensate for the varying sensitivity of the human ear to sounds of different frequency.

$L_{A90,T}$ — The A-weighted sound level exceeded for 90% of the measurement period of duration T.

$L_{Aeq,T}$ — The equivalent steady dBA sound level containing the same acoustic energy as the actual, measured, fluctuating level.

$L_{A.r}$ — The specific equivalent continuous dBA sound pressure level, rated upwards by 5dB if tonal or intermittent in character.

$L_{C90,T}$ — The 'C'-weighted sound level exceeded for 90% of the measurement period of duration T.

$L_{Ceq,T}$ — The equivalent steady 'C'-weighted sound level containing the same acoustic energy as the actual, measured, fluctuating level.

1/3rd octave bands — An octave is a doubling or halving of frequency. One-third octave bands are even finer sub-divisions of the frequency range that are centred at specific frequencies, i.e. 125,160, 200, 250, 315,400, 500Hz etc.

FFT — Fast Fourier Transform – narrow band analysis to reveal tonal components with a measurement spectrum.

BS 4142: 2014

BS 4142 (1997) provides a procedure which can be used to assess the impact of industrial noise on residential properties based on the difference between the rated $L_{A,r}$ noise level from the installation and the background L_{A90} noise level. If there is a tonal, intermittent or percussive feature in the source noise then an additional dB corrections are added to the L_{Aeq} specific noise source level in recognition that it is more likely to attract attention.

Extract from BS4142 regarding Assessment of impact

Typically the greater the difference between the Rating and Background Level, the greater the magnitude of the impact.

a) A difference of around +10 dB or more is likely to be an indication of a significant adverse impact, depending upon context

b) A difference of around +5 dB or more is likely to be an indication of an adverse impact, depending upon context

c) The lower the rating level is relative to the measured background sound level the less likely it is that the specific sound source will have an adverse or significant adverse impact. Where the rating level does not exceed the background sound level, this is an indication of the specific noise source having a low impact, depending on the context.

Note 2 Adverse impacts include, but are not limited to, annoyance and sleep disturbance. Not all adverse impacts will lead to complaints and not every complaint is proof of an adverse impact

Table 1: Details of monitoring positions

Position	Grid Reference Easting: Northings	Distance to Power Station centre/m (Approx)
102 Kelsterton Road	327960, 370700	380
Rockcliffe Cottages	327150, 371265	830
Kelsterton Farm	327565, 370800	480
Woodfield 'Railway' Cottages	327415, 371110	540
Kelsterton Gatehouse[#]	327905, 370720	360

Note Kelsterton Hostel Gatehouse was stated within the Power Station's original Operational Noise Programme. However due to it and other properties on Kelsterton Road being screened by the A548 carriageway, surveys have historically concentrated on quantifying the nearby noise climate with measurements based at 102 Kelsterton Road only.

Table 2 Estimate of Specific Noise Level from Operations on the Site – January 2016

Position	Night time Background Mean L_{A90}		Estimated Specific L_{Aeq} dB Noise Level from Site	Rating Level $L_{A,r}$ dB [Note 1]	Rating Level $L_{A,r}$ minus Background L_{A90} dB	Night-time BS 4142:2014 Impact Assessment [Note 2]
	Aug 07	July 12	Plant On-load	Plant On-load	Plant On-load	Plant On-load
102 Kelsterton Road	33.2	33.3	34	34	1	*Low*
Kelsterton Farm	36.2	34.5	40	40	4-5	*Adverse*
Rockcliffe Cottages	36.2	33.8	38	38	2-4	*Low to Adverse*
Woodfield 'Railway' Cottages		35.3	40	40	5	*Adverse*

Note 1 Based on subjective observations and tonal assessments of FFTs the noise signature from the plant on this occasion was not considered to have a tonal character during the night time operation of U2, GTP, AGI and U3 CTs, hence no penalty has been applied at any of the locations.

Note 2 According to BS 4142 these assessments of impacts depend upon context. Bearing in mind the dominance of the traffic noise in the community these assessments are considered to a pessimistic quantification of the plant's noise impact in the community.

Table 3: Comparison of Dec 2009/Dec 2010/Dec 2011, Nov 2012, Dec 2013, Sep 2014 and Jan 2016 BS 4142 Differences

Position	Period	Rating Level $L_{A,r}$ minus Background L_{A90}									Trend 2014-2016
		Dec 2009	Dec 2010	Dec 2011	Nov 2012	Nov/Dec 2013		Sep 2014		Jan 2016	
						Off-Load	On-Load	Off-Load	On-Load	On-Load	
102 Kelsterton Road	Night	+6	+6	+4	N/A	N/A	N/A	+1	N/A	+1	-
	Evening	+2	+2	0	N/A	N/A	N/A	-3	N/A	-3	-
	Day	-12	-12	-14	N/A	N/A	N/A	-17	N/A	-17	-
Kelsterton Farm	Night	+7	+12	+6	+5	+5	+12	+4	N/A	+5	-
	Evening	-2	+3	-3	N/A	-4	+3	-5	N/A	-4	-
	Day	-12	-7	-12	N/A	-14	-7	-15	N/A	-14	-
Rockcliffe Cottages	Night	+7	+7	+2	+5	+2	N/A	+3	+8	+3	⮟
	Evening	-2	-2	-7	N/A	-7	N/A	-6	-1	-6	⮟
	Day	-4	-5	-9	N/A	-9	N/A	-8	-4	-8	⮟
Woodfield 'Railway' Cottages	Night	+10	+10	+7	+15	+13	+16	+8	+17	+5	⮟
	Evening	+2	+2	0	N/A	+5	+8	0	+9	-3	⮟
	Day	-5	-5	-7	N/A	-2	+1	-7	+2	-10	⮟

Table 4: Fan operative state and presence of Outlet Attenuators during surveys

Cell/Fan	U1	U2	U3	U4
	Outlet Attenuators	Outlet Attenuators	Outlet Attenuators	Outlet Attenuators
B5	None	None	Yes	None
B4	None	None	Yes	Yes
B3	None	None	Yes	Yes
B2	None	None	Yes	None
B1	None	None	Yes	Yes
A1	None	None	Yes	Yes
A2	None	None	Yes	Yes
A3	None	None	Yes	Yes
A4	None	None	None	Yes
A5	None	None	None	None

Key

Denotes – Fan Not available for operation
Denotes – Fan available for operation
Yes – denotes presence of attenuators in cell outlet
None – denotes that no attenuators are present in cell outlet

Table 5: Predicted CT and Total Plant noise level for various CT scenarios

Scenario		A	B	C	D	E	F	G
Description	Non-CT Plant noise	2008 State	Jan/Feb 2016 Status	Broken U3 cells repair (outlet attenuators removed)	Broken U4 cells repair (outlet attenuators removed)	All U3 outlet attenuators removed	All U4 outlet Attenuators removed	All U3&U4 outlet Attenuators removed
102 Kelsterton Road		40.4	40.6	42.0	42.3	42.9	42.9	44.4
Kelsterton Farm		40.4	40.3	41.1	42.4	41.6	43.0	43.8
Rockcliffe Cottages		40.5	40.9	42.1	42.2	42.7	42.7	44.0
Woodfield Railway Cottages		42.6	42.1	43.5	44.0	43.7	44.6	45.6
Total Site Noise								
102 Kelsterton Road	37.6	42.2	42.3	43.4	43.5	44.0	44.0	45.2
Kelsterton Farm	36.1	41.7	41.7	42.3	43.3	42.7	43.8	44.5
Rockcliffe Cottages	33.8	41.3	41.6	42.7	42.7	43.2	43.2	44.4
Woodfield Railway Cottages	37.5	43.7	43.4	44.4	44.9	44.6	45.3	46.2
Increase over 2008 baseline								
102 Kelsterton Road			0.1	1.2	1.3	1.8	1.8	3.0
Kelsterton Farm			0.0	0.6	1.6	1.0	2.1	2.7
Rockcliffe Cottages			0.3	1.4	1.4	1.9	1.9	3.0
Woodfield Railway Cottages			-0.4	0.7	1.1	0.9	1.6	2.4

Note: As U4B1 has been identified as being a prominent noise source and due for repair. Its contribution has been excluded from the calculation in order that the prediction can reflect the more typically noise emission from the cells.

Scenario A Post 2008: Modified U1 and U2 cells, all U3 and all U4 cells assumed to in original state but with reduced Dry Stage inlet silencing

Scenario B As Scenario A: except with only the U3 and U4 cells that were available in Jan/Feb 2016 (plus reflecting the outlet attenuator states- i.e. some removed)

Scenario C As Scenario B: except with all currently unavailable U3 fans running with outlet attenuators removed (i.e. available U3 and U4 cells in their current state)

Scenario D As Scenario B: except with all currently unavailable U4 fans running with outlet attenuators removed (i.e. available U3 and U4 cells in their current state)

Scenario E As Scenario B: except with all ten U3 fans running with outlet attenuators removed

Scenario F As Scenario B: except with all ten U4 fans running with outlet attenuators removed

Scenario G As Scenario B: except with all ten U3 and all ten U4 fans running with outlet attenuators removed

Table 6: Individual contributions from individual cells for Post-2008 state (Scenario A) and modified state (Scenario G) with all U3 and U4 outlet attenuators removed

	102 Kelsterton Road			Kelsterton Farm			Rockcliffe Cottages			Woodfield Railway Cottages		
	Post 2008	Modified	Increase	Post 2008	Modified	Increase	Post 2008	Modified	Increase	Post 2008	Modified	Increase
U1	**34.5**	**34.5**	**0.0**	**34.5**	**34.5**	**0.0**	**36.8**	**36.8**	**0.0**	**36.7**	**36.7**	**0.0**
U1A	32.4	32.4	0.0	31.1	31.1	0.0	34.6	34.6	0.0	33.0	33.0	0.0
U1A1	25.2	25.2	0.0	23.1	23.1	0.0	27.4	27.4	0.0	24.5	24.5	0.0
U1A2	25.5	25.5	0.0	24.6	24.6	0.0	27.5	27.5	0.0	23.9	23.9	0.0
U1A3	25.7	25.7	0.0	24.4	24.4	0.0	27.7	27.7	0.0	26.1	26.1	0.0
U1A4	25.6	25.6	0.0	23.1	23.1	0.0	27.8	27.8	0.0	27.1	27.1	0.0
U1A5	25.0	25.0	0.0	25.0	25.0	0.0	28.0	28.0	0.0	27.3	27.3	0.0
U1B	30.4	30.4	0.0	31.8	31.8	0.0	32.6	32.6	0.0	34.3	34.3	0.0
U1B1	27.0	27.0	0.0	25.2	25.2	0.0	26.4	26.4	0.0	29.1	29.1	0.0
U1B2	26.2	26.2	0.0	25.0	25.0	0.0	25.7	25.7	0.0	28.7	28.7	0.0
U1B3	19.1	19.1	0.0	23.1	23.1	0.0	25.4	25.4	0.0	26.3	26.3	0.0
U1B4	17.3	17.3	0.0	26.2	26.2	0.0	25.4	25.4	0.0	25.8	25.8	0.0
U1B5	16.7	16.7	0.0	24.2	24.2	0.0	25.2	25.2	0.0	25.0	25.0	0.0
U2	**37.5**	**37.5**	**0.0**	**34.8**	**34.8**	**0.0**	**36.6**	**36.6**	**0.0**	**36.3**	**36.3**	**0.0**
U2A	32.8	32.8	0.0	32.8	32.8	0.0	34.1	34.1	0.0	34.4	34.4	0.0
U2A1	27.3	27.3	0.0	24.7	24.7	0.0	27.0	27.0	0.0	23.7	23.7	0.0
U2A2	24.9	24.9	0.0	24.3	24.3	0.0	26.8	26.8	0.0	26.3	26.3	0.0
U2A3	25.9	25.9	0.0	26.6	26.6	0.0	26.8	26.8	0.0	28.2	28.2	0.0
U2A4	25.5	25.5	0.0	27.1	27.1	0.0	27.1	27.1	0.0	28.6	28.6	0.0
U2A5	25.1	25.1	0.0	25.9	25.9	0.0	27.5	27.5	0.0	28.5	28.5	0.0
U2B	35.7	35.7	0.0	30.4	30.4	0.0	33.0	33.0	0.0	31.7	31.7	0.0
U2B1	28.1	28.1	0.0	24.9	24.9	0.0	26.7	26.7	0.0	22.7	22.7	0.0
U2B2	28.5	28.5	0.0	21.6	21.6	0.0	26.3	26.3	0.0	23.5	23.5	0.0
U2B3	28.8	28.8	0.0	20.3	20.3	0.0	26.0	26.0	0.0	23.7	23.7	0.0
U2B4	29.0	29.0	0.0	22.8	22.8	0.0	25.5	25.5	0.0	26.1	26.1	0.0
U2B5	29.2	29.2	0.0	25.5	25.5	0.0	25.4	25.4	0.0	26.5	26.5	0.0
U3	**30.1**	**39.6**	**9.5**	**27.3**	**36.4**	**9.1**	**30.0**	**38.8**	**8.8**	**34.4**	**39.6**	**5.2**
U3A	25.1	35.8	10.7	24.6	33.5	8.8	27.6	36.3	8.7	34.1	38.8	4.7
U3A1	20.6	30.8	10.2	18.6	27.3	8.7	21.5	29.1	7.6	21.4	29.3	7.9
U3A2	18.4	30.1	11.7	18.6	27.2	8.6	19.8	29.1	9.3	26.5	31.6	5.1
U3A3	17.4	28.0	10.6	17.8	26.6	8.8	20.1	29.3	9.2	28.6	32.5	3.8
U3A4	16.4	26.1	9.8	16.8	25.6	8.8	20.5	29.5	9.0	28.3	32.5	4.2
U3A5	16.5	27.4	10.9	15.6	25.2	9.6	21.0	29.7	8.7	27.4	32.1	4.7
U3B	28.4	37.2	8.8	24.0	33.4	9.4	26.3	35.2	8.9	23.6	32.2	8.6
U3B1	21.4	31.1	9.7	18.9	27.0	8.1	21.2	28.9	7.7	17.6	25.7	8.1
U3B2	22.6	31.5	8.9	15.7	25.9	10.2	20.4	28.6	8.2	16.9	26.2	9.3
U3B3	21.4	31.5	10.1	15.3	25.4	10.0	19.1	28.2	9.0	15.7	25.2	9.5
U3B4	20.7	27.8	7.2	16.2	26.3	10.1	18.0	27.8	9.7	15.8	23.9	8.1
U3B5	21.0	27.5	6.6	17.9	27.1	9.2	16.1	27.3	11.2	17.0	25.0	8.0

	102 Kelsterton Road			Kelsterton Farm			Rockcliffe Cottages			Woodfield Railway Cottages		
	Post 2008	Modified	Increase	Post 2008	Modified	Increase	Post 2008	Modified	Increase	Post 2008	Modified	Increase
U4	**31.3**	**40.0**	**8.7**	**36.5**	**41.4**	**4.9**	**29.4**	**39.1**	**9.7**	**38.0**	**42.5**	**4.5**
U4A	28.3	37.7	9.4	33.3	38.2	4.9	26.9	36.6	9.8	36.3	40.5	4.2
U4A1	22.0	31.3	9.3	26.7	31.6	4.9	19.2	29.1	9.8	29.3	33.0	3.7
U4A2	21.7	31.0	9.3	26.6	31.2	4.6	19.5	29.5	9.9	29.7	33.6	3.9
U4A3	21.5	30.7	9.2	26.2	31.0	4.7	19.8	29.7	9.8	30.1	33.7	3.6
U4A4	20.8	30.4	9.6	26.1	31.3	5.2	20.1	30.0	9.9	28.4	33.3	4.9
U4A5	20.4	30.0	9.6	26.0	31.2	5.2	20.4	29.9	9.5	29.0	34.1	5.1
U4B	28.3	36.1	7.8	33.6	38.5	4.9	25.8	35.4	9.5	33.2	38.1	5.0
U4B1	22.3	31.5	9.2	26.9	31.7	4.8	19.4	28.9	9.5	27.5	32.2	4.7
U4B2	21.1	27.7	6.6	26.4	31.2	4.7	19.1	28.7	9.6	26.5	31.7	5.1
U4B3	20.6	27.9	7.3	26.5	31.2	4.7	18.8	28.4	9.6	25.9	30.9	5.0
U4B4	20.9	28.2	7.2	26.7	31.7	5.0	18.6	28.0	9.4	25.5	30.6	5.2
U4B5	21.3	28.9	7.6	26.6	31.6	5.0	18.3	27.8	9.5	25.0	29.9	4.9
Grand Total	**40.4**	**44.4**	4.0	**40.4**	**43.8**	3.4	**40.5**	**44.0**	3.5	**42.6**	**45.6**	3.0
Balance of Non-CT plant	37.6	37.6		36.1	36.1		33.8	33.8		37.5	37.5	
Total for whole plant	42.2	45.2	3.0	41.7	44.5	2.7	41.3	44.4	3.0	43.7	46.2	2.4

Notes: the table shows specific L_{Aeq} noise level from individual components at selected residential receptors, I.e.

- U4 is the total L_{Aeq} level from all U4 CT sources
- U4B is the total L_{Aeq} from the 5 CTs that make up the B-side of UT CTs
- U4B5 is the total L_{Aeq} from the U4B5 cell, and includes contributions from the outlet, 2 x Dry Stage Inlet and 2 x Wet Stage Inlet.

Table 7: Model Estimates of specific contributions from individual cells – Jan/Feb 2016 plant state (Scenario B)

	102 Kelsterton Road	Kelsterton Farm	Rockcliffe Cottages	Woodfield Railway Cottages
U1	**34.5**	**34.5**	**36.8**	**36.7**
U1A	32.4	31.1	34.6	33.0
U1A1	25.2	23.1	27.4	24.5
U1A2	25.5	24.6	27.5	23.9
U1A3	25.7	24.4	27.7	26.1
U1A4	25.6	23.1	27.8	27.1
U1A5	25.0	25.0	28.0	27.3
U1B	30.4	31.8	32.6	34.3
U1B1	27.0	25.2	26.4	29.1
U1B2	26.2	25.0	25.7	28.7
U1B3	19.1	23.1	25.4	26.3
U1B4	17.3	26.2	25.4	25.8
U1B5	16.7	24.2	25.2	25.0
U2	**37.5**	**34.8**	**36.6**	**36.3**
U2A	32.8	32.8	34.1	34.4
U2A1	27.3	24.7	27.0	23.7
U2A2	24.9	24.3	26.8	26.3
U2A3	25.9	26.6	26.8	28.2
U2A4	25.5	27.1	27.1	28.6
U2A5	25.1	25.9	27.5	28.5
U2B	35.7	30.4	33.0	31.7
U2B1	28.1	24.9	26.7	22.7
U2B2	28.5	21.6	26.3	23.5
U2B3	28.8	20.3	26.0	23.7
U2B4	29.0	22.8	25.5	26.1
U2B5	29.2	25.5	25.4	26.5
U3	**30.4**	**27.5**	**31.1**	**32.9**
U3A	27.4	25.3	29.8	32.5
U3A1	9.1	2.4	9.6	9.1
U3A2	2.1	2.9	8.3	14.1
U3A3	1.3	3.4	8.4	16.5
U3A4	0.8	2.7	8.5	16.7
U3A5	27.4	25.2	29.7	32.1
U3B	27.3	23.3	25.1	22.7
U3B1	21.4	18.9	21.2	17.6
U3B2	12.9	1.8	7.1	5.2
U3B3	21.4	15.3	19.1	15.7
U3B4	20.7	16.2	18.0	15.8
U3B5	21.0	17.9	16.1	17.0
U4	**32.6**	**36.4**	**32.1**	**37.1**
U4A	25.1	30.1	23.2	33.5
U4A1	12.0	16.9	8.0	19.8
U4A2	21.7	26.6	19.5	29.7
U4A3	21.5	26.2	19.8	30.1
U4A4	9.7	16.6	8.8	20.0
U4A5	9.3	16.5	9.2	20.5

	102 Kelsterton Road	Kelsterton Farm	Rockcliffe Cottages	Woodfield Railway Cottages
U4B	31.8	35.2	31.5	34.7
U4B1	12.4	16.9	8.5	18.4
U4B2	27.7	31.2	28.7	31.7
U4B3	11.2	16.9	8.0	17.3
U4B4	20.9	26.7	18.6	25.5
U4B5	28.9	31.6	27.8	29.9
Grand Total U1CTs +U2CTs + U3CTs +U4CTs	**40.6**	**40.3**	**40.9**	**42.1**
U1	34.5	34.5	36.8	36.7
U2	37.5	34.8	36.6	36.3
U3	30.4	27.5	31.1	32.9
U4	32.6	36.4	32.1	37.1

Note: The U1 cooling towers were not operational at the time of the overnight testing, but the U1 model results have been included - for completeness.

Table 8: Comparison of Unit specific noise level – measured with model predictions

	Kelsterton Farm			Woodfield Railway Cottages		
	Measured (Estimate 1) L_{Aeq} dB	**Measured (Estimate 2) L_{Aeq} dB**	**Model Estimate L_{Aeq} dB**	**Measured (Estimate 1) L_{Aeq} dB**	**Measured (Estimate 2) L_{Aeq} dB**	**Model Estimate L_{Aeq} dB**
U1 CTs	N/A	N/A	34.5	N/A	N/A	36.7
U2 CTs	36.6	28.8	34.8	40.5	41.3	36.3
U3 CTs	<<37	---	27.5	<<40	---	32.9
U4 CTs	38.3#	35.6#	36.4	36#	33.0#	37.1

No measurements were specifically made with all available U4 fans running but with U4B1 shutdown. However it is during these tests it is estimated that U4B1 fan was responsible for a 370Hz tonal peak of around 40dB at Kelsterton Farm and around 38dB at Woodfield Railway Cottages. In terms of contributions to the overall U4 noise level, the A-weighted L_{Aeq} level from this tone alone is equivalent to approximately 35dBA at Kelsterton Farm and 33dBA at Woodfield Railway Cottages. These contributions from U4B1 have been subtracted from the overall L_{Aeq} estimate for U4 to allow a comparison between measured and modelled levels from U4 contribution (excluding U4B1).

Note: A-weighting at 370Hz is around -5dB.

Table 9: Estimates of 370Hz tonal level at key receptors for Scenarios

Scenario	Kelsterton Farm	Rockcliffe Cottages	Woodfield Railway Cottages
B	33.6	27.9	33.8
C	36.2	30.7	36.6
D	34.8	28.8	34.9
E	36.8	31.0	37.0
F	35.3	29.2	35.3
G	37.7	31.7	37.7
Increase relative to Scenario B			
C	2.5	2.9	2.8
D	1.1	0.9	1.1
E	3.1	3.2	3.2
F	1.7	1.3	1.5
G	4.0	3.9	3.9

Assumptions

- Individual cells tonal noise emission are scaled in accordance with variation from average of current Dry Stage Inlet indicative levels
- Model results have been tuned to aligned with measured 370Hz tonal level from 6 January survey at Kelsterton Farm and Woodfield Railway Cottages
- U1 emissions are assumed to be subject to the same tuning adjustment at U2 data
- Removal of outlet attenuators is assumed to result in a 5dB increase in tonal emission
- Individual cell variation in cell tonal emission is normalised to an average level upon removal of outlet attenuators

Scenario A Post 2008: Modified U1 and U2 cells, all U3 and all U4 cells assumed to in original state but with reduced Dry Stage inlet silencing

Scenario B As Scenario A: except with only the U3 and U4 cells that were available in Jan/Feb 2016 (plus reflecting the outlet attenuator states- i.e. some removed)

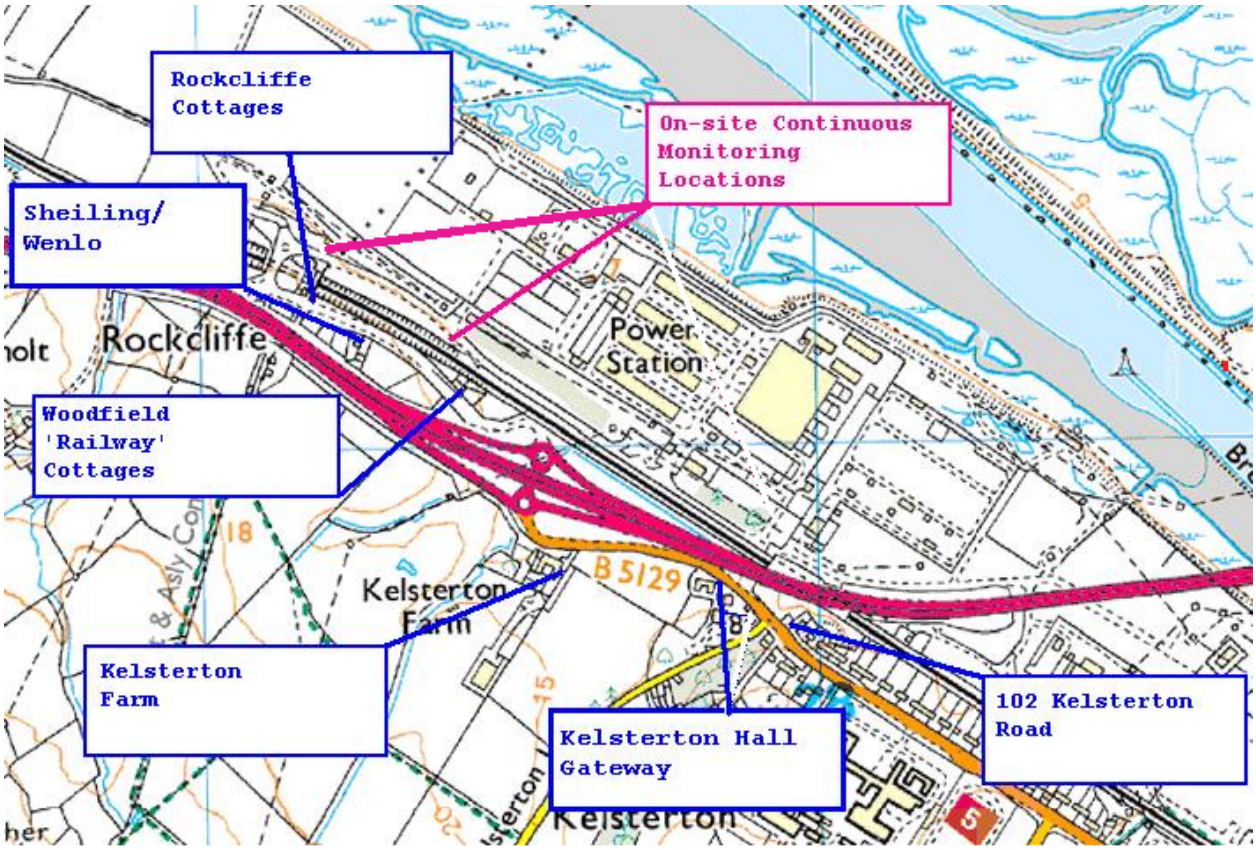
Scenario C As Scenario B: except with all currently unavailable U3 fans running with outlet attenuators removed (i.e. available U3 and U4 cells in their current state)

Scenario D As Scenario B: except with all currently unavailable U4 fans running with outlet attenuators removed (i.e. available U3 and U4 cells in their current state)

Scenario E As Scenario B: except with all ten U3 fans running with outlet attenuators removed

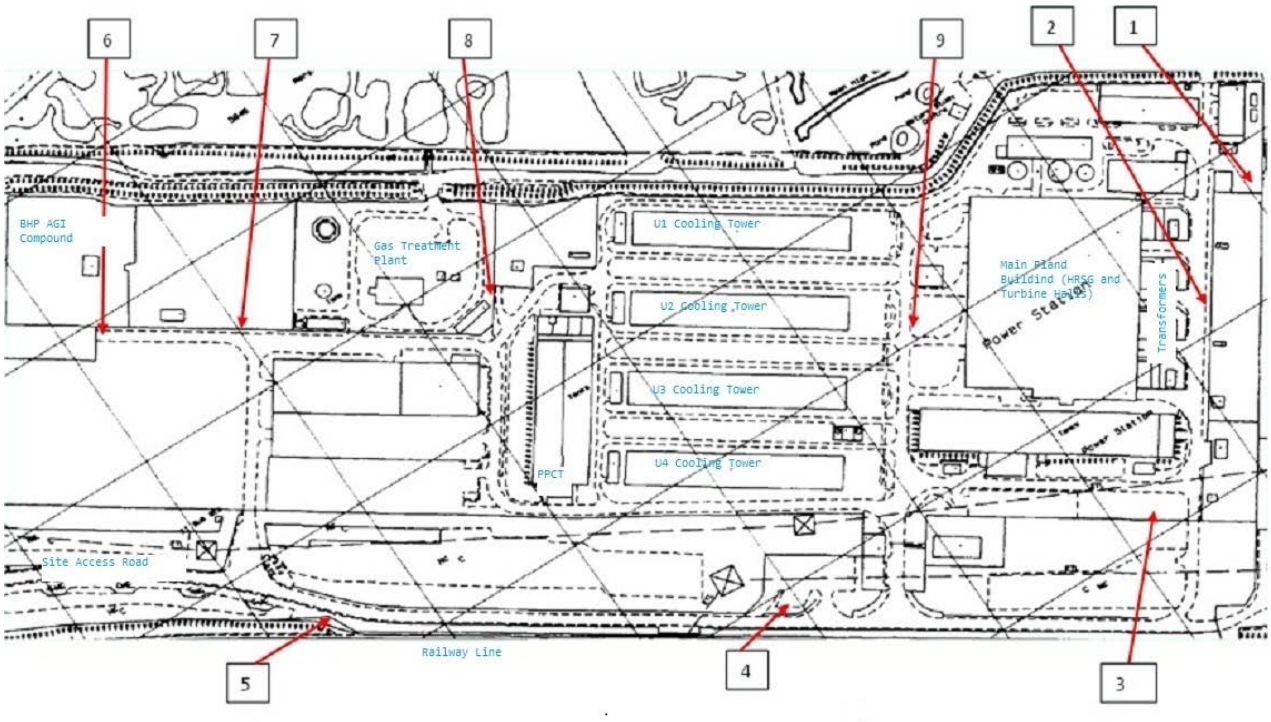
Scenario F As Scenario B: except with all ten U4 fans running with outlet attenuators removed

Scenario G As Scenario B: except with all ten U3 and all ten U4 fans running with outlet attenuators removed



Reproduced from Ordnance Survey digital map data supplied by EMAPSITE

Figure 1: Map showing monitoring locations



U1A5	U1A4	U1A3	U1A2	U1A1	U1B1	U1B2	U1B3	U1B4	U1B5
U2A5	U2A4	U2A3	U2A2	U2A1	U2B1	U2B2	U2B3	U2B4	U2B5
U3A5	U3A4	U3A3	U3A2	U3A1	U3B1	U3B2	U3B3	U3B4	U3B5
U4A5	U4A4	U4A3	U4A2	U4A1	U4B1	U4B2	U4B3	U4B4	U4B5

Note: U1 and U2 Cooling Tower Cells have upgraded low noise fans, modified dry inlet attenuators and no outlet silencing. U3 and U4 have original fans, modified dry inlet attenuators and majority have original outlet attenuators. U4 B2, B5, A5 cells and U3 A4 and A5 cells have no outlet attenuators.

Figure 2: Site map showing key plant areas, Cooling Tower locations and cell naming convention

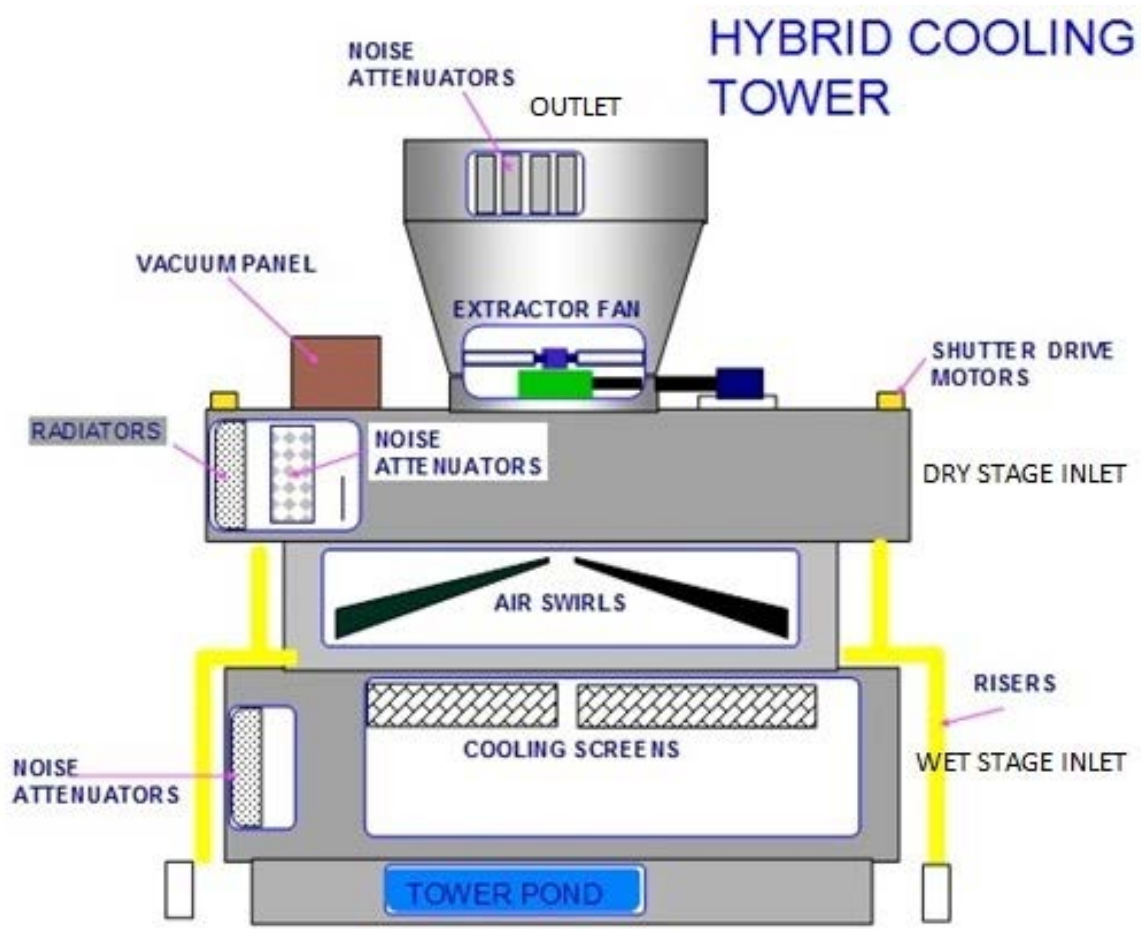


Figure 3: Schematic Cross-section of Hybrid Cooling tower showing main plant components

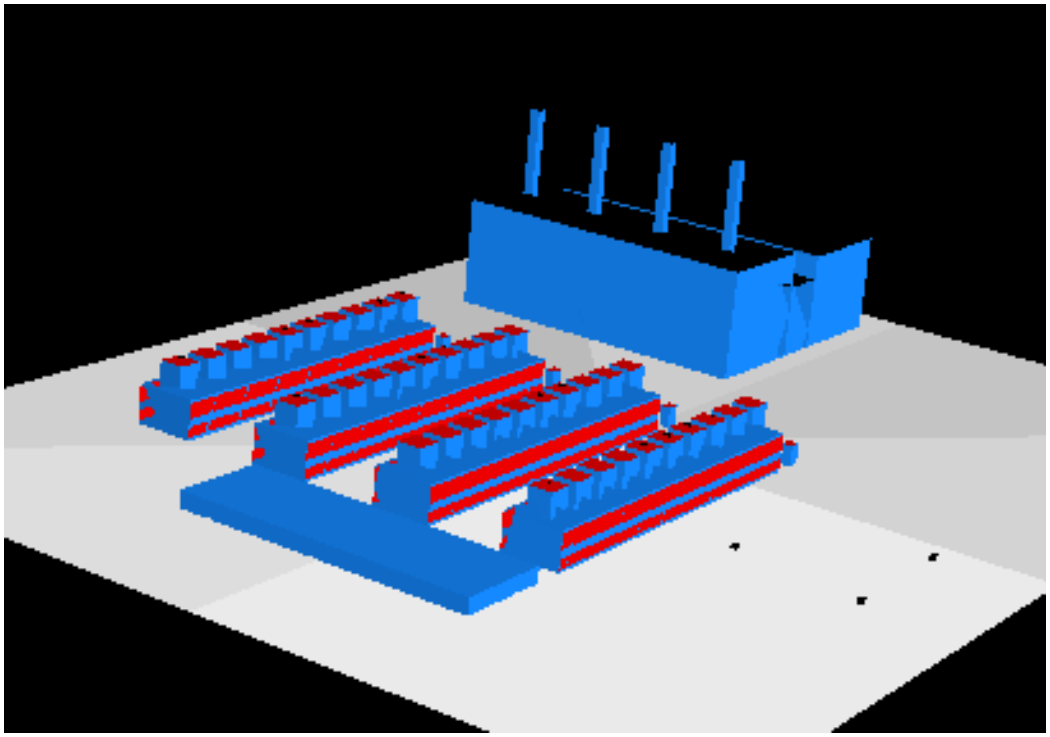
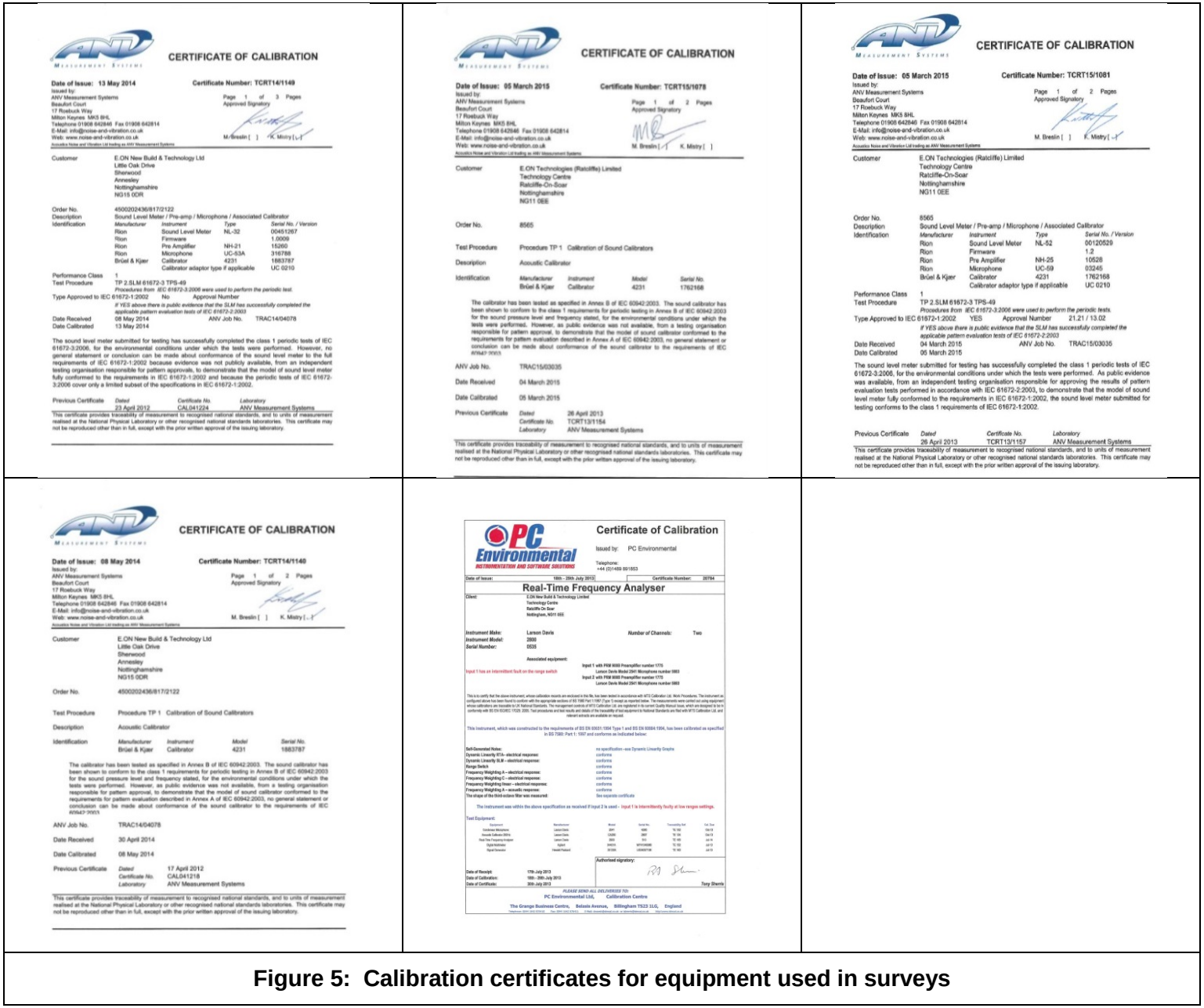


Figure 4: 3-D view of power station buildings, cooling towers within noise model
(Cooling Tower noise sources shown in red, building structures in blue)



CERTIFICATE OF CALIBRATION

Date of Issue: 13 May 2014 Certificate Number: TCRT14/1149

Issued by:
ANV Measurement Systems
Beaufort Court
17 Roebuck Way
Milton Keynes MK5 8HL
Telephone 01908 642846 Fax 01908 642814
E-Mail: info@noise-and-vibration.co.uk
Web: www.noise-and-vibration.co.uk

Page 1 of 3 Pages
Approved Signatory
M. Breslin [ ] K. Mistry [ ]

Customer: E.ON New Build & Technology Ltd, Little Oak Drive, Sherwood, Annesley, Nottinghamshire, NG15 0DR

Order No. 4500202436/817/2122
Description: Sound Level Meter / Pre-amp / Microphone / Associated Calibrator
Identification:

Manufacturer	Instrument	Type	Serial No. / Version
Rion	Sound Level Meter	NL-32	00451267
Rion	Firmware		1.0009
Rion	Pre Amplifier	NH-21	15260
Rion	Microphone	UC-53A	316788
Brüel & Kjær	Calibrator	4231	1883787
	Calibrator adaptor type if applicable		UC 0210

Performance Class 1
Test Procedure: TP 2.SLM 61672-3 TPS-49
Procedures from IEC 61672-3:2006 were used to perform the periodic test.
Type Approved to IEC 61672-1:2002 No Approval Number
If YES above there is public evidence that the SLM has successfully completed the applicable pattern evaluation tests of IEC 61672-2:2003
Date Received 08 May 2014 ANV Job No. TRAC14/04078
Date Calibrated 13 May 2014

The sound level meter submitted for testing has successfully completed the class 1 periodic tests of IEC 61672-3:2006, for the environmental conditions under which the tests were performed. However, no general statement or conclusion can be made about conformance of the sound level meter to the full requirements of IEC 61672-1:2002 because evidence was not publicly available, from an independent testing organisation responsible for pattern approvals, to demonstrate that the model of sound level meter fully conformed to the requirements in IEC 61672-1:2002 and because the periodic tests of IEC 61672-3:2006 cover only a limited subset of the specifications in IEC 61672-1:2002.

Previous Certificate	Dated	Certificate No.	Laboratory
	23 April 2012	CAL041224	ANV Measurement Systems

This certificate provides traceability of measurement to recognised national standards, and to units of measurement realised at the National Physical Laboratory or other recognised national standards laboratories. This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.

CERTIFICATE OF CALIBRATION

Date of Issue: 05 March 2015 Certificate Number: TCRT15/1078

Issued by:
ANV Measurement Systems
Beaufort Court
17 Roebuck Way
Milton Keynes MK5 8HL
Telephone 01908 642846 Fax 01908 642814
E-Mail: info@noise-and-vibration.co.uk
Web: www.noise-and-vibration.co.uk

Page 1 of 2 Pages
Approved Signatory
M. Breslin [ ] K. Mistry [ ]

Customer: E.ON Technologies (Ratcliffe) Limited, Technology Centre, Ratcliffe-On-Soar, Nottinghamshire, NG11 0EE

Order No. 8565
Test Procedure: Procedure TP 1 Calibration of Sound Calibrators
Description: Acoustic Calibrator
Identification:

Manufacturer	Instrument	Model	Serial No.
Brüel & Kjær	Calibrator	4231	1762168

The calibrator has been tested as specified in Annex B of IEC 60942:2003. The sound calibrator has been shown to conform to the class 1 requirements for periodic testing in Annex B of IEC 60942:2003 for the sound pressure level and frequency stated, for the environmental conditions under which the tests were performed. However, as public evidence was not available, from a testing organisation responsible for pattern approval, to demonstrate that the model of sound calibrator conformed to the requirements for pattern evaluation described in Annex A of IEC 60942:2003, no general statement or conclusion can be made about conformance of the sound calibrator to the requirements of IEC 60942:2003.

ANV Job No. TRAC15/03035
Date Received 04 March 2015
Date Calibrated 05 March 2015

Previous Certificate	Dated	Certificate No.	Laboratory
	26 April 2013	TCRT13/1154	ANV Measurement Systems

This certificate provides traceability of measurement to recognised national standards, and to units of measurement realised at the National Physical Laboratory or other recognised national standards laboratories. This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.

CERTIFICATE OF CALIBRATION

Date of Issue: 05 March 2015 Certificate Number: TCRT15/1081

Issued by:
ANV Measurement Systems
Beaufort Court
17 Roebuck Way
Milton Keynes MK5 8HL
Telephone 01908 642846 Fax 01908 642814
E-Mail: info@noise-and-vibration.co.uk
Web: www.noise-and-vibration.co.uk

Page 1 of 2 Pages
Approved Signatory
M. Breslin [ ] K. Mistry [ ]

Customer: E.ON Technologies (Ratcliffe) Limited, Technology Centre, Ratcliffe-On-Soar, Nottinghamshire, NG11 0EE

Order No. 8565
Description: Sound Level Meter / Pre-amp / Microphone / Associated Calibrator
Identification:

Manufacturer	Instrument	Type	Serial No. / Version
Rion	Sound Level Meter	NL-52	00120529
Rion	Firmware		1.2
Rion	Pre Amplifier	NH-25	10528
Rion	Microphone	UC-59	03245
Brüel & Kjær	Calibrator	4231	1762168
	Calibrator adaptor type if applicable		UC 0210

Performance Class 1
Test Procedure: TP 2.SLM 61672-3 TPS-49
Procedures from IEC 61672-3:2006 were used to perform the periodic tests.
Type Approved to IEC 61672-1:2002 YES Approval Number 21.21 / 13.02
If YES above there is public evidence that the SLM has successfully completed the applicable pattern evaluation tests of IEC 61672-2:2003
Date Received 04 March 2015 ANV Job No. TRAC15/03035
Date Calibrated 05 March 2015

The sound level meter submitted for testing has successfully completed the class 1 periodic tests of IEC 61672-3:2006, for the environmental conditions under which the tests were performed. As public evidence was available, from an independent testing organisation responsible for approving the results of pattern evaluation tests performed in accordance with IEC 61672-2:2003, to demonstrate that the model of sound level meter fully conformed to the requirements in IEC 61672-1:2002, the sound level meter submitted for testing conforms to the class 1 requirements of IEC 61672-1:2002.

Previous Certificate	Dated	Certificate No.	Laboratory
	26 April 2013	TCRT13/1157	ANV Measurement Systems

This certificate provides traceability of measurement to recognised national standards, and to units of measurement realised at the National Physical Laboratory or other recognised national standards laboratories. This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.

CERTIFICATE OF CALIBRATION

Date of Issue: 08 May 2014 Certificate Number: TCRT14/1140

Issued by:
ANV Measurement Systems
Beaufort Court
17 Roebuck Way
Milton Keynes MK5 8HL
Telephone 01908 642846 Fax 01908 642814
E-Mail: info@noise-and-vibration.co.uk
Web: www.noise-and-vibration.co.uk

Page 1 of 2 Pages
Approved Signatory
M. Breslin [ ] K. Mistry [ ]

Customer: E.ON New Build & Technology Ltd, Little Oak Drive, Sherwood, Annesley, Nottinghamshire, NG15 0DR

Order No. 4500202436/817/2122

Test Procedure: Procedure TP 1 Calibration of Sound Calibrators
Description: Acoustic Calibrator
Identification:

Manufacturer	Instrument	Model	Serial No.
Brüel & Kjær	Calibrator	4231	1883787

The calibrator has been tested as specified in Annex B of IEC 60942:2003. The sound calibrator has been shown to conform to the class 1 requirements for periodic testing in Annex B of IEC 60942:2003 for the sound pressure level and frequency stated, for the environmental conditions under which the tests were performed. However, as public evidence was not available, from a testing organisation responsible for pattern approval, to demonstrate that the model of sound calibrator conformed to the requirements for pattern evaluation described in Annex A of IEC 60942:2003, no general statement or conclusion can be made about conformance of the sound calibrator to the requirements of IEC 60942:2003.

ANV Job No. TRAC14/04078
Date Received 30 April 2014
Date Calibrated 08 May 2014

Previous Certificate	Dated	Certificate No.	Laboratory
	17 April 2012	CAL041218	ANV Measurement Systems

This certificate provides traceability of measurement to recognised national standards, and to units of measurement realised at the National Physical Laboratory or other recognised national standards laboratories. This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.

PC Environmental
INSTRUMENTATION AND SOFTWARE SOLUTIONS

Certificate of Calibration

Issued by: PC Environmental
Telephone: +44 (0)1489 891053

Date of Issue: 18th - 29th July 2013 Certificate Number: 20784

Real-Time Frequency Analyser

Client: E.ON New Build & Technology Limited, Technology Centre, Ratcliffe On Soar, Nottingham, NG11 0EE

Instrument Make: Larson Davis
Instrument Model: 2900
Serial Number: 0535
Number of Channels: Two

Associated equipment:
Input 1 with PRM 9000 Preamplifier number 1775
Larson Davis Model 2541 Microphone number 0803
Input 2 with PRM 9000 Preamplifier number 1773
Larson Davis Model 2541 Microphone number 0802

Input 1 has an intermittent fault on the range switch

This is to certify that the above instrument, whose calibration records are enclosed in this file, has been tested in accordance with MTS Calibration Ltd. Work Procedures. The instrument as configured above has been found to conform with the appropriate sections of BS 7580 Part 1:1997 (Type 1) except as reported below. The measurements were carried out using equipment whose calibrations are traceable to UK National Standards. The management controls of MTS Calibration Ltd. are registered in its current Quality Manual Issue, which are designed to be in conformity with BS EN ISO/IEC 17025: 2005. Test procedures and test results and details of the traceability of test equipment to National Standards are filed with MTS Calibration Ltd. and relevant extracts are available on request.

This instrument, which was constructed to the requirements of BS EN 60651:1994 Type 1 and BS EN 60804:1994, has been calibrated as specified in BS 7580: Part 1: 1997 and conforms as indicated below:

Self-Generated Noise:	no specification - see Dynamic Linearity Graphs
Dynamic Linearity RTA - electrical response:	conforms
Dynamic Linearity SLM - electrical response:	conforms
Range Switch	conforms
Frequency Weighting A – electrical response:	conforms
Frequency Weighting C – electrical response:	conforms
Frequency Weighting Zmax – electrical response:	conforms
Frequency Weighting A – acoustic response:	conforms
The shape of the third-octave filter was measured:	See separate certificate

The instrument was within the above specification as received if Input 2 is used - Input 1 is intermittently faulty at low range settings.

Test Equipment:

Equipment	Manufacturer	Model	Serial No.	Traceability Ref.	Cal. Due
Wireless Microphone	Larson Davis	2541	4006	TC 152	Oct 13
Acoustic Calibrator 2560a	Larson Davis	CAL200	2997	TC 151	Oct 13
Real-Time Frequency Analyser	Larson Davis	2900	531	TC 145	Jul 14
Digital Multimeter	Agilent	34401A	MY41048286	TC 153	Jul 13
Signal Generator	Hewlett Packard	33120A	US36070199	TC 161	Jul 13

Authorised signatory: Tony Sherris

Date of Receipt: 17th July 2013
Date of Calibration: 18th - 29th July 2013
Date of Certificate: 30th July 2013

PLEASE SEND ALL DELIVERIES TO:
PC Environmental Ltd, Calibration Centre
The Grange Business Centre, Belasis Avenue, Billingham TS23 1LG, England

Figure 5: Calibration certificates for equipment used in surveys

APPENDIX A

Noise Measurements to Test Off-site Sensitivity to Cooling Tower Fan Operation

A1 Introduction

Off-site measurements were made on 5 & 6th January 2016 to quantify the current impact from Connah's Quay Power Station Cooling Towers (CT). The surveys took place during the following periods:

- Offsite 5th Jan 2016 17:00 to 6th Jan 2016 04:30 (Survey #1)
- Off-site 6th Jan 2016 19:30 to 21:00 (Survey #2).

Where possible, unit blocks, groups or individual fans were operated in an attempt to quantify specific contributions at off-site locations. On-site measurements in or around cells were also made in an attempt to characterise the relative magnitude of individual cells noise emissions.

A2 Measurement Surveys

For the off-site noise surveys, measurements were made at key noise sensitive receptors:

- Rockcliffe Cottages
- Woodfield Railway Cottages
- Kelsterton Farm.

For brevity no measurements were made at 102 Kelsterton Road, as this location is subject to significant contributions from traffic and historically (primarily due to the dual carriageway acting as a barrier) has been insensitive to the cooling tower noise. U3 CT fans were kept running throughout the period for operational reasons and U1 CT fans were non-operational throughout the whole exercise. This restriction in plant flexibility meant that it was not possible to analyse and quantify all specific contributions from groups or individual cells at off-site locations. Initially, measurements concentrated on overnight periods when the units were off-load and when the ambient/background noise level had subsided to a minimum. This ensured that the ratio of fan noise contribution to other noise was maximised and represented a robust worst-case scenario measurement. Narrow FFT band measurements have concentrated on quantifying the magnitude of the characteristic tonal frequency of 370Hz from the cooling towers at residential and on-site locations.

The No 1 Purge Pond Cooling Tower (PPCT) was operational throughout and was almost indiscernible off-site. The Gas Treatment Plant (GTP) was operational throughout the period and at Rockcliffe Cottages and Shieling/Wenlo properties was arguably the most dominant plant noise contributor at these positions.

A2.1 Offsite Survey #1-5th January 2016 17:00 to 6th January 2016 04:30

U2 and U3 were on-load during first part of the survey. Following both units coming off load in the late evening U2 and U4 fans was switched on in a staged sequence to quantify the relative contribution from these cells. U4 cells were also switched on in groups: i.e. only cells with outlet attenuators in place and then only cells without outlet attenuators in place. See approximate test schedule below:

- Test 1 – U3 cells only
- Test 2 – U2 and U3 cells only
- Test 3 - U2, U3 and U4 cells only
- Test 4 - U3 and U4 cells only
- Test 5 – U3 cells and U4 (un-attenuated cells U4B2[#] and U4B5 only)
- Test 6 – U3 cells and U4 (attenuated cells U4A3, U4A2, U4B1 and U4B4 only)
- Test 7 – U3 cells and U4 (un-attenuated cells U4B2[#] and U4B5 only) (repeat of Test 5)
- Test 8 – U3 cells plus progressive switch on fans U4A3, U4A2, U4B1[#] and U4B4 only

Note: U4B1 and U4B2 would not start for Test 5-8.

Regrettably, it was not possible to start-up U4B2 at the time for the 'no-attenuators' tests, so only U4B5 fan was running for the test of U4 fans without outlet attenuators (however, see 6th January evening tests). Likewise for the 'attenuated' cells test, U4B1 could not be started and therefore the data collected during this test did not account for its normal contribution.

A2.1.1 Weather Conditions

Damp and cold, calm or very low wind speed conditions. There was very little wind induced noise from local foliage. Measurements had to be suspended twice due to heavy rain - which meant that the roads were wet and hence traffic noise was probably elevated compared to equivalent dry road conditions. Overall the circumstances that prevailed represented broadly typical of winter night time conditions from a noise propagation perspective.

A2.1.2 Results

A table summarising the results of the monitoring is given in Table A1 for the overall L_{Aeq} noise level and percentile indices and Table A2 for the narrow band analysis of the tonal character.

Early in the exercise and during lulls in the traffic the plant was audibly tonal with a drone from the CTs subjectively discernible at Woodfield Railway Cottages and Kelsterton Farm - but not at Rockcliffe Cottages or at Shieling/Wenlo at the time the measurements were taken (U2, U3 and U4 on load). For this reason the measurements concentrated on quantifying the noise level at Woodfield Railway Cottages and Kelsterton Farm receptors where there was greatest sensitivity. Fortunately, the discrete and precise frequency nature of tonal noise means that a narrow band analysis can quantify the magnitude of the tone even though it may be partially masked by other broadband noise. The recent update of the BS4142 methodology (used for assessing the severity of impacts from industrial noise on noise sensitive receptors) requires the specific noise level contribution from the plant to have a penalty of up to 6 dB applied depending upon how audibly prominent the tone is compared to the ambient noise level.

For this reason the prominence of the 370 Hz tone has been assessed using ISO 1996 type methodology and where the broadband is insufficient to mask out the tone a penalty correction is calculated. See Table A2.

A2.1.3 Observation on Off-site FFTs (Survey #1)

Figure A1 shows narrow band FFTs spectrum measured at the key noise sensitive receptors during periods when there was U2 & U3 Fans operating and when there were U2 & U3 & U4 fans operating.

- At some locations the assessment suggests that (when averaged over the measurement period) the 370Hz tone would not be deemed audible. This was primarily due to the magnitude of the background noise - which at the time masks out the tone and renders it inaudible.

- At Rockcliffe the 370Hz tone didn't attract a penalty throughout the whole period - even overnight when the ambient noise level had subsided.

- At Shieling/Wenlo the 370Hz tone didn't attract a penalty throughout the whole period - even overnight when the ambient noise level had subsided.

- At Kelsterton Farm the 370Hz tone was assessed as being prominent relative to the adjoining broadband noise during the tests when all U4 cells were operational, attracting a 6dB penalty according to ISO 1996.

- At Rockcliffe Cottages and Kelsterton Farm the noise contribution from U2 and U3 would not appear to be overly tonal around the 370Hz frequency. At Woodfield Railway Cottages, the noise spectrum during U2 and U3 CT fan operation has a 370Hz tonal peak, but it relatively minor compared to adjoining broadband noise so is masked out.

- Problems with starting of U4B1 and U4B2 cells prevented them from being involved in the sensitivity exercises. Nevertheless, the measurements suggest that the noise from the remaining four available U4 fans (U4B5, U4B4, U4A2 and U4A3) was not particularly tonal at Kelsterton Farm and Woodfield Railway Cottages. This suggests that U4B1 and or U4B2 fans are primarily responsible for prominent 370Hz tonal peak at these two locations. (Subsequent tests during survey #2, see later, indicate that U4B1 has a the highest tonal contribution off-site).

A2.1.4 Overall Noise Levels

The overall noise levels measured at key residential locations in the community with the various combinations of Unit CTs operational are summarised in Table A3. The specific noise levels from each Unit's operational CT's are estimated by subtraction of noise levels. The L_{Aeq} is not a reliable measure of the noise from the CTs as it is strongly influenced by traffic noise contributions. It is necessary to rely on the L_{A90} level as a measure of the steady noise from the plant, and derived coarse specific noise level estimates from changes in this index.
The restriction of not being able to switch off U3 cells off prevents an estimate of the underlying background noise level and affects the robustness of the specific noise level estimates for both U2 CTs and U3 CTs. Nevertheless, the apparent changes in noise levels arising from CTs being switched on and off have been used to estimate the specific noise levels. The range of estimates for U3 CTs specific noise level at Kelsterton Farm emphasises the uncertainty associated with this technique and also how much this position potentially benefits from screening from intervening CTs.

2.3 Off-site FFTs (Survey #2) – 6th January 2016

Due to problem with the operation of U4B1 and U4B2 during Survey #1, a further survey was undertaken. Regrettably, the overnight forecast was for heavy rain, therefore it was necessary to undertake the measurements in the evening. This meant that the ambient noise level was higher and more variable than Survey #1 which took place in quieter overnight conditions. As a result the overall L_{Aeq} and tonal measurements are subject to more interference/contributions

from other sources and are less robust. With U2 and U3 on load, U4 fans were switched off in the following test sequence.

- Test 1 – U2, U3 and U4 on load
- Test 2 – U2, U3 on load, U4 off-load but all available CT fans on.
- Test 3 - As Test 2, but U4B1 fan off
- Test 4 - As Test 3, but U4B2 fan off
- Test 5 – As Test 4, but U4B5 fan off
- Test 6 – As Test 5, but U4A3 fan off
- Test 7 – As Test 6, but U4A2 fan off
- Test 8 – As Test 7, but U4B4 fan off.

Measurements concentrated on Woodfield Railway cottages - as subjectively this location appeared to be less susceptible to interference from road traffic noise. (Both Kelsterton Farm and Woodfield Railway Cottages experience noise level from traffic using the dual carriage way - but the Farm also receives contributions from the local road to Connah's Quay).

A2.3.1 Results

Results from the off-site measurements during staged switch off of U4 CT fans are given in Table A4 (overall L_{Aeq} and Ln statistics) and in Table A5 (Narrow band FFT statistics). The FFT narrow band results are shown in Figure A2. The figure shows how the 370Hz tone is reduced significantly by the switching off of CT fan U4B1. After this there is very little change in the 370Hz tonal level as subsequent U4 fans are switched off. (U2 fans and U3 fans remained on throughout).

A2.3.2 Observation on Off-site FFTs (Survey #2)

- The staged switching off of U4B1 Fan reduced the tonal 370Hz noise level from 40.4-41.7dB down around 33.5dB. Subsequent switching off of remaining fans (including U4B2 fan which has no outlet attenuators) did not result any significant reductions in level. The presence of relatively high levels of ambient noise prevents any definitive conclusion being drawn about the relative magnitude of the remaining U4 fans compared to U2 and U3 CT fans

- Based on changes in level, it is estimated that the specific *tonal* noise level contributions from U4B1 are as follows:

    - U4B1 at Woodfield Railway cottages -> 39 to 41dBA

- Switching off of U4B2 and U4B5 fans (un-attenuated outlets) did not result in change in noise level at Woodfield Cottages that might be considered significant (within measurement uncertainty)

Table A1: Overall L_{Aeq} and Ln percentile levels measured during 5-6th January 2016 (Survey #1)

State	Date	Rec	Description	L_{Aeq}	L_{A10}	L_{A50}	L_{A90}	L_{A99}
U2 Fans On & U3 Fans On & U4 Fans On	06/01/2016 02:21	35	Hostel	50	52.3	41.1	40.5	40.2
U2 & U3 On load	05/01/2016 18:50	7	Kelsterton Farm	58.3	61.6	56.5	50.9	47.7
U2 & U3 On load	05/01/2016 20:24	11	Kelsterton Farm	54.6	58.8	50.9	43.2	42.1
U3 On load	05/01/2016 22:34	16	Kelsterton Farm	55.7	58.9	54.1	48.1	44.8
U2 Fans On & U3 Fans On	05/01/2016 23:54	21	Kelsterton Farm	50	54.6	42.4	38.2	37.4
U2 Fans On & U3 Fans On	06/01/2016 00:09	22	Kelsterton Farm	47.7	52.3	39.1	37.4	36.9
U2 Fans On & U3 Fans On	06/01/2016 00:34	24	Kelsterton Farm	47.4	47.1	38	36.7	36.3
U3 Fans Only	06/01/2016 01:12	28	Kelsterton Farm	46.1	50	38.2	37.5	37.3
U2 Fans On & U3 Fans On	06/01/2016 01:19	29	Kelsterton Farm	48.6	53.8	41.9	40.1	39.6
U2 Fans On & U3 Fans On & U4 Fans On	06/01/2016 02:09	34	Kelsterton Farm	43.4	44.2	42.4	41.3	40.7
U2 Fans On & U3 Fans On & U4 Fans On	06/01/2016 02:48	38	Kelsterton Farm	43.3	44	43	42.3	41.8
U3 Fans On & U4 Fans On	06/01/2016 03:02	39	Kelsterton Farm	45.6	45.2	43	42.1	41.7
U3 Fans On and Attenuated U4 fans	06/01/2016 03:26	42	Kelsterton Farm	44.7	44	39.8	38.8	38.3
U3 Fans On and B5 Only	06/01/2016 03:32	43	Kelsterton Farm	48.4	48.7	39.3	37.8	37.3
U3 Fans On and B5 Only	06/01/2016 03:36	44	Kelsterton Farm	49.9	52.6	46.2	40.5	38.5
U3 Fans and B5 Only	06/01/2016 04:08	48	Kelsterton Farm	45	45.5	41.6	39.5	38.8
U3 Fans and Mixed U4s	06/01/2016 04:21	49	Kelsterton Farm	54.2	58.9	44.8	42.1	41.4
U2 & U3 On load	05/01/2016 18:20	3	Rockcliffe Cottages	59.7	62	55.7	50.7	48
U2 & U3 On load	05/01/2016 19:58	8	Rockcliffe Cottages	52.8	54.8	51.3	47.2	43.5
U3 On load	05/01/2016 21:22	12	Rockcliffe Cottages	49.3	52.3	48.9	41.4	40.2
U3 On load	05/01/2016 22:47	17	Rockcliffe Cottages	47.8	51.2	46.7	43.6	42.1
U3 On load	05/01/2016 22:52	18	Rockcliffe Cottages	50.4	54.6	48.5	42.7	41
U3 Fans Only	06/01/2016 00:55	27	Rockcliffe Cottages	48.2	52.9	44.3	37	36.5
U2 Fans On & U3 Fans On	06/01/2016 01:35	31	Rockcliffe Cottages	46.9	51.5	41.8	40.9	40.4
U2 Fans On & U3 Fans On & U4 Fans On	06/01/2016 02:31	36	Rockcliffe Cottages	45.5	50.2	39	38.1	37.6
U2 & U3 On load	05/01/2016 18:33	5	Wenlo/Shieling	61	60	53	49.4	47.8
U2 & U3 On load	05/01/2016 20:06	9	Wenlo/ Shieling	49.4	52	48.8	45.4	43.7
U3 On load	05/01/2016 21:29	13	Wenlo/ Shieling	50.4	51.5	47.1	44.3	43.1
U3 On load	05/01/2016 22:58	19	Wenlo/ Shieling	50.8	53.6	50.5	44.7	43.6
U2 & U3 On load	05/01/2016 18:39	6	Woodfield Railway Cottages	58.3	61.5	56	50.1	46.1
U2 & U3 On load	05/01/2016 20:15	10	Woodfield Railway Cottages	55.4	58.9	53.6	46.9	44.7
U3 On load	05/01/2016 22:23	15	Woodfield Railway Cottages	52	56.5	47.1	43.5	42.5
U2 Fans On & U3 Fans On	05/01/2016 23:46	20	Woodfield Railway Cottages	41.2	42.5	40.2	39.5	39
U2 Fans On & U3 Fans On	06/01/2016 00:24	23	Woodfield Railway Cottages	41.5	41.8	40.3	39.5	39.3
U3 Fans Only	06/01/2016 00:48	26	Woodfield Railway Cottages	47.2	50.9	41.8	40.3	39.9
U2 Fans On & U3 Fans On	06/01/2016 01:27	30	Woodfield Railway Cottages	48.3	50.9	44.7	43.6	43.1
U2 Fans On & U3 Fans On	06/01/2016 01:45	32	Woodfield Railway Cottages	44.8	46.2	44.1	43.4	43
U2 Fans On & U3 Fans On & U4 Fans On	06/01/2016 02:03	33	Woodfield Railway Cottages	46.2	47.5	44.8	44.2	43.7
U2 Fans On & U3 Fans On & U4 Fans On	06/01/2016 02:40	37	Woodfield Railway Cottages	47	47	42.7	41.5	41
U3 Fans On & U4 Fans On	06/01/2016 03:09	40	Woodfield Railway Cottages	51.8	54.4	44.1	41.1	40.6
U3 Fans On and Attenuated U4 fans	06/01/2016 03:18	41	Woodfield Railway Cottages	43.8	46.4	42.5	41.6	41.2
U3 Fans On and B5 Only	06/01/2016 03:42	45	Woodfield Railway Cottages	54.3	56.2	45.7	42	41
U3 Fans and B5 Only	06/01/2016 04:02	47	Woodfield Railway Cottages	48.6	53.1	44	41.4	40.4

Table A2: Tonal assessment of off-site measurements 5-6th January 2016 (Survey #1)
Note: U4B1 Fan on 01:54-03:33

Time	Position Description	370Hz tonal level dB	Masking Noise Level	Tone Level minus Masking Level dB	Audibility Penalty (0 to 6dB)	Comment
05/01/2016 18:56	Kelsterton Farm(18:56 -Rec6)	31.3	42.6	-9.2	0.0	U2 & U3 On load
05/01/2016 20:34	Kelsterton Farm(20:34 -Rec11)	28.5	36.3	-5.6	0.0	U2 Fans On & U3 On load
05/01/2016 22:41	Kelsterton Farm(22:41 -Rec15)	29.3	38.9	-7.4	0.0	U2 Fans On & U3 On load
06/01/2016 00:00	Kelsterton Farm(00:00 -Rec20)	21.6	28.7	-4.9	0.0	U2 Fans On & U3 Fans On
06/01/2016 00:11	Kelsterton Farm(00:11 -Rec21)	23.4	27.9	-2.4	0.0	U2 Fans On & U3 Fans On
06/01/2016 00:38	Kelsterton Farm(00:38 -Rec25)	22.4	27.2	-2.6	0.0	U2 Fans On & U3 Fans On
06/01/2016 00:44	Kelsterton Farm(00:44 -Rec26)	20.1	23.8	-1.5	0.0	U3 Fans Only
06/01/2016 01:17	Kelsterton Farm(01:17 -Rec29)	21.4	24.2	-0.6	0.0	U3 Fans Only
06/01/2016 01:24	Kelsterton Farm(01:24 -Rec30)	22.9	28.3	-3.2	0.0	U2 Fans On & U3 Fans On
06/01/2016 02:14	Kelsterton Farm(02:14 -Rec33)	39.2	32.8	8.5	4.5	U2 Fans On & U3 Fans On and U4 Fans on (Tone primarily from U4B1)
06/01/2016 02:53	Kelsterton Farm(02:53 -Rec38)	40.2	33.4	9.0	5.0	U2 Fans On & U3 Fans On and U4 Fans on (Tone primarily from U4B1)
06/01/2016 03:06	Kelsterton Farm(03:06 -Rec39)	41.9	32.3	11.7	6.0	U3 Fans On and U4 Fans on (Tone primarily from U4B1)
06/01/2016 03:29	Kelsterton Farm(03:29 -Rec42)	40.6	26.6	16.1	6.0	U3 Fans On and U4 Fans (with outlet attenuators on (Tone primarily from U4B1)
06/01/2016 03:39	Kelsterton Farm(03:39 -Rec44)	18.2	26.7	-6.3	0.0	U3 Fans On and U4B5 Fan only (no outlet attenuators)
06/01/2016 04:12	Kelsterton Farm(04:12 -Rec47)	21.9	25.9	-1.9	0.0	U3 Fans On and U4B5 Fan only (no outlet attenuators)
06/01/2016 04:22	Kelsterton Farm(04:22 -Rec48)	24.7	27.3	-0.4	0.0	U3 Fans On and U4B5&U4A3 Fans only
06/01/2016 04:24	Kelsterton Farm(04:24 -Rec49)	25.3	27.3	0.2	0.0	U3 Fans On and U4B5&U4A3 &A2 Fans only
05/01/2016 18:27	Rockcliffe Cottages(18:27 -Rec2)	27.7	37.3	-7.4	0.0	U2 & U3 On load
05/01/2016 20:04	Rockcliffe Cottages(20:04 -Rec8)	25.5	35.7	-8.0	0.0	U2 & U3 On load
05/01/2016 21:29	Rockcliffe Cottages(21:29 -Rec12)	27.2	34.3	-4.9	0.0	U2 Fans On & U3 On load
05/01/2016 22:52	Rockcliffe Cottages(22:52 -Rec16)	29.5	34.8	-3.1	0.0	U2 Fans On & U3 On load
05/01/2016 22:55	Rockcliffe Cottages(22:55 -Rec17)	28.7	33.3	-2.4	0.0	U2 Fans On & U3 Fans On
06/01/2016 00:20	Rockcliffe Cottages(00:20 -Rec22)	20.0	25.4	-3.2	0.0	U2 Fans On & U3 Fans On
06/01/2016 01:03	Rockcliffe Cottages(01:03 -Rec28)	18.5	25.9	-5.2	0.0	U3 Fans Only
06/01/2016 01:41	Rockcliffe Cottages(01:41 -Rec31)	21.9	29.0	-5.0	0.0	U2 Fans On & U3 Fans On
06/01/2016 02:35	Rockcliffe Cottages(02:35 -Rec35)	17.9	26.8	-6.7	0.0	U2 Fans On & U3 Fans On and U4 Fans on
05/01/2016 18:35	Wenlo(18:35 -Rec4)	26.3	34.0	-5.5	0.0	U2 & U3 On load
05/01/2016 20:11	Wenlo(20:11 -Rec9)	26.4	33.5	-4.9	0.0	U2 & U3 On load
05/01/2016 21:34	Wenlo(21:34 -Rec13)	30.9	32.7	0.3	0.0	U2 & U3 On load
05/01/2016 23:00	Wenlo(23:00 -Rec18)	26.2	32.6	-4.3	0.0	U3 On load
05/01/2016 18:48	Woodfield Railway Cottages (18:48 -Rec5)	30.7	40.4	-7.5	0.0	U2 & U3 On load
05/01/2016 20:21	Woodfield Railway Cottages (20:21 -Rec10)	31.0	39.4	-6.3	0.0	U2 & U3 On load
05/01/2016 22:29	Woodfield Railway Cottages (22:29 -Rec14)	31.0	37.4	-4.2	0.0	U2 Fans On & U3 On load

Time	Position Description	370Hz tonal level dB	Masking Noise Level	Tone Level minus Masking Level dB	Audibility Penalty (0 to 6dB)	Comment
05/01/2016 23:49	Woodfield Railway Cottages (23:49 -Rec19)	24.3	29.6	-3.2	0.0	U2 Fans On & U3 Fans On
06/01/2016 00:27	Woodfield Railway Cottages (00:27 -Rec24)	24.7	30.3	-3.5	0.0	U2 Fans On & U3 Fans On
06/01/2016 00:52	Woodfield Railway Cottages (00:52 -Rec27)	26.1	30.5	-2.3	0.0	U3 Fans Only
06/01/2016 01:50	Woodfield Railway Cottages (01:50 -Rec32)	28.5	33.2	-2.5	0.0	U2 Fans On & U3 Fans On
06/01/2016 02:46	Woodfield Railway Cottages (02:46 -Rec37)	33.4	32.4	3.2	0.0	U2 Fans On & U3 Fans On and U4 Fans on
06/01/2016 03:15	Woodfield Railway Cottages (03:15 -Rec40)	38.1	32.0	8.2	4.2	U3 Fans On and U4 Fans (Tone primarily from U4B1)
06/01/2016 03:22	Woodfield Railway Cottages (03:22 -Rec41)	38.3	31.5	8.9	4.9	U3 Fans On and U4 Fans (with outlet attenuators) on (Tone primarily from U4B1)
06/01/2016 04:01	Woodfield Railway Cottages (04:01 -Rec45)	21.5	28.9	-5.3	0.0	U3 Fans On and U4B5 Fan only (no outlet attenuators)

Note: based on changes in tonal level following switching of individual units/cells it is possible to infer the following about specific tonal contributions.

Kelsterton Farm	U2 CTs U4 CTs	18dB at 370Hz 40dB at 370Hz
Rockcliffe Cottages	All U2 and U3 Fans U3 Fans Only	28dB at 370Hz 18dB at 370Hz
Woodfield Railway Cottages	U4 All available fans U4B5 fan Only	38dB at 370Hz <21dB at 370Hz

Table A3: Key L_{Aeq} and L_{A90} levels are key receptors and estimates of specific noise level contributions

	Rockcliffe Cottages		Woodfield Railway Cottages		Kelsterton Farm	
	L_{Aeq}	L_{A90}	L_{Aeq}	L_{A90}	L_{Aeq}	L_{A90}
U3 CTs Only	48.2	37.0	47.2	40.3	46.1	37.5
U2 and U3 CTs Only	46.9	40.9	44.8	43.4	48.6	40.1
U3,U2 and U4 CTs Only	45.5	38.1	46.2	44.2	43.3	42.3
U3 and U4 CTs Only	---	---	51.8	41.1	45.6	42.1
Specific Plant Noise Level based on L_{A90} subtraction						
	Rockcliffe Cottages		**Woodfield Railway Cottages**		**Kelsterton Farm**	
U3 CTs	<37		<40		<37	
U2 CTs (Estimate 1)	39		40.5		36.6	
U2 CTs (Estimate 2)	---		41.3		28.8	
U4 CTs	---		36		38.3	

Table A4: Overall L_{Aeq} and Ln percentile levels measured during 6th January 2016 (Survey #2)

Date	Record	Description	L_{Aeq}	L_{A10}	L_{A50}	L_{A90}	L_{A99}
06/01/2016 19:27	13	Rockcliffe Cottages	57.9	61.9	56.1	49.8	47.5
06/01/2016 19:35	14	Wenlo	52	54.4	51.2	48.4	46.9
06/01/2016 19:47	15	Woodfield Railway Cottages	61.7	63.4	56.8	49.9	48.3
06/01/2016 19:59	16	Kelsterton Farm	57.4	60.8	56.1	51.8	47.7
06/01/2016 20:14	17	Woodfield Railway Cottages	57.7	61.9	54.2	50.3	47.4
06/01/2016 20:23	18	Woodfield Railway Cottages	60.6	63.7	56.9	50.9	48.1

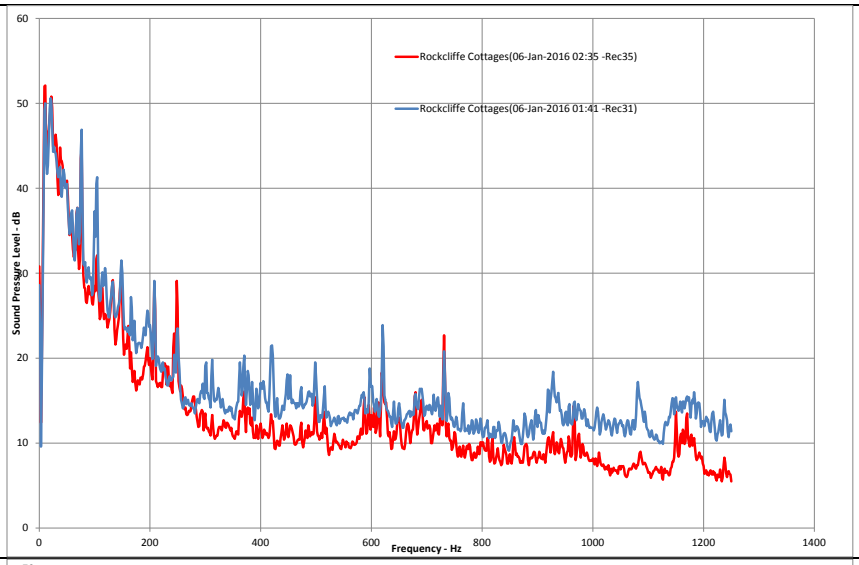
Note: due to relatively high levels of ambient noise affecting the L_{Aeq} and L_{A90} levels it is not possible to use this data to infer any specific noise level contributions from individual or groups of fans/cells.

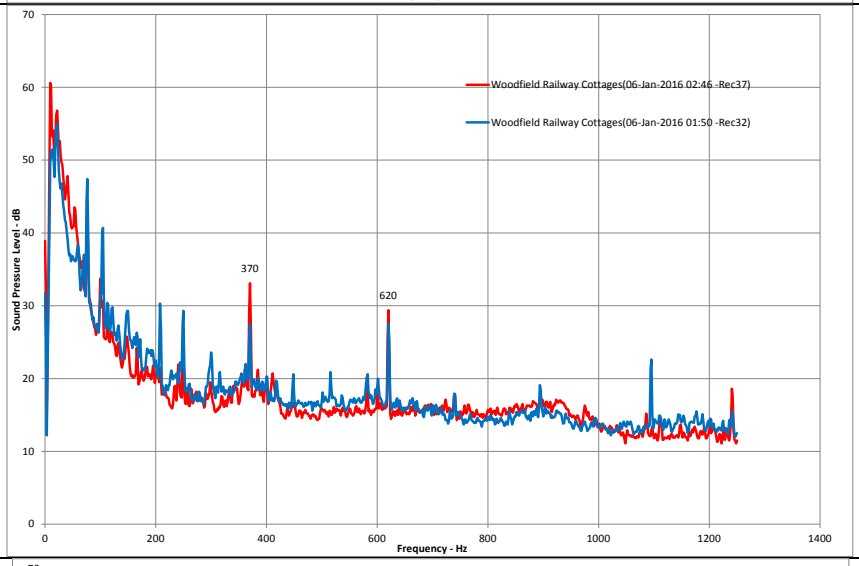
Table A5: Tonal assessment of off-site measurements 6th January 2016 (Survey #2)

Time	Position and Description	370Hz tonal Level dB	Masking Noise Level	Tone Level Minus Masking Level dB	Audibility Penalty (0 to 6dB)	Comment
06/01/2016 19:31	Rockcliffe Cottages(19:31 -Rec23)	33.5	41.2	-5.5	0.0	
06/01/2016 19:45	Wenlo(19:45 -Rec24)	33.6	37.2	-1.4	0.0	
06/01/2016 20:07	Kelsterton Farm(20:07 -Rec27)	39.1	41.3	-0.1	0.0	Primarily due to U4B1 fan
06/01/2016 19:53	Woodfield Railway Cottages (19:53 -Rec25)	40.4	44.4	-1.8	0.0	Primarily due to U4B1 fan
06/01/2016 20:20	Woodfield Railway Cottages (20:20 -Rec28)	41.7	44.5	-0.6	0.0	Primarily due to U4B1 fan
06/01/2016 20:27	Woodfield Railway Cottages (20:27 -Rec30)	33.5	42.9	-7.2	0.0	after U4B1 off
06/01/2016 20:32	Woodfield Railway Cottages (20:32 -Rec31)	33.3	40.6	-5.1	0.0	after U4B2 off
06/01/2016 20:36	Woodfield Railway Cottages (20:36 -Rec32)	33.0	40.7	-5.5	0.0	after U4B5 off
06/01/2016 20:40	Woodfield Railway Cottages (20:40 -Rec33)	32.9	39.9	-4.8	0.0	after U4A3 off
06/01/2016 20:46	Woodfield Railway Cottages (20:46 -Rec34)	32.1	38.3	-4.0	0.0	after U4A2 off
06/01/2016 20:51	Woodfield Railway Cottages (20:51 -Rec35)	33.8	41.8	-5.9	0.0	after U4B4 off

Note: based on changes in tonal level following switching off of individual cells it is possible to infer the following about specific tonal contributions at Woodfield Railway Cottages:

U4B1 fan	40dB at 370Hz
Other U4 fans (excluding B4B1)	28dB at 370Hz
U3 fans	32dB at 370Hz





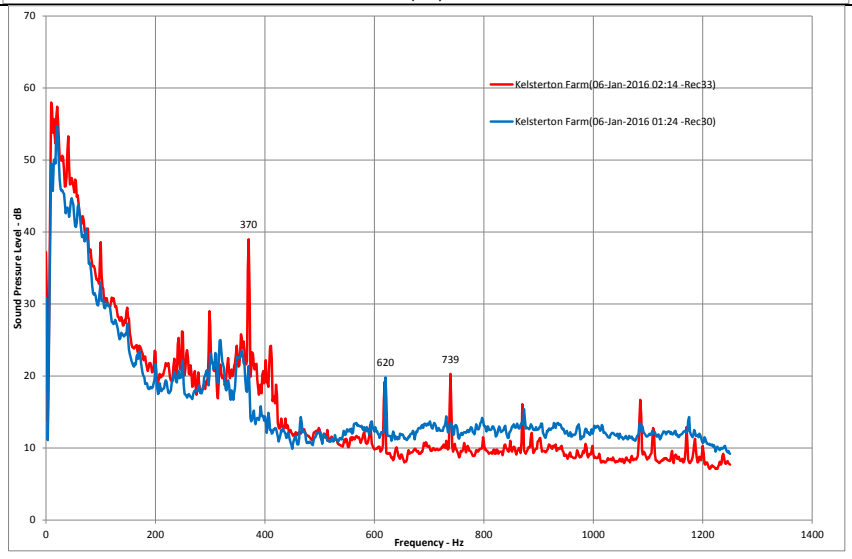


Figure A1: Narrow Band Spectrum for U2&U3 CT fan operation (Blue) and U2&U3&U4 CT Fan operation (Red)

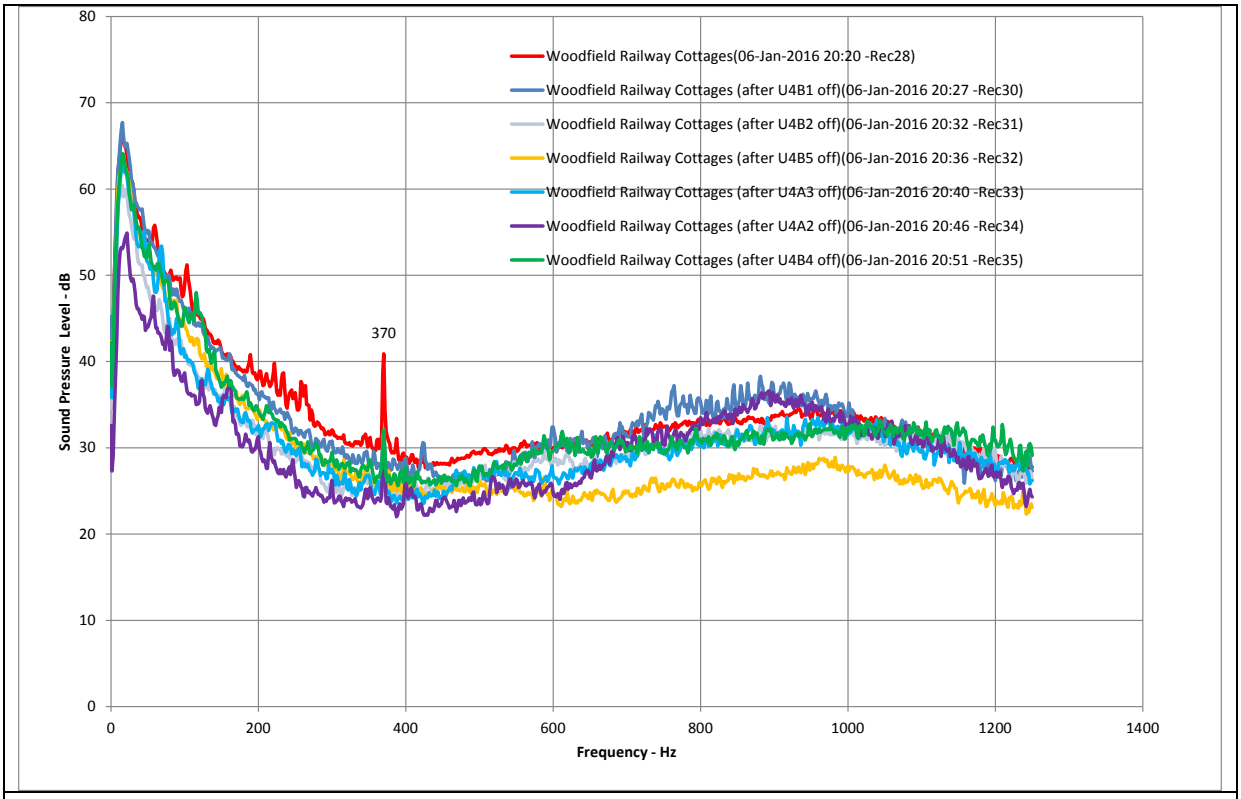


Figure A2: Narrow band spectrum measured at Woodfield Railway cottages during staged U4 CT fan shutdown.(6th Jan 2016 Survey #2)

APPENDIX B

Noise Measurements to Test Off-site Sensitivity to U4 Cooling Tower Fan Operation 25-26th January 2016

To check the observations from the 5-6th January 2016 surveys and improved the robustness of any assessment, a further measurement exercise was undertaken overnight on 25-26th January 2016.

On this occasion the National Grid required that U2 remained on-load throughout plus operational restrictions meant that available U3 fans remained on even though U3 itself was off-load. These circumstance meant that the options for switching on and off options were restricted to U4 fans.

Similar to other exercises the overall L_{Aeq} and Lnn percentiles and 370Hz tonal peak levels and audibility penalties at the receptors for various plant states are given in the Table B1 and B2 respectively.

As with previous exercises the measurements concentrated on quantifying the overall noise level at Woodfield Railway Cottage. Although measurements were made at Kelsterton Farm, the light breeze from the SW direction meant that Kelsterton Farm was slightly upwind of the CTs. Although a common wind direction in the UK, the associated propagation effects compromised the robustness of source sensitivity measurements at this location so data analysis has concentrated on Woodfield Railway Cottages where levels were less influenced by the stability of the L_{A90} and L_{A99} levels at Woodfield Railway Cottages throughout the period of different operation of U4 CTs shows that the overall noise level from the site remained largely unaffected by the operation of the various U4 fans – including the U4B1 fan.

Overall, this shows that the current configuration of U4 fans (including U4B2 and U4B5 with outlet attenuators removed removed) have a relatively minor contribution at Woodfield Railway Cottages. This provides empirical evidence that further removal of outlet attenuators on other U3 or U4 cells would not be expected to increase the site's overall L_{Aeq} footprint significantly (purely based on simple decibel addition of more sources to an existing level), [See Section 7 for more comprehensive model sensitivity and scenario analysis].

The background noise levels were believed to be slightly raised relative to normal overnight conditions due to breeze induced foliage noise, however it is worth noting that for the majority of measurements did not attract a tonal penalty. The only exception to this was at Kelsterton Farm at 23:44 - during a period when U2 was on-load and all available U3 and 4 CT fans were running. Once U4B1 and other U4 fans were shutdown although there was a 370Hz tone still apparent in the spectrum from U2 and 3 fans it was sufficiently low level to be indiscernible. Later on in the exercise when pairs of fans (U4B2/U4B5 or U4A2/U4A3) were switched on the tonal noise level at Woodfield Railway cottages did increase subtly but is almost within measurement uncertainty.

Hence, for the circumstances that prevailed during the exercise, the combined tonal noise from all available U2, U3 and U4 cells (including two U4 cells without outlet attenuators, but excluding U4B1) is not discernibly tonal and hence the plant noise's BS4142 rating level would not be increased. See January 2016 in Table 2 in which the impact is assessed in accordance with BS4142 and ranges from low to adverse.

Based on a logarithmic subtraction of tonal dB levels, the specific tonal contributions from unit blocks of CTs and individual cells are estimated below. The following CT fan combinations were calculated to have given rise to following 370Hz tonal levels:

	Tonal 370Hz Level
U4 fans (including U4B1)	
Kelsterton Farm	32
Rockcliffe Cottages	25
Wenlo/Shieling	24
Woodfield railway cottages	29
U2 and U3 combined	
Kelsterton Farm	24
Rockcliffe Cottages	23
Wenlo/Shieling	26
Woodfield railway cottages	24-26
U4B2 and U4B5 together	
Woodfield railway cottages	16- 24dB

Table B1: Overall L_{Aeq} and Lnn Levels measured 25-26th January 2016

Time	**Position**	**L_{Aeq}**	**L_{A01}**	**L_{A10}**	**L_{A50}**	**L_{A90}**	**L_{A99}**	**Plant Status**
22:57	Woodfield Railway Cottages	60.4	74.5	60	44.9	38.6	37.7	U2 On-load and U3+U4 fans on
23:26	Woodfield Railway Cottages	54.6	64.6	59.3	46.4	40.5	38.7	U2 On-load and U3+U4 fans on
23:58	Woodfield Railway Cottages	55.5	67	60.5	40.9	38	37.2	U2 On-load and U3+U4 fans on **(U4B1 off)**
00:13	Woodfield Railway Cottages	52.1	63	56.8	45.1	38.4	37.2	U2 On-load and U3 fans on
01:00	Woodfield Railway Cottages	47.6	61.3	46.1	40.2	38.7	38	U2 On-load and U3 fans on
01:51	Woodfield Railway Cottages	40.4	44	41	39.5	38.7	38	U2 On-load and U3 fans on
02:20	Woodfield Railway Cottages	40.6	46.2	42.4	39.4	38.4	37.8	U2 On-load and U3 fans on
02:29	Woodfield Railway Cottages	47.6	61	48	41	39.3	38.6	U2 On-load and U3 fans on, **plus U4 B2 and B5**
02:38	Woodfield Railway Cottages	40	42.3	40.9	39.8	38.8	37.9	U2 On-load and U3 fans on, **plus U4 A3 and A4**
02:46	Woodfield Railway Cottages	49.9	60.8	54.9	40.4	38.9	38.2	U2 On-load and U3 Fans on

Table B2: 370Hz tonal level, audibility and penalty assessment 25-26th January 2016

Time	Description	370Hz Tonal Level dB	Masking Noise Level	Tone Level Minus Masking Level dB	Audibility Penalty (0 to 6dB)	Comment – Plant State
21:59	Kelsterton Farm (25-Jan-2016 21:59 -Rec7)	33.0	35.3	-0.1	0.0	U2 on load and U3+U4 Fans
23:44	Kelsterton Farm (25-Jan-2016 23:44 -Rec15)	33.0	29.1	6.1	2.1	U2 on load and U3+U4 Fans
02:09	Kelsterton Farm (26-Jan-2016 02:09 -Rec29)	23.7	35.2	-9.4	0.0	U2 on load and U3 Fans
21:36	Rockcliffe Cottages (25-Jan-2016 21:36 -Rec5)	27.0	38.8	-9.6	0.0	U2 on load and U3+U4 Fans
22:44	Rockcliffe Cottages (25-Jan-2016 22:44 -Rec9)	22.7	32.0	-7.2	0.0	U2 on load and U3+U4 Fans
01:37	Rockcliffe Cottages (26-Jan-2016 01:37 -Rec26)	23.0	29.9	-4.8	0.0	U2 on load and U3 Fans
22:50	Wenlo/Shieling (25-Jan-2016 22:50 -Rec10)	28.1	30.9	-0.6	0.0	U2 on load and U3+U4 Fans
01:43	Wenlo/Shieling (26-Jan-2016 01:43 -Rec27)	26.2	29.4	-1.1	0.0	U2 on load and U3 Fans
21:26	Woodfield Railway Cottages (25-Jan-2016 21:26 -Rec4)	30.2	33.4	-1.0	0.0	U2 on load and U3+U4 Fans
23:33	Woodfield Railway Cottages (25-Jan-2016 23:33 -Rec13)	30.5	32.9	-0.2	0.0	U2 on load and U3+U4 Fans
01:56	Woodfield Railway Cottages (26-Jan-2016 01:56 -Rec28)	23.7	31.1	-5.3	0.0	U2 on load and U3 Fans
02:22	Woodfield Railway Cottages (26-Jan-2016 02:22 -Rec30)	23.3	32.6	-7.2	0.0	U2 on load and U3 Fans
02:32	Woodfield Railway Cottages (26-Jan-2016 02:32 -Rec31)	24.1	31.7	-5.5	0.0	U2 on load and U3 Fans and U4 B2 and B5 fans
02:41	Woodfield Railway Cottages (26-Jan-2016 02:41 -Rec32)	26.8	33.7	-4.8	0.0	U2 on load and U3 Fans and U4 A2 and A3 fans
02:48	Woodfield Railway Cottages (26-Jan-2016 02:48 -Rec33)	26.0	32.6	-4.5	0.0	U2 on load and U3 Fans

APPENDIX C

On-site Survey of U1, U2, U3 and U4 CT Fans

Measurements were made on U2, U3 and U4 CT during daytime unit load operation on 6th January 2016 (and on U1 once it had returned to service in February 2016) as follows:

- Narrow band FFT measurement in Dry section corridor (west) (Spatial average during walk through individual cell).

- Overall L_{Aeq} measurement in Dry section corridor (west) (Spatial average during walk through individual cell).

See Tables C1 and C2 for overall L_{Aeq} dB levels and 370Hz tonal levels measured within dry stage inlet corridor of the cells with operational fans.

The L_{Aeq} levels give a relative indication of the overall noise level generated internally by the fan and a broad indication of its broadband noise emission into the environment. The key observation is that, in terms of overall L_{Aeq} dB noise level , there is only a small amount of noise level difference across the range of cells.

In terms of tonal noise composition at the characteristic gearbox gear-meshing frequency of 370Hz, unsurprisingly U4B1 has the highest tonal noise level. For the other U1-U4 fans the tonal levels range from 64-76dB, but with no consistent pattern.

Table C2: Overall L_{Aeq} dB noise level – Dry Inlet corridor (West side)

Cell	L_{Aeq} dB			
	U1	U2	U3	U4
B5		74.6	77.6	75.5
B4		76.7	77.1	76.7
B3	76.1	72.7	73.6	
B2	75.6	72.6		77.8
B1	75.7		74.6	78.4
A1		76.7		
A2	77.3	75.2		78.0
A3	76.7			75.7
A4	77.6	74.7		
A5	73.3	75.0	75.9	
Average of L_{Aeq} dB	76.0	74.8	75.8	77.0
Range	73-78	73-77	74-78	75-78

Denotes – Fan Not available for operation
Denotes – Fan available for operation

Table C2: Magnitude of 370Hz tonal level – Dry Stage inlet corridor (West side)

Cell	Level of 370Hz Tone dB			
	U1	U2	U3	U4
B5		71.5	73.7	66.8
B4		74.3	75.9	67.6
B3	71.6	71.6	68.0	
B2	69.7	69.5		72.4
B1	68.7		67.3	78.3
A1		70.3		
A2	64.3	70.1		76.5
A3	70.3			67.0
A4	76.2	64.3		
A5	69.5	70.0	73.0	
Average of 370Hz Tone	70.0	70.2	71.6	71.4
Range	64-76	64-74	67-76	67-78

Denotes – Fan Not available for operation
Denotes – Fan available for operation

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