SOUND SOLUTION
Acoustic Consultancy Ltd

Report on Environmental Impact Noise Survey and Assessment

Report Number: AVB/2942/B

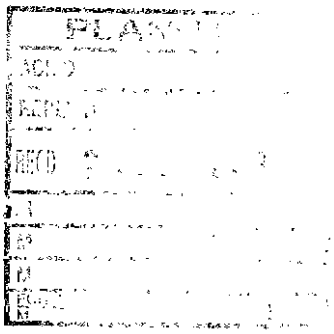
Issue Date: 20th November 2008

Produced for:

Spring & Co

Site at:

Reynolds House
Manchester Techno Park
Archway
Hulme
M15 5RN



Produced by:

Sound Solution Acoustic Consultancy Ltd.

Rev.	Draft	Issue	Date	Notes	By:-
A	1		19th November 2008	Original	JCB
B			20th November	QC Edit	DMB

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Checked, Issued and Signed by Dave Ball MIOA,
Acoustic Consultant & Operations Manager



Summary

As a requirement of a planning application, Sound Solution Acoustic Consultancy (SSAC) have been commissioned by Spring & Co to complete an environmental impact noise survey and assessment at:-

Reynolds House, Manchester Techno Park, Archway, Hulme, M15 5RN

Under the reference Project Bowfell a new building, the Bowfell Energy Centre, is planned. This building will introduce new noise sources to the surrounding environment in the form of 2 off standby generator sets at the internal ground floor and 3 cooling modules and 2 UPS condensers at the roof. The generator plant is standby emergency use only; the cooling modules and UPS condensers will operate 24 hrs per day at duties dependant on system demand.

The aim of the environmental impact noise survey is to assess and quantify the impact of noise from the proposed plant on the nearest and/or most sensitive residential premises by means of BS4142:1997 'Rating industrial noise affecting mixed residential and industrial areas. ' with additional reference to World Health Authority (WHO) guidelines.

The survey will concentrate on what is adjudged to be the most sensitive operating period with respect to noise levels at the nearest and/or most sensitive residential properties; these are flats at some 80m to the North West on Ormsgill Street. The most sensitive period is adjudged to be between midnight and 06:00am.

The building and plant items are not yet in existence and their noise level assessments have been completed as a desk top analysis, based on manufacturer and client advised information, for comparison against site measured background noise levels at the most sensitive period.

Based on BS4142:1997 and WHO assessments herein and subject to specifications and assumptions reported in our findings then we can conclude that;-

-The installation and 24 hr operation of 2 UPS condensers, 3 cooling modules and generators will have no significant impact on the existing acoustic environment at local residential properties.

-Calculated noise levels due to these noise sources all running together indicate a BS4142:1997 rating level (L_{Aeq}) of 3 to 6dB below the night time background (L_{A90}) indicating that complaints of noise nuisance are unlikely when all proposed noise sources are operating.

-Furthermore WHO figures are not exceeded, the resultant noise level from these units at the outdoor area on Ormsgrill Street is below the WHO guideline noise levels for night time.

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1.0 Introduction

Referenced as Project Bowfell a new energy centre building is proposed to be built attached to Reynolds House, Manchester Techno Park, Archway, Hulme, M15 5RN.

As part of these proposals it is planned to install 2 off generator sets within the ground floor westerly area and 3 cooling modules and 2 UPS Condensers to the 'South 'end of the roof.

To satisfy local planning requirements Sound Solution Acoustic Consultancy (SSAC) has been commissioned by Spring & Co to complete an environmental impact noise survey and assessment with respect to the proposed plant and the nearest and/or most sensitive residential properties.

The survey and assessment has been completed in accordance with BS4142:1997 for comparison of specific noise sources on existing background noise levels. Reference is also made to WHO guidelines, 1999, as part of the assessment.

Background noise levels are as recorded by SSAC at what is adjudged to be typical of the most sensitive time with respect to plant planned operations.

Specific noise levels due to the proposed plant items will be assigned via a desk top calculation based on manufacturer's acoustic data.

This report therefore describes a noise impact assessment of the site with respect to the nearest and/or most sensitive residential facade at the most sensitive time and will examine calculated specific noise levels due to proposed new plant item noise sources in comparison with recorded background levels and 'nuisance' ratings according to BS4142:1997. It will further look at noise level limits as set by WHO Guidelines 1999.

The report includes the following information:

- Location of the nearest sensitive residential facades likely to be affected by the proposed new plant noise levels.
- Desk top assessment of Specific Noise Level due to the proposed new plant at 1m from the nearest and/or most sensitive facade.
- Site measurement of existing background noise levels as defined in BS4142:1997 and at a period adjudged to be representative of the most sensitive.
- Evaluation of noise nuisance rating in accordance with BS4142:1997.
- Comparison of results against WHO guidelines.

2.0 Standards and Guidance

2.1. BS4142:1997[2] —Method for Rating Industrial Noise Affecting Mixed Residential and Industrial Areas

2.1.1 Scope

In general, the expected amount of community complaints rises as a function of increasing noise, if the noise level goes up, the volume of complaints will increase.

BS4142:1997 enables an assessment of potential noise nuisance and likelihood of complaints by comparing a specific noise level due to the industrial plant or equipment with assessed or measured daytime and/or night-time background noise levels at sensitive positions. Whilst it is allied to planning requirements it is also a useful tool for assessing existing plant or equipment that may be the subject of noise nuisance complaint. (For definitions of terms see attached Glossary)

Note that BS4142 is not suitable for assessing the noise measured inside buildings or when background and rating noise level are very low, a rating level below about 35dB(A) and a background level below about 30dB(A) are considered very low.

2.1.2 Rating Method

The difference between a specific noise level and the background level (re BS4142 definitions for daytime or night-time assessments) corrected for tonal, intermittent, irregular or impact effects is referred to as the assessment level, and BS4142:1997 gives the following guidelines on assessing the likely hood of noise nuisance complaints.

- *An assessment level greater than +5dB(A) begins to make it very likely that complaints will occur*
- *An assessment level of +5dB (A) is of marginal significance.*
- *An assessment level below 5dB(A), the lower the value the less likelihood there is that complaints will occur*
- *An assessment level of -10dB or less is a positive indication that complaints are unlikely.*

Note that the day is usually divided between day time 0700-2300(16hrs) and night 2300-0700. (8hrs), this can vary dependant on social and environmental conditions.

2.0 Standards and Guidance (Cont.)

2.2 World Health Organization. Guidelines for Community Noise. Geneva. 1999[1]

To evaluate outdoor noise the World Health Organisation, WHO[1] stipulates that to protect the majority of the people from being seriously annoyed during the day time, the sound pressure levels on balconies, terraces and outdoor living areas should not exceed 55dB L_{Aeq} for steady continuous noise. At night, sound pressure levels at the outside facades of living spaces should not exceed 45 db L_{Aeq}, to allow people to sleep with a bedroom window open.

Table 1. WHO Guidelines values for community noise in specific environments.

Specific environment	Critical Health effect(s)	Ambient L_{Aeq} (dB)	Time base Hrs	Ambient $L_{Amax,(fast)}$
Outdoor living area	Serious annoyance, daytime and evening	55	16	-
	Moderate annoyance, daytime and evening	50	16	-
Dwelling, indoors	Speech intelligibility and moderate annoyance, daytime and evening	35	16	
Inside bedrooms	Sleep disturbance, night-time	30	8	45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60

Sound ordinances which define acceptable noise level criteria are there to create and maintain a relaxing environment to live in, the main purpose of this is that levels must be kept low enough to avoid complains from the community.

The WHO guidelines are a rather blanket statement that takes no account of an existing acoustic environment, ideally it would require all acoustic environments to be within these limits and on going legislation and plans for noise mapping is a step towards this goal. BS4142:1997 should be used with reference to the above and any decisions on noise nuisance or reduction of such should attempt to work within the aims of both standards and accept any flexibility this offers.

BS4142:1997 is often the more stringent of the two assessment methods.

[1] World Health Organization. Guidelines for Community Noise. Geneva. 1999

[2] BS4142:1997. Method for Rating Industrial Noise Affecting Mixed Residential and Industrial areas.



3.0 Survey details

3.1 Site Description.

The site under study is the Bowfell Energy Centre located at Internet Facilitators Ltd., Reynolds House, Manchester Techno Park, Archway, Hulme, M15 5RN.

This is a proposed new building to the north east of the existing Reynold's House at which it is planned to install 3 cooling modules and 2 UPS Condensers to the roof area south end and 2 off standby generator sets internally at a central ground floor location.

To a north westerly aspect, and in direct line of sight, for the most part, are the nearest and most sensitive residential flats at Ormsgill Street at a direct line of sight and a mean distance of around 80m from the centre of the proposed new building roof.

3.2 Noise Sources.

The additional noise sources to be introduced to the area will be primarily 3 cooling modules and 2 UPS condensers. Our assessment will be based on advised noise levels supplied by the manufactured.

These units will run 24hrs per day. They have standard and night time run settings although the night time setting is automatically overridden in the event of increased capacity demand. Operational running sequences will vary according to such demands.

From plans submitted by the client it would appear that they are to be located on the building roof to the south end.

Two off generator sets are to be located within the proposed new building, indoors to the North West ground floor area. However it is noted that these are for standby emergency use only and will only be subject to any continuous running in the event of and for the duration a power failure. Such a failure has not occurred for at least the last two and a half years or longer. Otherwise the generator sets will be subject to only day time running for maintenance checks for approximately 30 minutes on a monthly basis.

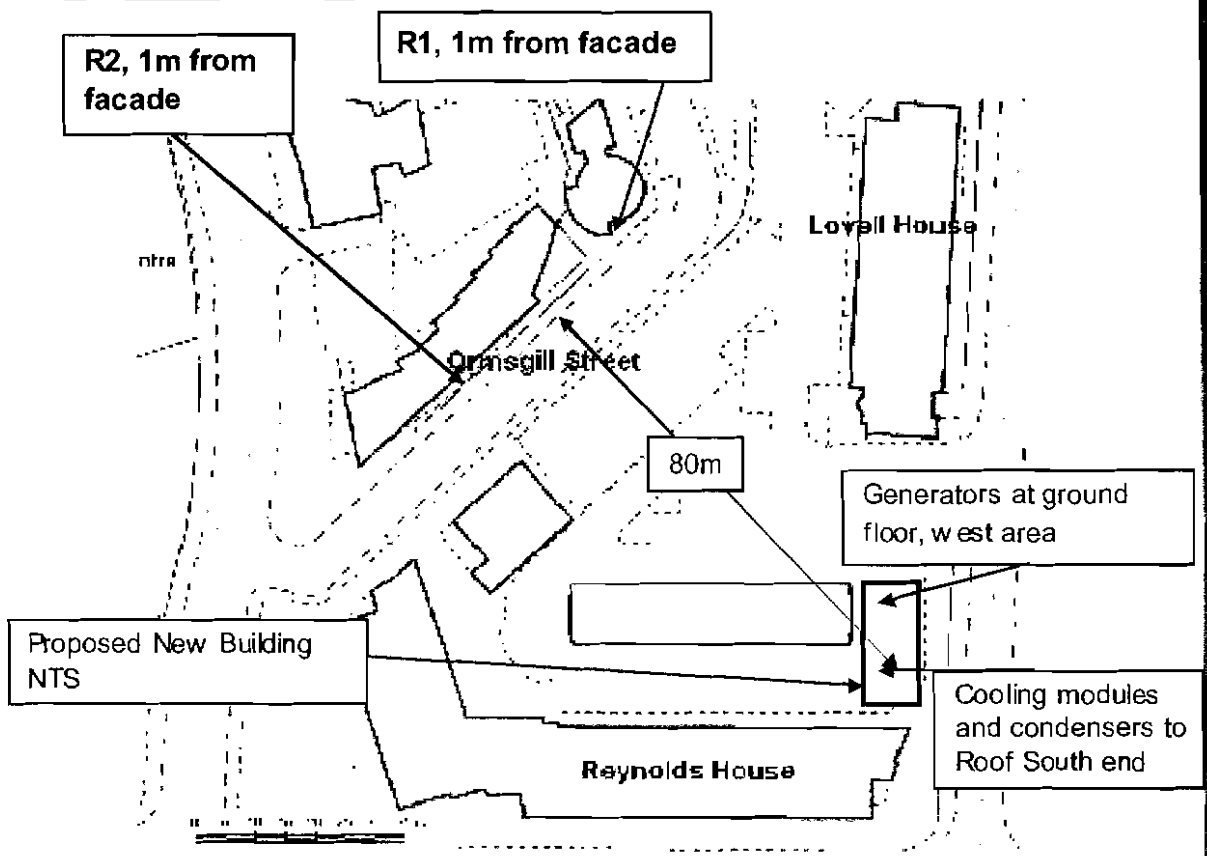
3.0 Survey details (Cont.)

3.3 Measurement Positions

In order to determine the existing ambient and background noise levels at the most sensitive residential property, two positions were chosen –see Fig 1.

The nearest and most sensitive residential properties are to the west side, of the proposed building, where there are ground and first floor residential flats on Ormsgill Street 2 positions were examined along this road each at 1m from the facade of ground floor flats and 1.5m above ground. The microphone was tri-pod mounted at all times.

Fig 1--Microphone Positions



The microphone positions follow the guidelines in BS4142:1997[2]

[2] BS4142:1997. Method for Rating Industrial Noise Affecting Mixed Residential and Industrial areas.

3.0 Survey details (Cont.)

3.4 Sound Measurements.

For BS4142:1997 the usual assessment periods are day time as 0700-2300hrs (16hrs), and/or night time 2300-0700hrs (8hrs), although these can be varied slightly dependant on local circumstances.

The 3 cooling modules and the two UPS condensers will run 24hrs a day and so any assessment must be based on night time periods as the most sensitive time with respect to these units.

The generator sets are standby emergency sets and would only run at night if there were a night time power failure; they will initially be subject to night time assessments as a worst case scenario. Such a scenario will form part of the report discussions.

With this in mind back ground measurements were recorded over a 1hour night time period between 00:30pm and 01:40 am, this was considered to represent the most sensitive time.

The existing ambient noise in the area is characterised by traffic noise, existing ACCU's located in the proximity of Lovell House and Reynolds House and the occasional overhead aircraft at night times.

Measurements of specific noise level were not possible as the proposed cooling modules and UPS condensers are not yet installed.

For the purposes of this survey and assessment the following parameters were recorded:- L_{Aeq}, L_{AMax} and L_{A90}--(For glossary of terms see Appendix B).

Assessment of specific noise level against measured background will be completed as a desk top calculation based on available manufacturer's data.

The meter was subject to a calibration check before and after measurements, there were no calibration problems.

Further survey details are given in Appendix A.



4.0 Quality Assurance

All staff involved in the testing procedure are accredited as members of the Institute of Acoustics. This membership indicates experience in the field of acoustics and that the members' skills and work record have been scrutinised by the membership committee.

5.0 Results

5.1. Measured Background Noise Levels.

Noise levels were recorded as at Table 2 below, these represent ambient and background noise levels without the proposed new plant installations.. They are representative of night time area background noise between a representative sensitive period of 00:30 am and 01:40am

Table 2—Existing NIGHT TIME Ambient / Background prior to Installation of ACCU

		DAYTIME MEASUREMENT 00:30 to 01:40		
RECEIVER POSITION	PERIOD	AMBIENT $L_{Aeq\,(30\,mins)}$	AMBIENT $L_{Amax\,(Fast)}$	BACKGROUND $L_{A90\,(30mins)}$
R1	00.30 to 01:00	49.4	72.2	46.4
R2	01:10 to 01:40	51.0	69.4	46.2

From the above we can assign a typical area background $L_{A90\,(30min)}$ as **46dB (A)**
(Based on the lowest recorded and rounded to nearest whole number)

Weather conditions were noted as random wind gusts, dry with a temperature of approximately 9 degrees centigrade- R1 was sheltered from wind gusts, readings were consistent and the conditions were not considered detrimental to sound measurements.

5.2. Calculated Noise Levels

5..2.1. Cooling modules, Condenser units and Generators

To evaluate the specific noise level at the sensitive receiver positions a calculation is completed using the ISO 9613[3] implemented in a computer program developed by "SOUNDPLAN". The ISO 9613 predicts the sound pressure level (as described in parts 1 to 3 of ISO 1996) under favourable meteorological conditions from sources of known sound emission. This method is applicable in practice for a different noise sources and environments. It is applicable, directly or indirectly, to most situations concerning road or rail traffic, industrial noise sources, construction activities, and many other ground-based noise sources. This is state of the art industry recognised

[3] International Organization for Standardization. ISO 1996. Acoustics-Attenuation of sound during propagation outdoors- Part 1 and 2.

5.0. Results (Cont.)

environmental sound mapping software (Appendix C illustrates the calculation methods employed by SOUNDPLAN)

Our calculations are based on manufacturer's details relative to the condensers, cooling modules and generator these are as Table 3, and 4.

Table 3.-Manufacturer Octave Ban Sound Pressure Level. @ 1m around (free field) and 1m off ground. –Single Unit.

	Octave Band Centre Frequency/Hz								All pass Sound Level/dB(A)
	63	125	250	500	1K	2K	4K	8K	
Octave Band Sound Pressure levels /dB	59	62	60	54	50	46	41	35	57

Table 4.-Manufacturer Octave Ban Sound Power Level.–Single Unit Cooling module hybrid model 300S.

	Octave Band Centre Frequency/Hz								All pass Sound Power Level
	63	125	250	500	1K	2K	4K	8K	
Octave Band Sound Power levels	-	89	82	82	79	80	74	72	86

For the Generator the only acoustic information available is 70 dB(A) at 1 meter (free field) distance.

We have calculated the condensers, cooling modules and generator noise levels at two receiver positions which correspond to 1 meter from the facades of 2 nearest sensitive properties and 1.5m above ground. Table 4 gives the resultant calculations.

Note that the calculated levels assume continuous running and so can be taken as being equivalent to a night time BS4142:1997 specific noise level reference period of 5 minutes.

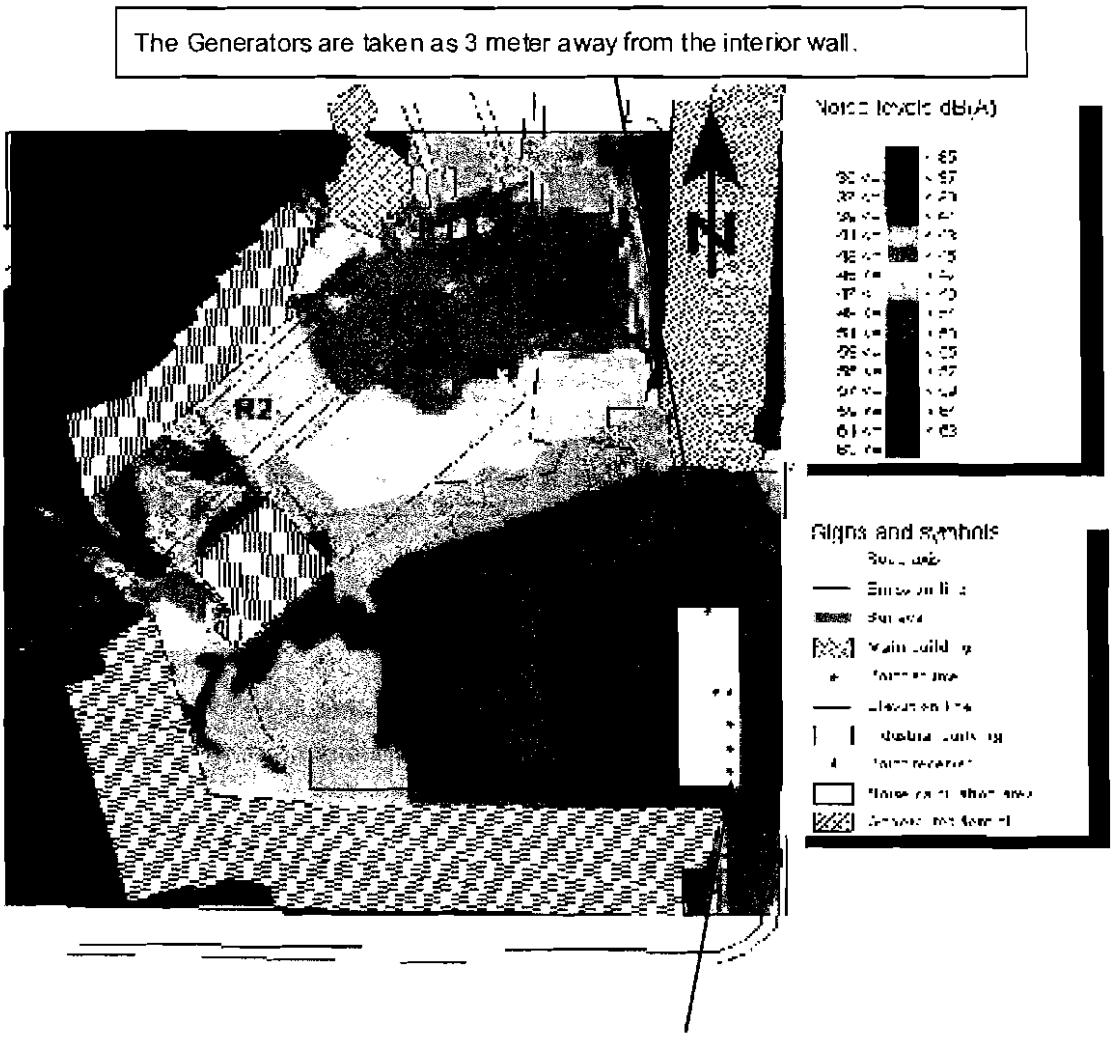
We have assumed that the 2 UPS condenser, 3 cooling units and the generator may be running continuously at standard setting over any 5 minute night time period.

Calculations for noise levels from the 2 off generators being internally located take into consideration the wall enveloping them (Cavity brick wall and aluminium louvers -50% free air and 100 mm blades).

5.0. Results (Cont.)

Fig 2 illustrates the receiver positions and shows noise mapping for the 2 off UPS condensers, 3 cooling modules and the generator all running and relates to surfaces 2m above ground, table 5 gives the calculated levels that are equivalent to the specific noise level.

Fig 2—Noise Map for 3 cooling modules, 2 UPS condensers and generators.



5.0. Results (Cont.)

Table 5—Calculated Noise level at Receivers for 3 cooling modules, 2 UPS condensers and generators.

Location	Calculated Specific Noise level noise $L_{Aeq\ (5mins)}$
R1	43
R2	40

Thus taking the worse case from above the 5 minute reference period specific noise level at 1m from the facade of direct line of sight properties on Ormsgill Street and 1.5m above ground is calculated as **43dB(A)** due to generators sets running in the westerly ground floor area of the Bowfell Energy Centre combined with 2 UPS condensers and 3 cooling modules.

(Note that all levels are rounded to the nearest whole number for assessment purposes and that in each case the assessment is based on the highest specific noise level calculated for Receiver R1 or R2)

6.0 Assessments

6.1 BS4142:1997, Night Time Assessments

Our assessment is based on all 2 UPS condensers, 3 cooling modules and generators running together at standard setting for at least any 5 minutes throughout the night time period.

Note that it is our opinion that a +5dB correction for tonal, irregular, intermittent or impulsive noise acoustic characteristics is not necessary. The spectral levels at Table 3 show a drop down from low frequency, especially the 6dB drop at 250Hz to 500, that is a general progression to lower values at high frequencies. In fact the band levels are pretty level between 63Hz to 250 Hz without any distinct tone

Table 6—BS41442 Assessment, 2 condensers, 3 cooling modules and generators at R1

Line Ref:- a	Calculated Specific noise levels (Table 4.) $L_{Aeq\,(5min)}$ /dB(A)	1m from facade at Ormsgill Street9 (R1)	**43**
b	Corrections for acoustic characteristics /dB		**0**
c	Rating Level $L_{Ar\,(5min)}$ /dB(A)	1m from facade at Ormsgill Street (R1 to R2)	**43**
d	Background level (Table 2) $L_{A90\,(2hrs)}$ /dB(A)	1m from facade at Ormsgill Street (R1 to R2)	**46**
e	Assessment rating over background (Line d – line e) /dB	1m from facade at Ormsgill Street (R1 to R2)	-3

THIS ASSESSMENT LEVEL IS AN INDICATION THAT COMPLAINTS OF NOISE NUISANCE AT R1 ARE UNLIKELY

6.0 Assessment (Cont.)

Table 7—BS41442 Assessment, 2 condensers, 3 cooling modules and generators at R2

Line Ref:- a	Calculated Specific noise levels (Table 4.) $L_{Aeq(5min)}$ /dB(A)	1m from facade at Ormsgill Street9 (R1)	40
b	Corrections for acoustic characteristics /dB		0
c	Rating Level $L_{Ar(5min)}$ /dB(A)	1m from facade at Ormsgill Street (R1 to R2)	40
d	Background level (Table 2) $L_{A90(2hrs)}$ /dB(A)	1m from facade at Ormsgill Street (R1 to R2)	46
e	Assesement rating over background (Line d – line e) /dB	1m from facade at Ormsgill Street (R1 to R2)	-6

THIS ASSESSMENT LEVEL IS AN INDICATION THAT COMPLAINTS OF NOISE NUISANCE AT R2 ARE UNLIKELY

6.2 W.H.O. Assessment-

Where we have steady continuous noise levels then we can complete an assessment with reference to WHO guidelines, these refer to night time (or day time) acceptable continuous noise levels at indoor and outdoor living spaces.

It is the ambient level that is of interest and it is referenced as LAeq dB. The ambient level is the all encompassing sound level including noise from all sources.

We have steady continuous noise sources and have estimated specific noise levels for each. The specific noise level is always referenced to 1m from a facade, this means that in calculating it a +3dB reflective contribution is added for facade effect which is relevant to compare with WHO noise levels reference.

Referring to Table 2 the existing ambient will be taken as the logarithmic mean of the two readings, 51dB and 49.4dB is 50.3dB

6.0. Assessments (Cont.)

6.2.1 Condensers, cooling modules and generators.

THE EXISTING NIGHT TIME AMBIENT EXCEEDS WHO GUIDELINE FIGURE OF 45dB(A)

From Table 5 the contribution to steady outdoor ambient of the proposed noise sources all running constantly in standard mode is specific noise level is at R1 is 43 and at R2 40. Those results are below the recommended noise limit value during night time by WHO.

7.0 Discussions of Results

The 2 assessment methods both illustrate acceptable noise levels from the proposed UPS condensers, cooling modules and generator at 1m from the nearest sensitive facades at Ormsgill Street. BS4142:1997 returns a -3dB at R1 and -6 at R2 assessment rating over background making the chance of night time noise nuisance complaints unlikely.

WHO figures are not exceeded, in fact the resultant noise level from these units at the outdoor area on Ormsgrill Street is below the WHO guidelines noise levels for night time.

It is noted however that the existing ambient exceeds WHO night time guidelines by 2dB(A)

When discussing the generator sets their function as emergency standby should be borne in mind, it would need a night time power failure for them to run at night.

Neither a night or day time failure has occurred for at least the last two and a half years.

Otherwise the generator sets will be subject to only day time running for maintenance checks for approximately 30 minutes on a monthly basis. Daytime ambient are certainly going to be higher than those at night due to busy main roads.

Bearing in mind the limited operation of the proposed generating sets then on the rare occasions that the 2 off proposed generator sets operate their noise levels should be acceptable.

All assessments have been based on the most sensitive night time periods, day time periods would return even better results and conclusions.

8.0. Conclusions

Based on BS4142:1997 and WHO assessments herein and subject to specifications and assumptions reported in our findings then we can conclude that;-

The proposed installation and 24 hr operation of 2 UPS condensers, 3 cooling modules and generators will have no significant impact on the existing acoustic environment at local residential properties.

-Calculated noise levels due to these noise sources all running together indicate a BS4142:1997 rating level (L_{Aeq})of 3 to 6dB below the night time background (L_{A90}) indicating that complaints of noise nuisance are unlikely when all proposed noise sources are operating.

-Furthermore WHO figures are not exceeded, the resultant noise level from these units at the outdoor area on Ormsgrill Street is below the WHO guideline noise levels for night time.

SOUND SOLUTION Acoustic Consultancy Ltd

Appendix A

Survey Details

A1. Location of Survey

Reynolds House, Manchester Techno Park, Archway, Manchester, MR15 5RN

A2. Date & Time of Survey

6th March 2008, between 00:30am and 01:40am

A3. Personnel Present During Survey

Dave Ball, MIOA Sound Solution Acoustic Consultancy Ltd

A4. Instrumentation

Item	Description	Manufacturer	Serial No.	Calibration Expiration Date.
Nor-118	Analyser/Noise Generator	Norsonic	28952	July 2008
Nor-1225	Microphone	Norsonic	29913	July 2008
Nor-1206	Pre-amplifier	Norsonic	30575	July 2008
Nor-1251	Sound Level Calibrator	Norsonic	31233	August 2008

A5. Calibration

Before and after the survey the measurement apparatus was check calibrated to an accuracy of $\pm$0.3 dB using the Sound Level Calibrator. The Calibrator produces a sound pressure level of 114 dB re 2 x 10^{-5} Pa at a frequency of 1 kHz.

Appendix B

Glossary of Terms re environmental noise assessments.

Lw:- Sound power level re 2 x 10 -12 Watts

Lp = Sound Pressure level re 2 x 10 -5 Pascals

dB. Abbreviation for decibel – a scale used in sound measurement. It is equivalent to 10 times the logarithm (to base 10) of the ratio of a given sound pressure to a reference pressure.

dBA. A value used for "A-weighted" sound pressure levels. "A" frequency weighting is an adjustment ade to sound-level measurement to approximate the response of the human ear.

L_{A90}. The A-weighted sound pressure level that is exceeded for 90% of the time over which a given sound is measured. This is considered to represent the background noise for the purposes of BS4142:1997

L_{A10}. The A-weighted sound pressure level that is exceeded for 10% of the time over which a given sound is measured.

L_{Aeq} (equivalent continuous noise level). The level of noise equivalent to the energy average of noise levels occurring over a defined measurement period.

L_{Amax}. The A-weighted sound pressure level that represents the maximum noise level measured over the time that a given sound is measured.

Specific Noise Source. Specific plant or equipment giving rise to receiver specific noise levels
At 1m from a sensitive facade
This is described using the L_{Aeq} descriptor for the purposes of BS4142:

Receiver. The person or point at which the noise level is heard or measured.

Ambient Noise. Level The all-encompassing noise within a given environment. It is the composite of sounds from many sources, both near and far. Including any specific noise source
This is described using the L_{Aeq} descriptor for the purposes of BS4142:1997

Residual Noise Level. The A-weighted equivalent sound pressure level remaining at a given position in a given situation when the specific noise source is suppressed to a degree such that it does not contribute to the ambient noise.
This is described using the L_{Aeq} descriptor for the purposes of BS4142:1997

Specific Noise Level $L_{Aeq(Tr)}$ The A-weighted equivalent sound pressure level that represents the noise level of a specific noise source at 1m from the nearest sensitive facade for Tr reference time period as defined in BS4142 where Tr = 1 hour daytime and Tr=5 mins night time. It is a logarithmic subtraction of ambient noise minus residual noise
This is described using the L_{Aeq} descriptor for the purposes of BS4142:1997

Background noise level. The underlying A weighted sound pressure level of noise present in the ambient noise, excluding the Specific noise source under investigation
This is described using the L_{A90} descriptor for the purposes of BS4142

Rating Level. Arithmatic subtraction, Specific Noise level minus Background Noise Level, dB(A)

Appendix B (Cont.)

Community annoyance. Includes noise annoyance due to: - characteristics of the noise (e.g. sound pressure level, tonality, impulsiveness, low-frequency content), - characteristics of the environment (e.g. very quiet suburban, suburban, urban, near industry), - miscellaneous circumstances (e.g. noise avoidance possibilities, cognitive noise, unpleasant associations), - human activity being interrupted (e.g. sleep, communicating, reading, working, listening to radio/TV, recreation).

Sound Pressure Level, in decibels sound pressure level is given by the formula

$$L_p = 10\log\left(\frac{p}{p_o}\right)^2$$

Where

p is the root mean square sound pressure, in pascals (Pa).

p_o is the reference sound pressure (20 µPa)

A-weighted sound pressure level, in decibels. Sound pressure level of A-weighted sound pressure is given by the formula

$$L_{pA} = 10\log\left(\frac{p_A}{p_o}\right)^2$$

Equivalent continuous A-weghted sound pressure level, in decibels. Value of the A-weighted sound pressure level of a continuous, steady sound that, within a special time interval T, has the same mean square sound pressure as a sound under consideration whose level varies with time, given by the formula

$$L_{AeqT} = 10\lg\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2}\frac{p_A^2(t)}{p_o^2}dt\right]$$

Where

$L_{Aeq,T}$ is the equivalent continuous a-weighted sound pressure level, in decibels, determined over a time interval T starting at t_1 and ending at t_2;

p_o is the reference sound pressure (20 µPa);

pA (t) is the instantaneous A-weighted sound pressure of the sound signal

* Equivalent continuous A-weighted sound pressure level during time interval T is also called time interval average sound level, $L_{A,T}$, in decibels, with the averaging time interval usually indicated in the format, for example one-hour average sound level, $L_{A,1h}$.

Sleep disturbance. Awakenings and disturbance to sleep stages.

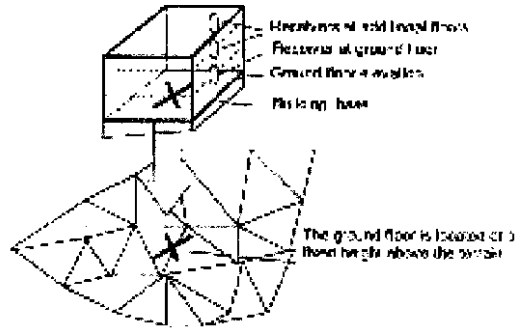
Tonality. Noise containing a prominent frequency and characterised by a definite pitch. Often defined as being 5dB or more above neighbouring octave or 1/3rd octaves

Appendix C

Calculation method

C.1 Creation and calculation of the ground model.

The building and the building affected close to it is an important factor in the outdoor noise propagation assessment. The buildings have been referenced to the ground floor elevation (zl) as show in the Figure bellow. All heights (building height, receivers, etc...) are measured from this position. The terrain elevation assigned to the building is the mean elevation in the middle of the building. This elevation is used in the digital ground model.



Definition of the building.

Any variation in the building height was assigned via the terrain elevation. We selected different types of building whether they are main building or an auxiliary building.

C.2 Receiver properties.

We calculated two types of receivers according to the following criteria: Receivers attached directly to buildings (front of the building) and receivers in the free field. The receivers attached to the building were sited relative to the position of the building. This criterion is followed because the buildings are always referenced with their elevation to the ground floor; therefore we referenced its attached receivers according to this position. For receiver in the free field we used its exact elevation according to a main size and the elevation of the terrain.

Appendix C (Cont.)

C.3 Principles and Standards.

ISO 9613.

ISO 9613 is a general purpose standard for outdoor noise propagation. The sound pressure at the receiver L_{eq} is the sum of all contributing frequencies. The sound pressure for a single frequency is calculated by:

$$L_S = [L_W + D_I + K_O] - [D_S + \Sigma D]$$

L_S Sound pressure for a single frequency
L_W sound power
D_I directivity of the source
K_O spherical model
D_S spreading
Σ D different contributions factors.

. air absorption.
. ground absorption and meteorological effects
. volume type absorption.
. screening.

K_O is defined by the spatial angle Ω with

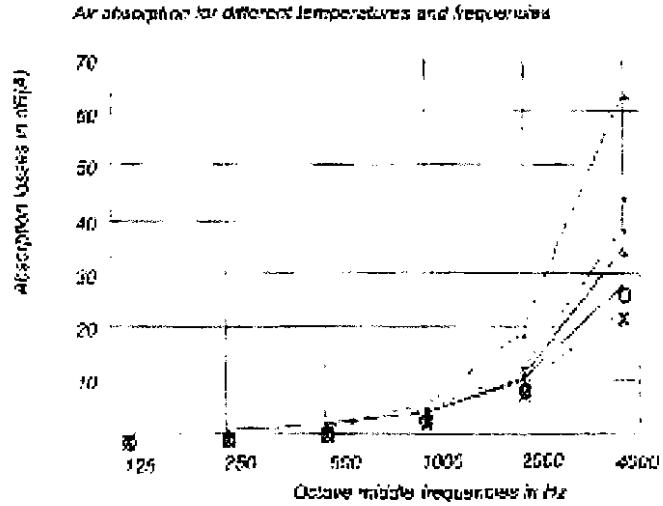
K_O = 10*lg(4*π/ Ω) dB(A)

The **spreading** of a point source is set to:

D_S = 20*log(dist.source,receiver)+11 dB(A)

The **air absorption** is significant for long distances. Air, does not permit sound waves to propagate without loss. The losses depend on the frequency, temperature, relative humidity and air pressure. The method used to evaluate air absorption is the ISO 9613. We must point out that the air absorption is to be significant at distances over 100 m above 2kHz. The other atmospheric mechanisms such as rain or fog do not produce high absorption levels.

Appendix C (Cont.)



Air absorption

The **ground and meteorological attenuation** (D_{BM}) depends on the average height of the line of sight above the terrain (H_M) and the distance from source to receiver (S_M). The ground impedance is ignored.

$$D_{BM} = [4.8-2*H_M/S_M*(17+300/S_M)]dB>0\ dB$$

The **volume type absorption**. A sound wave passing through of obstacles will be partly absorbed. The bigger the distance the sound travels in the "volume" type absorption, the higher the losses. The attenuation is following the next equation:

Losses= Distance through area* attenuation per meter.

The formulas of the screening define an insertion loss which is the combination of screening, volume absorption and the ground attenuation. If the ground attenuation is bigger than the screening, the effect of the screening is zero dB. If the screening effect is bigger than the ground absorption, the ground absorption is ignored.

The screening is calculated with the formulas:

$$DZ=10*\log(C_1+C_2/\lambda*C_3*Z*K_W)dB$$

λ wavelength of the sound

Z extra path length

Appendix C (Cont.)

C_1 constant 3

C_2 factor 20 for normal calculations 40 for calculations using the ground reflection explicitly

C_3 factor=1 for single screen

$$factor=(1+(5^* \lambda/e)^2)/(1/3+(5^* \lambda/e)^2)$$

For multiple screens with e= distance between the screens

K_W correction factors for meteorological influences

$$K_W=\exp(-sqrt(A_q{}^*A_a{}^*S_m)/2^*Z)))$$

A_q distance source to screen

A_a distance screen to receiver

S_m distance source to receiver

The meteorological correction C_{met}. The result is the so called $L_{AT}(DW)$. In order to obtain long term value $L_{AT}(LT)$ a meteorological correction C_{met} must be applied.

$$L_{AT}(LT)=L_{AT}(DW)-C_{met}$$

C_{met} is calculated

$C_{met}=0$ if $d_p \leq 10(h_s+h_r)$

$C_{met}=C_o[1-10(h_s+hr)/d_p]$ if $d_p>10(h_s+h_r)$

With:

h_s source height (m)

h_r receiver height (m)

d_p distance (m) between the source and receiver projected to the horizontal ground plane

C_0 factor (in dB) which depends on local meteorological statistics for wind speed and direction and temperature gradients.

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Appendix C (Cont.)

This model assumes the following:

- As the laws of geometrical acoustics are used wave type phenomena are absent.
- Surfaces, which are all planes, reflect the sound energy spectrally as if from an infinite plane. Any surface absorbs sound energy according to an energy absorption coefficient, which is independent from the angle of incidence.
- Sound is treated as an energy function.

General equations.

Scattering of sound from obstacles in the room (tables, machines, etc) is accounted statistically. Thus, a characteristic is the scattering object density:

$$q = \frac{S}{4 * V} \qquad (1)$$

or the mean free path I_m of the sound rays between succeeding scatterings

$$I_m = \frac{1}{q} = \frac{4 * V}{S} \qquad (2)$$

S is the total surface of everything in the room volume *V* with objects bigger than the wavelength.

The sound energy in the room consists of direct and scattered sound. For a point sound source in a homogeneous, infinitely large room filled with scattering objects, this part of the energy density is:

$$E_d(r) = \frac{P}{4 * \Pi * c * r^2} * e^{-(q+m)*r} \qquad (3)$$

P Sound power of the source (W)

q scattering object density [1/m] defined in $q = \frac{S}{4 * V}$

c speed of sound [m/s]

r distance between sound and receiver [m]

m damping constant of air

Appendix C (Cont.)

The energy density of the direct sound in a closed room is the sum of the energy densities from the original and all mirror sources. For the mirror sources, the reflection losses must be taken into account. This sum is:

$$E_d = \sum_{i=-\inf}^{\inf} \sum_{j=-\inf}^{\inf} \sum_{k=-\inf}^{\inf} (1-\alpha)^{|i|} * (1-\alpha)^{|j|} * (1-\alpha)^{|k|} * E_d(r_{ijk}) \qquad (4)$$

$\alpha_x, \alpha_y, \alpha_z$ are the mean absorption coefficients of the room boundary planes (mirror planes). $r_{i,j,k}$ is the distance between the mirror source of the order *i,j,k* and the receiver.

Calculation of the Scattering Energy Density.

The energy density of the scattered sound in an infinitely wide flat room is:

$$E_S(r) = \frac{3 * q * p}{4 * \Pi * c * r} * e^{(-r * sqrt(3 * q * a))} \qquad (5)$$

With:

$$a = b + \alpha_S' q + m \qquad (6)$$

The α_S' is the mean absorption exponent of the scattering objects

$$\alpha_S' = -\ln(1 - a_S) \qquad (7)$$

The exponent *b* describes the sound energy losses due to absorption of floor and ceiling. It is calculated as follows:

For qh<1

$$b(\alpha_i) = -q * \ln\left\{ qh * \left(1 - \frac{\alpha_i}{4}\right) + \left(1 - \frac{\alpha_i}{2}\right) * \frac{2}{\alpha'}\left[1 - \exp\left(-\frac{\alpha'}{2} * \left(\frac{1}{qh} - 1\right)\right)\right]\right\} \qquad (8)$$

and for qh>=1

$$b(\alpha) = -q * \ln\left(1 - \frac{\alpha_i}{4} * qh\right) \qquad (9)$$

$$b = b(\alpha_{floor}) + b(\alpha_{ceiling}) \qquad (10)$$

h= mean height of the room

Appendix C (Cont.)

$\alpha_{floor}, \alpha_{ceiling}$ = mean absorption coefficient of floor and ceiling

The energy density in an infinite closed room is analogue to equation (4)

$$E_d = \sum_{i=-\inf}^{\inf} \sum_{j=-\inf}^{\inf} \sum_{k=-\inf}^{\inf} (1-\alpha)^{|i|} * (1-\alpha)^{|j|} * (1-\alpha)^{|k|} * E_d(r_{ijk}) \qquad (11)$$

The reflection coefficients for floor and ceiling are omitted because they are already included in the derivation of equations (8) or (9). A ray tracing method is again used in the summation.

MOP required