Noise & Vibration Assessment
Rail House, Manchester
For BRBR



PLANNING
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14 MAR 2008
DATE

March 08

Scott Wilson Ltd

D119458_NOIS_01

Noise & Vibration Assessment

RAIL HOUSE, MANCHESTER

Issue No	Current Status	Date	Prepared by	Reviewed by	Approved by
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1. INTRODUCTION

1.1 Background

1.1.1 Rail House, originally built in the 1960's, is located on the corner of Store Street and Boad Street, adjacent to Piccadilly railway station in Manchester city centre.

1.1.2 It is proposed to refurbish the existing office building to create 'Piccadilly Gate', a ten storey office development, with a further 3 storey adjoining office building linking the development to the railway station site.

1.2 Scope

1.2.1 Scott Wilson noise and vibration team have been instructed by British Railways Board (Residuary) Ltd. (BRBR) to undertake a survey of existing noise and vibration levels at Rail House, Manchester.

1.2.2 It is understood that the measurements (of noise levels in particular) can subsequently be used by the contractor to inform specific glazing and ventilation requirements in order to achieve internal noise levels, contributing to a BREEAM rating of 'excellent'.

2. NOISE AND VIBRATION MONITORING

2.1 Noise Measurement Protocol

2.1.1 Long-term noise monitoring was undertaken between Monday 3rd March and Monday 10th March 2008 at four locations on the façade of Rail House:

- **Location M1** – 9th floor, east facing, overlooking Boad Street;
- **Location M2** - 7th floor, south facing, towards Piccadilly railway station and adjoining car park;
- **Location M3** - 4th floor, north facing, overlooking Store Street and towards site of Piccadilly Tower construction site; and
- **Location M4** - 3rd floor, west facing, towards railway station entrance and adjacent car park.

2.1.2 Erected on specially constructed frames, the microphones were positioned 1 metre from each façade of the building, thus measuring façade noise levels including the L_{Aeq} and L_{A90} parameters, over contiguous 15-minute periods.

2.1.3 Supplementary short term noise measurements were undertaken at ground floor level around the perimeter of Rail House. In addition to logging octave band frequency data, these measurements could be compared to the measurements taken at differing floor levels, to establish any relationship between height and noise level.

2.2 Noise Monitoring Instrumentation

2.2.1 Location M1:

- Brüel and Kjær 2238 integrated sound level meter, serial number 2541000
- Brüel and Kjær 4188 microphone, serial number 2547570

2.2.2 Location M2:

- Brüel and Kjær 2238 integrated sound level meter, serial number 2381585.
- Brüel and Kjær 4188 microphone, serial number 2379764

2.2.3 Location M3:

- Brüel and Kjær 2238 integrated sound level meter, serial number 2541002
- Brüel and Kjær 4188 microphone, serial number 2547569

2.2.4 Location M4:

- Brüel and Kjær 2238 integrated sound level meter, serial number 2201511
- Brüel and Kjær 4188 microphone, serial number 2200371

2.2.5 Location M1, M2, M3 and M4:

- Brüel and Kjær acoustic calibrator 4231, serial number 2217874
- Brüel & Kjær outdoor microphone kits, type UA-1404

2.2.6 Location M5, 6, 7& 8:

- Brüel and Kjær 2260 integrated sound level meter, serial number 2001556
- Brüel and Kjær 4189 microphone, serial number 2020887

2.2.7 Calibration certificates for all noise monitoring instrumentation are available upon request.

2.3 Meteorological Conditions

2.3.1 Weather conditions are understood to have been suitable for noise monitoring for the majority of the measurement period. However, throughout the night of Sunday 9th March, strong winds and rain have resulted in measurements during this time period being excluded from any analysis.

2.3.2 Other periods of rain throughout the week are believed to have been light enough and of a duration considered tolerable in terms of the measurements logged.

2.4 Noise Sources

2.4.1 Noise sources noted whilst on site included road traffic noise from Store Street and Boad Street, which dominates the existing noise climate on the north and eastern facades of Rail House. Rail traffic and public address announcements from Piccadilly railway station, and car park movements in the station car park, dominate the existing noise climate on south and western facades.

2.4.2 During the monitoring period, construction work was ongoing at the site of Piccadilly Tower, a new development including for residential use, off Store Street. Particularly significant activities (e.g. the demolition of retaining walls and ground works) were ongoing in close proximity to Store Street on the day the noise equipment was erected and also (based on analysis of all the measurements) on the subsequent Tuesday and Thursday.

2.5 Vibration Monitoring Protocol

2.5.1 Measurements of existing vibration levels were undertaken on the ground floor of Rail House, to enable comparison with 'acceptable' levels in accordance with BS 6472[1]. Appendix A provides detail regarding human perception of ground borne vibration and lists these 'acceptable' levels.

2.5.2 Measurements were taken at ground floor level on concrete foundation by the façade of Rail House directly opposite Piccadilly railway station. Notably, no vibration was perceptible to the engineer during the survey period.

2.6 Vibration Monitoring Instrumentation

2.6.1 A Vibrock V801 Digital Seismograph (serial number 525) was employed during the survey of existing vibration levels.

2.6.2 The V801 is a tri-axial vibration analyser with electronic data storage of events. The unit is dual channel, enabling simultaneous analysis of two tri-axial transducers (for example, continuous vibration monitoring in one channel and VDV assessment in the second channel). When used in VDV mode the system complies with the requirements of BS 6472. The Vibrock V801 electronically stores the ppv vibration level and calculates the VDVs (both day and night).

2.6.3 Calibration certificates for the vibration monitoring instrumentation are available upon request.

[1] British Standard 6472: 'Evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz), British Standards Institution, 1992.

3. RESULTS OF NOISE AND VIBRATION MONITORING

3.1 Noise Monitoring Results

3.1.1 Results of the noise monitoring surveys are summarised in Tables 1 and 2. Time histories of the long-term noise monitoring are available in Appendix B, Figures B.1 to B.4.

Table 1: Long-term Noise Monitoring Results Summary

Monitoring Location	Date	Daytime (0700 to 1900)		Evening (1900 to 2300)		Nighttime (2300 to 0700)	
		$L_{Aeq,\ 12h}$ dB	$L_{A90,15min}$ dB*	$L_{Aeq,\ 4h}$ dB	$L_{A90,15min}$ dB	$L_{Aeq,\ 8h}$ dB	$L_{A90,15min}$ dB
M1	Monday 3rd March 2008	61†	57 to 59†	59	53 to 56	56	49 to 54
	Tuesday 4th March 2008	62	57 to 59	59	54 to 56	61	49 to 53
	Wednesday 5th March 2008	62	57 to 59	58	52 to 56	54	48 to 52
	Thursday 6th March	68	57 to 61	62	53 to 58	55	48 to 52
	Friday 7th March	62	56 to 59	58	53 to 56	56	49 to 52
	Saturday 8th March	59	53 to 57	58	52 to 55	55	47 to 52
	Sunday 9th March	58	51 to 57	58	53 to 57	59	49 to 56
	Monday 10th March	63†	59 to 60†	-	-	-	-
	Weekdays_3rd to 10th March	**64**	**56 to 61**	**59**	**52 to 58**	**55**	**48 to 54**
M2	Monday 3rd March 2008	63†	57 to 60†	62	54 to 60	58	45 to 58

Monitoring Location	Date	Daytime (0700 to 1900)		Evening (1900 to 2300)		Nighttime (2300 to 0700)	
		$L_{Aeq,\ 12h}$ dB	$L_{A90,15min}$ dB*	$L_{Aeq,\ 4h}$ dB	$L_{A90,15min}$ dB	$L_{Aeq,\ 8h}$ dB	$L_{A90,15min}$ dB
	Tuesday 4th March 2008	63	57 to 60	61	53 to 58	57	45 to 57
	Wednesday 5th March 2008	63	58 to 61	52	54 to 60	58	47 to 59
	Thursday 6th March	63	59 to 61	63	56 to 61	58	48 to 56
	Friday 7th March	66	58 to 62	62	54 to 60	59	50 to 58
	Saturday 8th March	63	56 to 60	61	54 to 58	56	46 to 54
	Sunday 9th March	61	53 to 59	61	54 to 59	59	48 to 59
	Monday 10th March	64†	59 to 63†	-	-	-	-
	Weekdays_3rd to 10th March	**64**	**57 to 63**	**62**	**53 to 61**	**58**	**45 to 59**
M3	Monday 3rd March 2008	77†	56 to 66†	61	52 to 55	58	49 to 52
	Tuesday 4th March 2008	74	57 to 66	60	52 to 54	58	49 to 59
	Wednesday 5th March 2008	65	57 to 62	60	53 to 56	57	50 to 52
	Thursday 6th March	77	58 to 66	63	53 to 58	58	50 to 52
	Friday 7th March	66	57 to 66	61	53 to 56	59	51 to 53
	Saturday 8th March	62	55 to 57	60	53 to 55	58	50 to 52
	Sunday 9th March	62	53 to 63	60	52 to 57	58	50 to 54
	Monday 10th March	66†	58 to 61†	-	-	-	-
	Weekdays_3rd to 10th March	**74 (66**)**	**56 to 66**	**61**	**52 to 58**	**58**	**49 to 59**

Monitoring Location	Date	Daytime (0700 to 1900)		Evening (1900 to 2300)		Nighttime (2300 to 0700)	
		$L_{Aeq,\ 12h}$ dB	$L_{A90,15min}$ dB*	$L_{Aeq,\ 4h}$ dB	$L_{A90,15min}$ dB	$L_{Aeq,\ 8h}$ dB	$L_{A90,15min}$ dB
M4	Monday 3rd March 2008	64†	57 to 60†	61	56 to 59	60	52 to 58
	Tuesday 4th March 2008	64	57 to 60	59	53 to 57	59	52 to 57
	Wednesday 5th March 2008	64	57 to 60	61	54 to 59	60	52 to 58
	Thursday 6th March	64	58 to 61	61	56 to 59	60	53 to 57
	Friday 7th March	65	58 to 63	60	55 to 59	59	53 to 58
	Saturday 8th March	62	57 to 59	60	56 to 58	58	53 to 56
	Sunday 9th March	60	55 to 58	60	55 to 58	60	53 to 58
	Monday 10th March	64†	58 to 61†	-	-	-	-
	Weekdays_3rd to 10th March	**64**	**57 to 63**	**60**	**53 to 59**	**60**	**52 to 58**

*Typical Range (10th - 90th percentile)
† Not full measurement periods
**Excluding periods of significant construction activity

3.1.2 At Location M1 (Boad Street façade), daytime L_{Aeq} levels were reasonably constant. However, on Thursday 6th March, daytime levels increased from approximately 10:00 am. It is expected this increase in noise level relates to the demolition of a retaining wall associated with the development of Piccadilly Tower. Rail House itself provided a degree of self-shielding between the microphone position on the Boad Street façade and the same activity on Monday 3rd March. However, as the demolition activity progressed along the retaining wall on Store Street, the effectiveness of this self-shielding was removed, resulting in increased noise levels incident on the Boad Street façade on the Thursday.

3.1.3 Lower noise levels are noted over the weekend daytime periods, as would be expected due to a reduction in road traffic movements relative to those during the working week. For similar reasons, noise levels are noted to reduce during the evening periods, and further still during nighttime periods.

3.1.4 At Location M2, overlooking Piccadilly railway station and the adjacent car park, noise levels follow a reasonably stable and typical pattern, dropping during the evening and nighttime periods as activity at the railway station and within the car park reduce.

3.1.5 At Location M3, (Store Street façade), measured daytime noise levels have been influenced by ongoing construction work at the site of Piccadilly Tower. L_{Aeq} levels are significantly in excess of the L_{A90} levels, indicating irregular and sporadic increases in noise levels. This is particularly evident on Monday 3rd, Tuesday 4th and Thursday 5th March. By removing these data from analysis of the overall weekday daytime noise level, it is considered a more representative indication of the existing noise climate can be achieved. Consequently, an overall L_{Aeq} of 66 dB (A) is included in Table 1.

3.1.6 Evening, nighttime and weekend noise levels are unaffected by the construction activities, and drop relative to daytime and weekday levels.

3.1.7 At Location M4, overlooking the entrance to Piccadilly railway station and the intervening car park area, noise levels follow a typical diurnal pattern, dropping during the weekend, evening and nighttime periods, as activity at the railway station and in particular within the car park reduces.

3.1.8 Results of the short term noise monitoring undertaken on Monday 3rd and Monday 10th March are summarised in Table 2. These measurements were taken at ground level in order to provide a reference against which the long-term measurements, taken at different floor heights could be compared, and any significant relationship identified.

3.1.9 Short-term measurements were also taken in order to gather information regarding the frequency content of noise incident on Rail House and therefore the proposed Piccadilly

Gate. This detailed information can be employed to further inform glazing and ventilation requirements during the design process.

Table 2: Short-term Noise Monitoring Results Summary

Monitoring Location	Reference	Date	Start time (hr:min)	Duration,T (hr:min)	$L_{Aeq,T}$ dB	Concurrent measurement at height
West façade in yard area	M5	Monday 3rd March 2008	12:18	00:32	62	65 (3rd floor)
Boad Street facade	M6	Monday 3rd March 2008	14:09	01:00	62	61 (9th floor)
Boad Street facade	M6	Monday 10th March 2008	09:02	00:30	62	62 (9th floor)
Railway station car park*	M7	Monday 10th March 2008	09:38	00:10	65	66 (3rd floor)
Store Street facade	M8	Monday 10th March 2008	08:58	00:02	67	65 (4th floor)

*free-field measurements in the railway station car park have been corrected to façade levels by adding 3dB

3.1.10 Comparison of L_{Aeq} measurements at ground level and those at different floor heights indicates an insignificant difference between the two noise levels at the majority of facades.

3.1.11 At Location M5, noise levels are noted to be 3 dB (A) less at ground floor level than those measured during the same time period on the 3rd floor. However, the ground floor measurements were taken in the yard area between Rail House and the railway station car park. The yard area is afforded some shielding because the car park lies at the same level as the second floor of the existing office block (in this location).

3.1.12 Relatively short measurements were undertaken at Location M8 due to interference from construction activities on the site of Piccadilly Tower.

3.1.13 Details of the frequency content of the measurements are available within Appendix C.

3.2 Vibration Monitoring Results

3.2.1 Measurements of existing vibration levels are summarised in Table 3.

Table 3: Vibration Monitoring Results Summary

	VDV $ms^{-1.75}$		
Time Period	**x-axis**	**y-axis**	**z-axis**
1 hour (measured)	0.006	0.025	0.025
16 hour (estimated*)	0.013	0.052	0.054
BS 6472 level relating to a 'low probability of adverse comment'	0.4	0.4	0.4
Impact (BS 6472)	< Low probability of adverse comment	< Low probability of adverse comment	< Low probability of adverse comment

*Based on 1 hour measurement

3.2.2 The results in Table 3 indicate vibration levels significantly lower than those at which there would be a 'low probability of adverse comment' from future building occupants.

4. SUMMARY

4.1 Noise

4.1.1 A survey of existing noise levels incident on Rail House has been undertaken over a week long period, at different heights and at each façade.

4.1.2 Daytime weekday noise levels over the monitoring period range from 61 to 66 dB L_{Aeq}.

4.1.3 During the design stage, the results of the noise survey can be employed by the contractor to inform of precise glazing and ventilation requirements, in order to satisfy internal noise targets.

4.1.4 Background (L_{A90}) noise levels measured on the Store Street façade can be employed during the design of any rooftop plant planned for Piccadilly Gate. The Local Authority should be consulted to establish their requirements in terms of what noise level (L_{Aeq}) from the plant would be considered acceptable in relation to the existing background noise level (L_{A90}) at the nearest noise sensitive properties, which (once completed) will be those in Piccadilly Tower.

4.2 Vibration

4.2.1 Vibration levels have been measured at Rail House and compared against the guidance in BS 6472.

4.2.2 Results indicate levels of vibration lower than those at which there may be a 'low probability of adverse comment' from future occupants of the offices in Piccadilly Gate.

Appendix A. NOISE AND VIBRATION TERMINOLOGY AND PERCEPTION

Noise

A.1 Between the quietest audible sound and the loudest tolerable sound there is a million to one ratio in sound pressure (measured in Pascals, Pa). Because of this wide range, a noise level scale based on logarithms is used in noise measurement called the decibel (dB) scale. Audibility of sound covers a range of approximately 0 to 140 dB. The human ear system does not respond uniformly to sound across the detectable frequency range and consequently instrumentation used to measure noise is weighted to represent the performance of the ear. This is known as the 'A weighting' and annotated as dB (A). Table lists the sound pressure level in dB (A) for common situations.

Table A.1: Noise Levels for Common Situations

Approximate Sound Pressure Levels dB(A)	Example
0	Threshold of hearing
30	Rural area at night
50	Quiet office, no machinery
80	General factory noise level
100	Pneumatic drill at 5m
140	Threshold of pain

A.2 The noise level at a measurement point is rarely steady, even in rural areas, and varies over a range dependent upon the effects of local noise sources. Close to a busy motorway, the noise level may vary over a range of 5 dB (A), whereas in a suburban area this variation may be up to 40 dB (A) and more due to the multitude of noise sources in such areas (cars, dogs, aircraft etc.) and their variable operation. Furthermore, the range of night-time noise levels will often be smaller and the levels significantly reduced compared to daytime levels. When considering environmental noise, it is necessary to consider how to quantify the existing noise (the ambient noise) to account for these second to second variations.

A.3 A parameter that is widely accepted as reflecting human perception of the ambient noise is the background noise level, L_{A90}. This is the noise level exceeded for 90 % of the measurement period and generally reflects the noise level in the lulls between individual noise events. Over a one hour period, the L_{A90} will be the noise level exceeded for 54 minutes.

A.4 The equivalent continuous A-weighted sound pressure level, L_{Aeq} is the single number that represents the total sound energy measured over that period. L_{Aeq} is the sound level of a notionally steady sound having the same energy as a fluctuating sound over a specified measurement period. It is commonly used to express the energy level from noise sources that vary in level over their operational cycle, or over specified time periods.

A.5 Most environmental noise measurements and assessments are undertaken as 'free-field', away from any existing reflecting surfaces (other than the ground). However, it is sometimes necessary to consider noise levels immediately external to a façade when considering the impact on occupants inside properties and this requires the addition of 3 dB(A) to the predicted (or measured) free-field level due to noise reflection from the façade.

Vibration

A.6 Ground vibrations may cause reactions ranging from 'just perceptible', through 'concern' to 'alarm' and 'discomfort'. The subjective response varies widely and is a function of situation, information, time of day and duration.

A.7 British Standard BS 6472: 1992 'Guide to evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz)' gives base curves of vibrations for minimal adverse comment, and also vibration dose values (VDVs) at which complaints are probable. VDVs may be used to assess the severity of impulsive and intermittent vibration, such as experienced from blasting at quarries or from rail traffic, and steady vibration such as from a busy road or fixed plant.

A.8 The adoption of the VDV parameter is based on social studies undertaken in the 1980s and early 1990s into human response to vibration. BS 6472 requires that the VDV be determined separate for the 16 hour daytime (07.00-23.00) and 8 hour night-time (23.00-07.00) periods.

A.9 The VDV is given by the fourth root of the integral of the fourth power of the acceleration after it has been frequency-weighted:

$$VDV = (\int_0^T a^4(t)dt)^{0.25}$$

where VDV is the vibration dose value (in $ms^{-1.75}$)
$a(t)$ is the frequency-weighted acceleration (ms^{-2})
T is the total period of the day (in seconds) during which vibration may occur

A.10 The basic procedure is to estimate, or measure, the frequency weighted root mean square (r.m.s.) acceleration levels, and to integrate the several components with respect to time over the day or night-time period so as to compute the VDV. The VDV is measured in each of the three whole-body orthogonal axes and the maximum from the three axes used. Where the vibration conditions are constant or regularly repeated throughout the day and

assessment is based on measured data, only one representative period need be measured, and the 16 hour daytime (or 8 hour night-time) overall VDV level may be calculated from the shortened measurement. The predicted or measured VDV may then be compared to data in the Appendix of BS 6472, reproduced below in Table 2, to identify the likelihood of complaint:

Table A.2: (from BS 6472: 1992) Vibration Dose Values ($ms^{-1.75}$) above which various degrees of adverse comment may be expected.

Place	Low probability of adverse comment	Adverse comment possible	Adverse comment probable
	VDV $ms^{-1.75}$		
Residential buildings (16h day)	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Residential buildings (8h night)	0.13	0.26	0.51
Office (16h day or 8h night)	0.4	0.8	1.6
Workshop (16h day or 8h night)	0.8	1.6	3.2

A.11 For example, at 0.8 $ms^{-1.75}$, adverse comment regarding daytime (or nighttime) vibration levels becomes possible for office property.

Appendix B. LONG-TERM NOISE MONITORING

Figure B.1: Long-term Noise Monitoring at Location M1

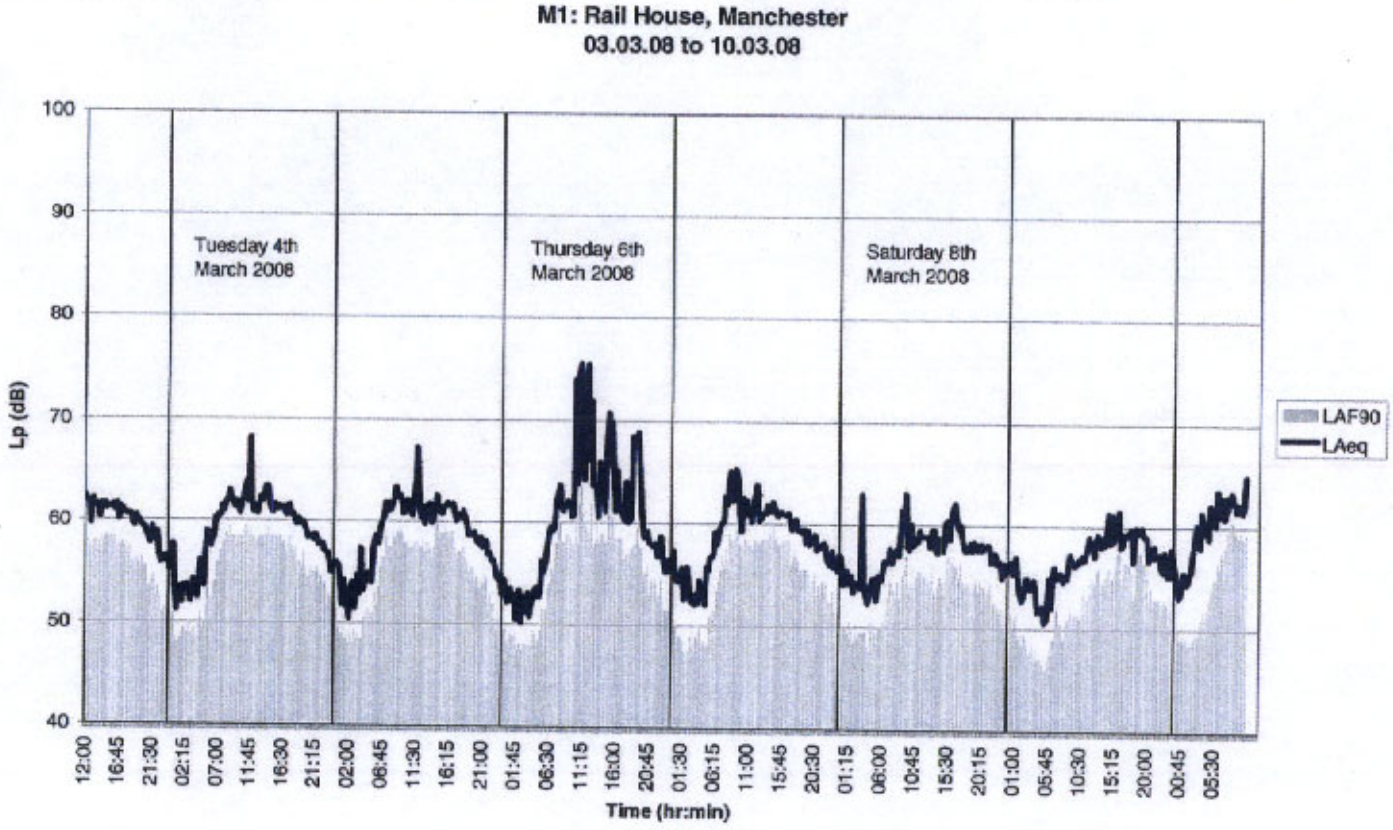


Figure B.2: Long-term Noise Monitoring at Location M2

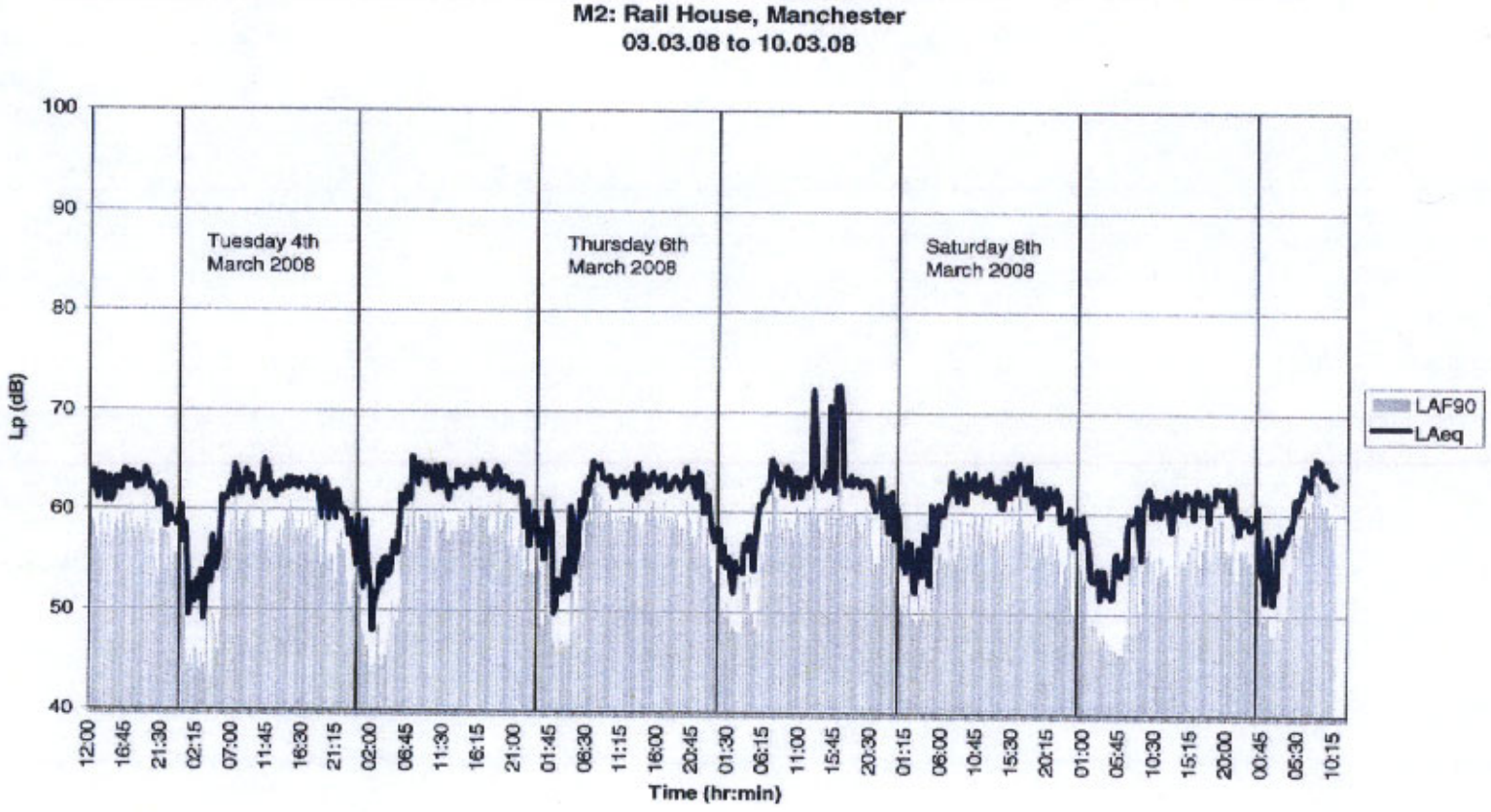


Figure B.3: Long-term Noise Monitoring at Location M3

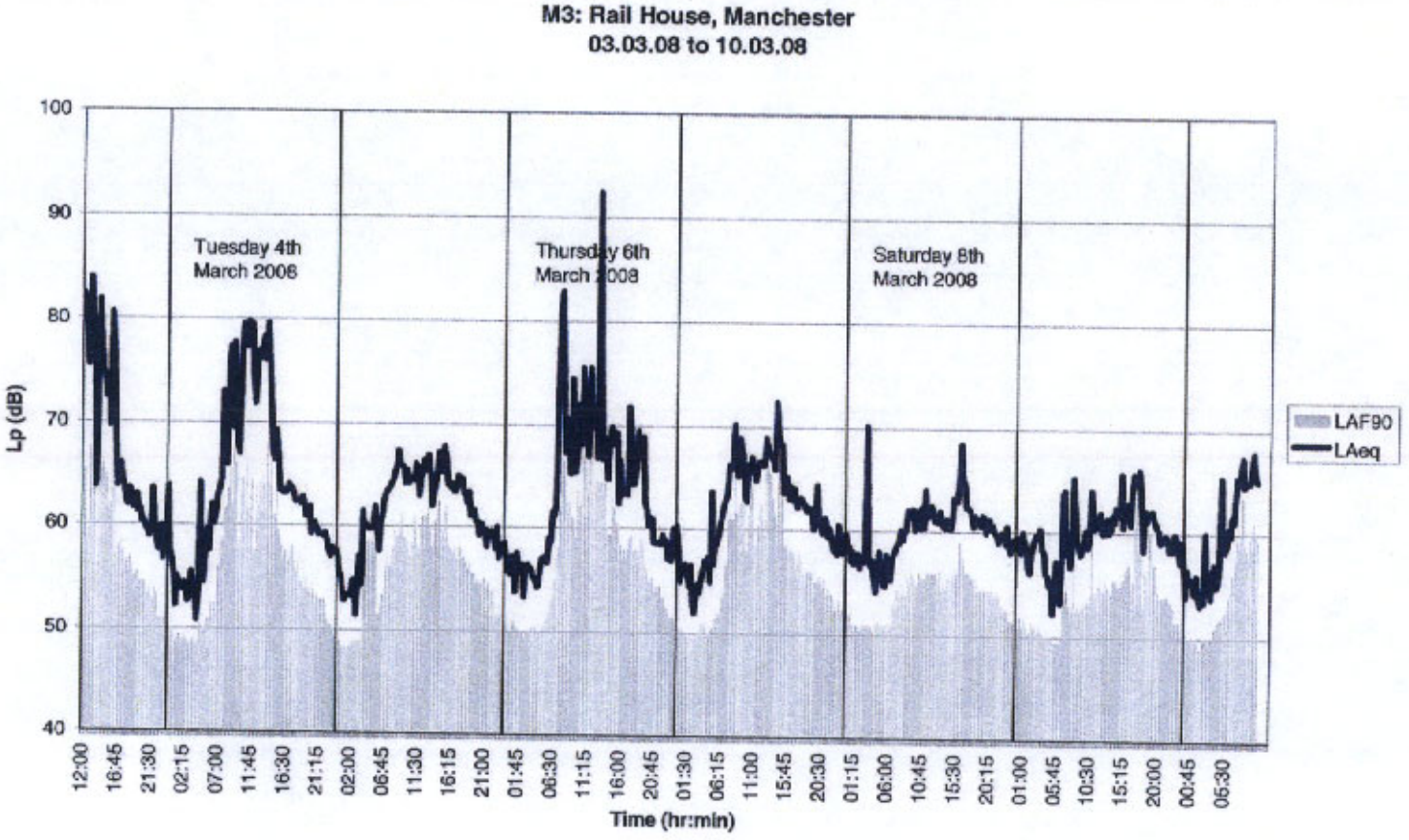
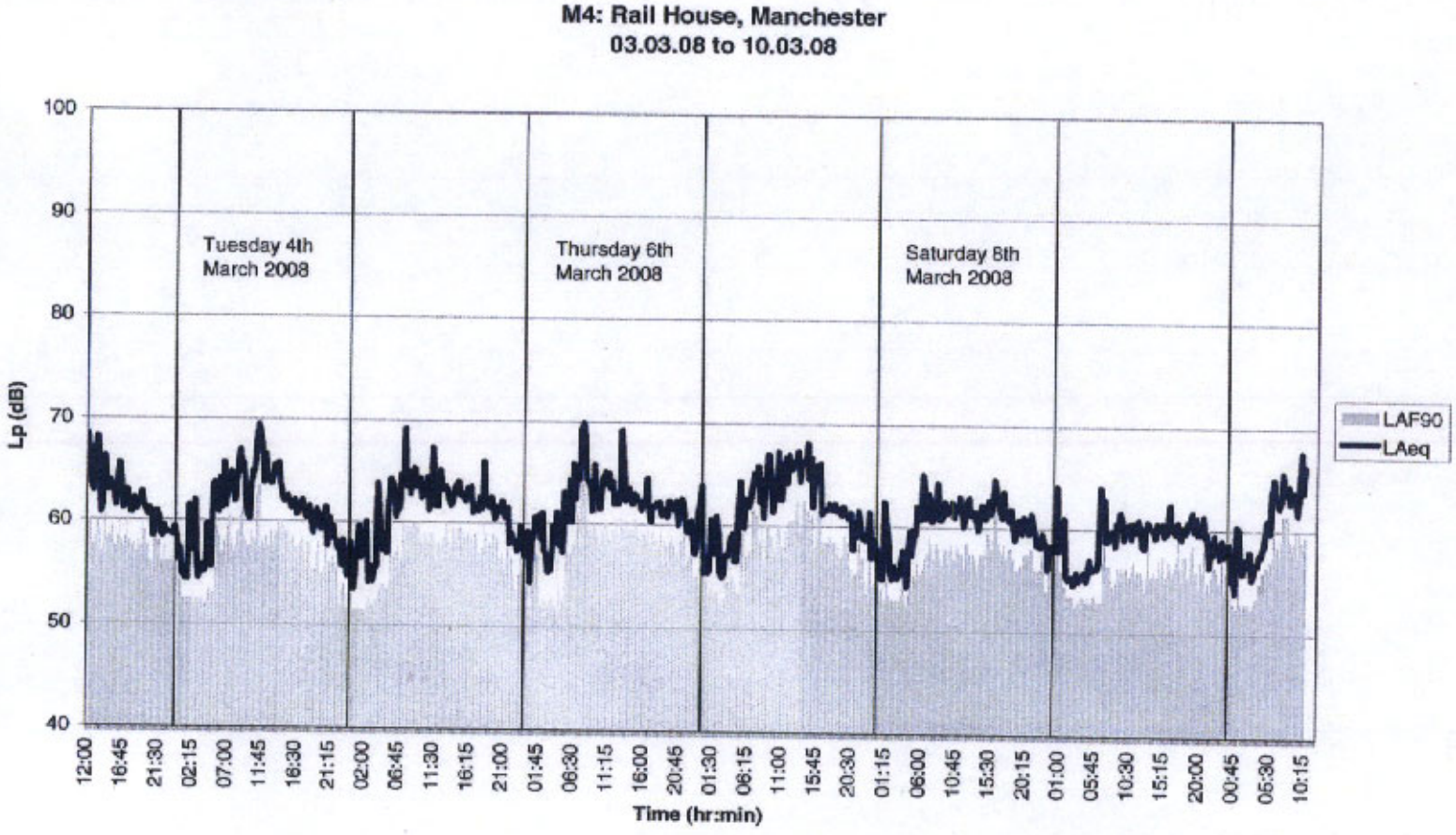


Figure B.4: Long-term Noise Monitoring at Location M4



Appendix C. SHORT-TERM (FREQUENCY) NOISE MONITORING

Table C.1: Octave Band Centre Frequency noise Measurements

Octave Band Centre Frequency (Hz)	Octave Band Sound Pressure Level (dB)									L_{Aeq} dB (A)
	31.5	63	125	250	500	1000	2000	4000	8000	
Boad Street facade	71.5	70.2	61.1	59.2	57.9	58.7	55.1	48.0	40.7	62
Store Street facade	72.3	72.4	64.9	62.7	61.5	62.9	60.1	52.5	45.7	67
Railway station car park facade	76.0	72.8	62.9	64.2	62.9	60.4	54.8	46.3	34.3	65

Figure C.1: Octave Band Measurements at the Boad Street Façade of Rail House

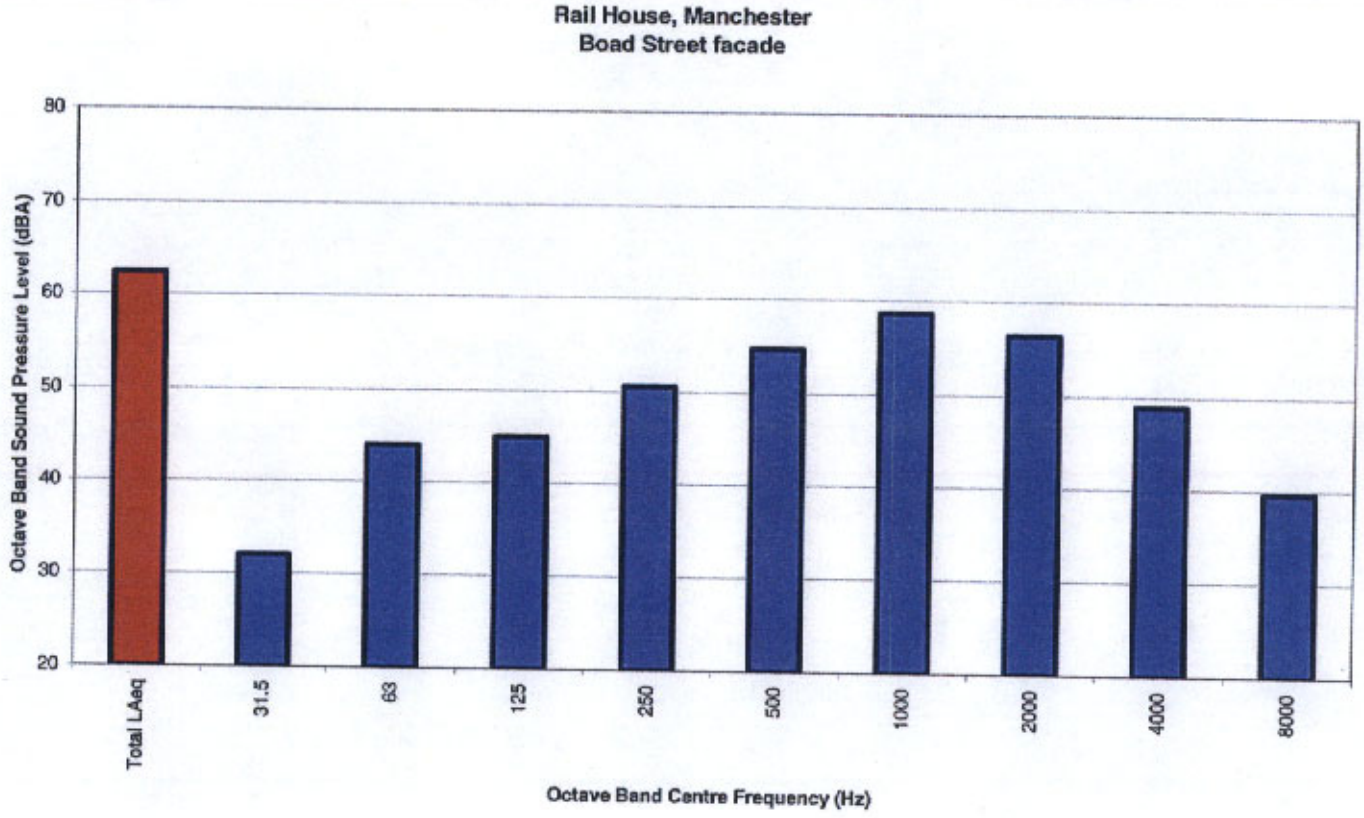


Figure C.2: Octave Band Measurements at the Store Street Façade of Rail House

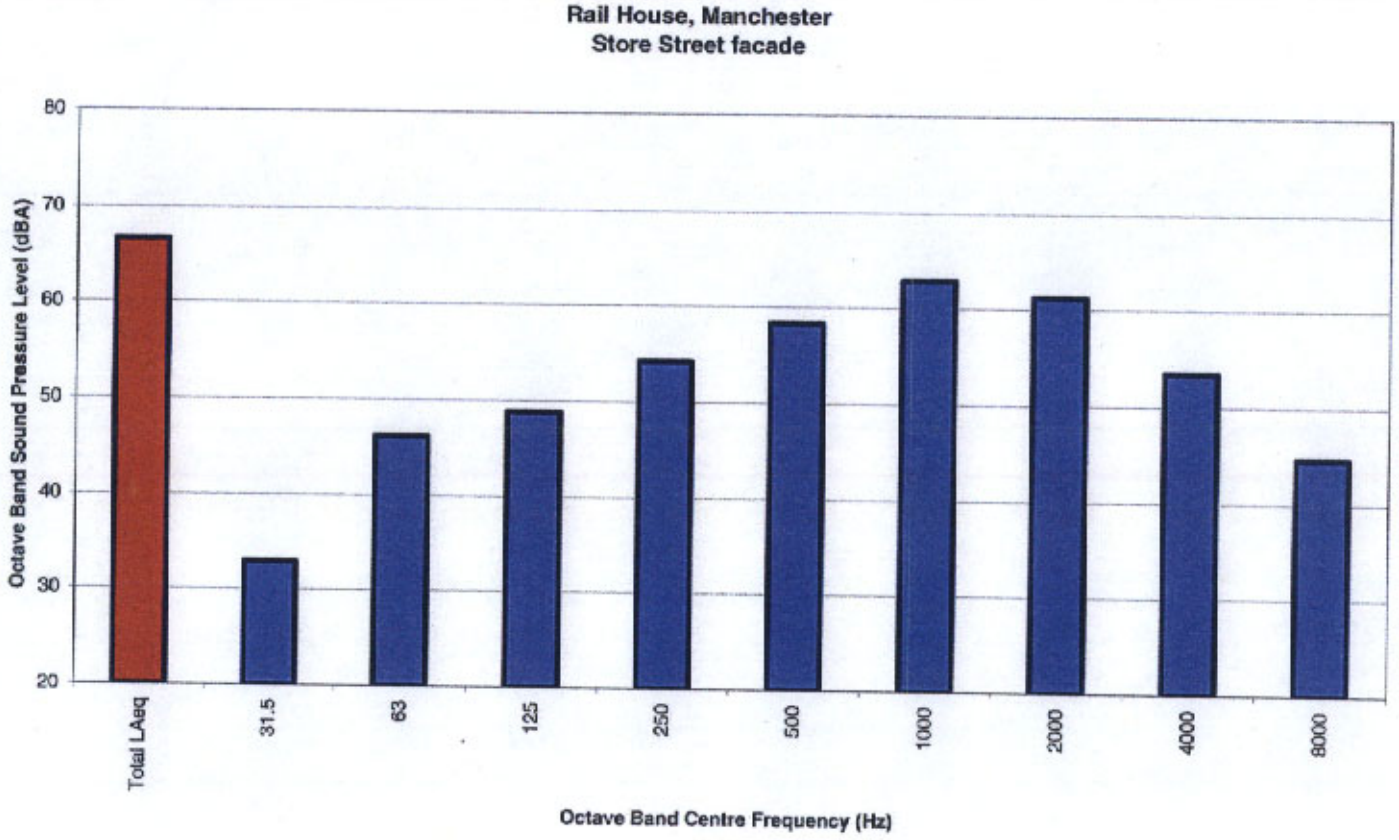


Figure C.3: Octave Band Measurements at the Railway Station Car Park Façade of Rail House

