59-61 Oak Grove
London NW2

TRAIN INDUCED VIBRATION
AND ASSESSMENT REPORT HT:19861/VAR1

For:

Pocket Living LLP
14 Floral Street
London
WC2E 9DH

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HANN TUCKER ASSOCIATES
Consultants in Acoustics
Noise and Vibration

Head Office
Duke House
1-2 Duke Street
WOKING
Surrey GU21 5BA

Tel : 01483 770595
Fax : 01483 729565

Northern Office
First Floor
346 Deansgate
MANCHESTER
M3 4LY

Tel : 0161 832 7041
Fax : 0161 832 8075

E-mail : enquiries@hanntucker.co.uk
www.hanntucker.co.uk

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Revision No.	Date	Description
1	27/01/2014	Minor alterations

1.0 INTRODUCTION

It is proposed to build a three storey including ground floor residential property on the site of 59-61 Oak Grove.

Hann Tucker Associates have therefore been commissioned to establish the current incident train induced vibrations and to subsequently use the results of the survey alongside the proposed construction details in order to predict the likely train induced vibration and re-radiated noise levels in the development.

2.0 OBJECTIVES

To establish, by means of site measurements, the magnitude and frequency distribution of ground borne vibration resulting from the movement of surface trains.

To present suitable train induced vibration and re-radiated noise criteria.

To assess the likely levels of vibration and re-radiated noise based on the results of the vibration survey and the proposed substructures and superstructures.

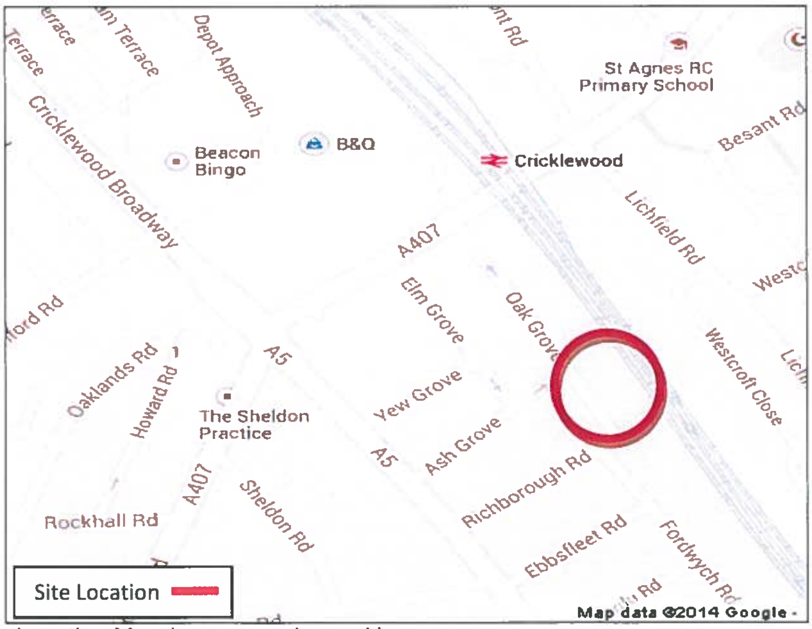
To recommend any potential amelioration measures if deemed necessary.

These objectives are as set out in Part 4 of our Outline Brief dated 10th December 2013 and written instructions received on 19th December 2013.

3.0 SITE DESCRIPTION

3.1 Location

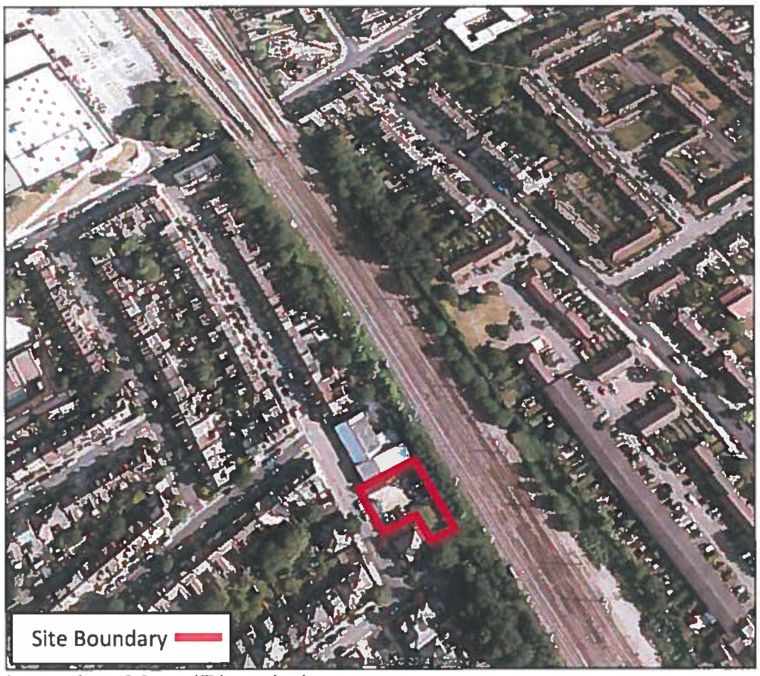
59-61 Oak Grove is within the administrative boundary of Camden. The dominant land use in the local vicinity is residential, however, there is some commercial. See Map below.



Location Map (maps.google.co.uk)

3.2 Description

The current site is waste ground predominantly made up of hardstanding with an automotive garage located to the north the railway lines to the east. Cricklewood station is approximately 200 metres to the north of the site and is served by the Thameslink route with additional trains running on the Midland Main Line through the station on a non-stop service. At Cricklewood railway station there are six railway lines which carry passenger trains only. The train lines run approximately north to south and are managed by First Capital Connect. At peak times, approximately ten trains will pass through Cricklewood station per hour whilst off peak this drops to around four. The railway lines are raised above ground level at a height of approximately 5 metres and noise from the trains on these lines is the dominant source in the area.



Location Map (Bluesky)

The superstructure is currently proposed to be loadbearing masonry with precast floors on top of piled foundations with reinforced concrete ground beams.

4.0 VIBRATION SURVEY

4.1 Instrumentation

The following instrumentation was used for the survey and subsequent analysis:

2No. Dytran Accelerometers
01dB – Symphonie PCMCIA Hardware Interface
01dB – dBTrig V4.704 Vibration Acquisition Software
01dB – dBTrait V4.704 Vibration Analysis Software
Microsoft Windows Based Laptop Computer

The 01dB hardware and software connects to two accelerometers via a PCMCIA dual channel unit. The system can record data in 'real-time' to a computer allowing simultaneous analysis in both the time and frequency domains.

The equipment was calibrated prior to the survey using a Bruel and Kjaer vibration calibrator Model #4294.

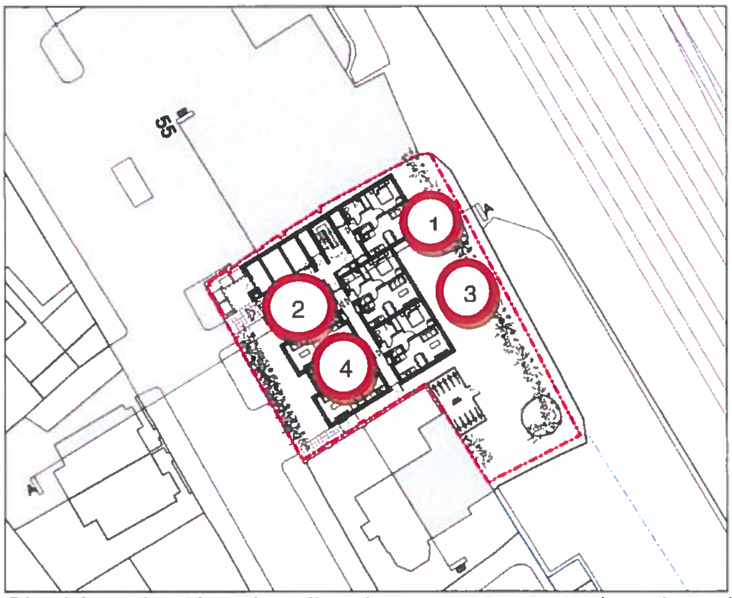
4.2 Procedure

A vibration survey was undertaken on 3rd January 2014 between approximately 13:00 hours and 15:00 hours.

Vibration measurements were undertaken in order to establish the prevailing vibration levels due to train movements.

The measurement positions are described in the table and shown on the site map below.

Position	Description
1	The accelerometer was positioned upon a heavy block adjacent to the eastern façade of the property, approximately 15 horizontal metres from the first railway line and 8 metres from the northern boundary.
2	The accelerometer was positioned upon a heavy block adjacent to the western façade of the property, approximately 34 horizontal metres from the first railway line and 8 metres from the northern boundary.
3	The accelerometer was positioned upon a heavy block adjacent to the eastern façade of the property, approximately 15 horizontal metres from the first railway line and 13 metres from the northern boundary.
4	The accelerometer was positioned upon a heavy block adjacent to the western façade of the property, approximately 34 horizontal metres from the first railway line and 13 metres from the northern boundary.



Site Map showing the vibration measurement locations (courtesy of HTA)

5.0 SURVEY RESULTS

Typical measured vibration levels for the different lines, directions, and number of train pass-bys from the measurement positions are presented on Graph 19861/G1 enclosed.

6.0 CRITERIA

6.1 Vibration

6.1.1 British Standard

British Standard BS 6472: 2008 "*Guide to Evaluation of Human Exposure to Vibration in Buildings*" advises that intermittent vibration events should not be judged based on perception alone but using the corresponding vibration dose value over a long period.

BS6472:2008 advises that "the VDV defines a relationship that yields a consistent assessment of continuous, intermittent, occasional and impulsive vibration and correlates well with subjective response" and also "the VDV is much more strongly influenced by vibration magnitude than by duration. A doubling of halving of the vibration magnitude is equivalent to an increase or decrease of exposure duration by a factor of sixteen."

The table below details the Vibration Dose Values ($m/s^{1.75}$) above which various degrees of adverse comment may be expected in Residential Buildings.

Time Period	Low probability of adverse comment	Adverse comment possible	Adverse comment probable
Daytime (07:00–23:00)	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Night-time(23:00–07:00)	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8

Please refer to Appendix A for an explanation of the vibration terminology used in this report.

6.1.2 Local Authority

We understand that Camden council noise and vibration standards with regards to planning applications states the following:

"Sites Which May Be Affected By Vibration. To protect residents from unacceptable vibration as a result of new development, particularly those which result in dwellings being situated adjacent to major roads and railways, the following internal Vibration Dose Values (VDV) should not be exceeded (taken from BS 6472:1992):

Place	*Vibration Levels (VDV ms-1.75)*
Critical area (e.g. hospital operating theatre)	*0.1*
Residential (day)	*0.2 to 0.4*
Residential (night)	*0.13*
Office	*0.4*
Workshops	*0.8*

If it is predicted that these levels will be exceeded, the developer should introduce measures to reduce levels to within these standards at the design stage."

6.2 Re-Radiated Noise

6.2.1 Local Authority

Currently no British Standards exist which recommend a method by which to assess intermittent ground-borne or structure-borne noise, such as that induced by trains.

We understand that Camden council noise and vibration standards with regards to planning applications states the following:

Where dwellings may be affected by ground-borne regenerated noise internally from, for example, railways or underground trains within tunnels, noise levels within the rooms should not be greater than 35dB(A)max."

This equates to train movement being audible during periods of low background noise but not to an extent likely to cause significant adverse comments.

Please refer to Appendix B for an explanation of the acoustic terminology used in this report.

6.2.2 Hann Tucker Associates Approach

Re-radiated noise is of greatest concern when it is the dominant noise, and also when the source cannot be seen, as in the case of trains in a tunnel. Criteria for re-radiated noise are, therefore, generally intended to apply to sources such as underground trains.

It is generally accepted, however, that people are more tolerant of noise from sources which can also be seen. Furthermore, where sources are visible, airborne noise intrusion through the façade in most cases masks the ground-borne noise which is re-radiated simultaneously.

Where bedroom façades are likely to be exposed to relatively high levels of train airborne noise, it could be considered reasonable to apply the same criteria for both re-radiated and airborne noise. For airborne noise intrusion, higher noise levels are generally considered acceptable, of around 45dBA L_{Amax} in the case of residential buildings - corresponding to a low probability of sleep disturbance according to the general consensus of research into this field.

In the absence of any Local Authority criteria, Hann Tucker Associates would often suggest the following criteria for re-radiated ground-borne on this type of site, where half of the site is exposed to airborne noise directly from passing trains:

Groundborne Noise Level, L_{Amax}'s dB	Impact Classification	Likely Effect	Typical Examples (Residential)
35-39	'LOW'	Probably audible during quiet periods but not considered to be cause for complaint	Ground floor room 20-70m from London Underground (LUL) tunnel, depending on depth and ground type.
40-44	'MEDIUM'	Probably audible at all times. Possible cause for complaint.	Ground floor room, 10-40m from LUL tunnel, depending on depth and ground type.
45-49	'HIGH'	Will be clearly audible probably leading to annoyance and complaint.	Rooms directly above shallow tunnels with poor quality jointed track.
>49	'VERY HIGH'	As above, complaints likely.	

7.0 TRAIN MOVEMENTS

The following table presents our estimates of the number of train passes for daytime (07:00 hours to 23:00 hours) and night-time (23:00 hours to 07:00 hours) periods. These predictions are based upon National Rail timetables, discussions with staff members at Cricklewood station, observations made during our survey and sources on the Internet.

	Daytime (07:00 – 23:00)	Night-Time (23:00 – 07:00)
Number of Trains	160	30

Note: The Vibration Dose Value parameter is mainly dictated by the magnitude of the individual train pass bys, and is relatively insensitive to the number of train events.

8.0 BUILDING RESPONSE

The building development superstructure will modify the surveyed vibration levels, superstructures often amplifying foundation vibration levels. Our analyses assumes the following:

(i) Empirically researched floor amplification factors as given within *"A Prediction for Rail Transportation Ground-borne Noise and Vibration"* (Ref 1) and *"Handbook for Urban Noise and Vibration Control"* (Ref 2).

(ii) The maximum recorded vibration levels for different train pass-bys shall be used.

(iii) The superstructure is currently proposed to be loadbearing masonry with precast floors.

(iv) Piled foundations with reinforced concrete ground beams are currently proposed.

9.0 PREDICTED LEVELS OF VIBRATION AND RE-RADIATED NOISE

9.1 Vibration Levels

Based on the maximum recorded vibration levels, we have calculated the predicted vibration levels within the proposed development at the worst affected noise sensitive floor. Using estimated train movement frequency, detailed in Section 7.0 and our predicted vibration levels (as shown in Graphs 19861/PV1 to 19861PV3), the following worst case e.V.D.V.'s have been calculated.

Period	Location	e.V.D.V. ($m/s^{1.75}$)
Daytime (07:00 – 23:00)	Position 1	0.18
Night-Time (23:00 – 07:00)		0.12
Daytime (07:00 – 23:00)	Position 2	0.13
Night-Time (23:00 – 07:00)		0.09
Daytime (07:00 – 23:00)	Position 3	0.26
Night-Time (23:00 – 07:00)		0.17
Daytime (07:00 – 23:00)	Position 4	0.17
Night-Time (23:00 – 07:00)		0.11

Please note these predicted vibration levels are approximate.

9.2 Re-radiated Noise Levels

Based on the maximum recorded vibration levels we have calculated the predicted re-radiated noise levels within the proposed development at the worst affected noise sensitive floor. Noise levels will decay slightly with height. A conservative estimate is to subtract 1dB per floor.

Our analysis indicates the following re-radiated (L_{smax}) noise levels, based on the predicted vibration levels for medium building amplification factors, the worst-case train pass-bys and the proposed substructure and superstructure constructions.

Location	Level (dB L_{smax})
Position 1	39
Position 2	32
Position 3	41
Position 4	36

Please note these predicted re-radiated noise levels are approximate.

10.0 DISCUSSION OF RESULTS

10.1 Surveyed

The magnitude of the vibration of different train pass-bys varied. We believe that this is mainly due to the train movements being in different directions and on different tracks. Other factors include speed and weight of trains as well as the condition of the rolling stock (i.e. rough wheels).

Whilst train movement was audible it was not subjectively noticeable as ground-borne vibrations during our survey.

10.2 Predicted

The predicted estimated Vibration Dose Values detailed in Section 9.1 are likely to be within the range required for a "low probability of adverse comment" and are, therefore, below Camden's limit of $0.4m/s^{1.75}$ for V.D.V.

For Positions 1 and 3, which directly face the railway lines, the measured worst-case levels of re-radiated noise detailed in Section 9.2 are likely to exceed the 35dBA(L_{smax}) criteria detailed in Section 6.2.1.

Our predictions for Positions 1 and 3 indicate that worst-case levels of around 39-41 dBA(L_{smax}) are likely. We would, therefore, suggest that there could be a low-medium impact on the residential premises that directly face the railway tracks.

It could be considered reasonable, however, to apply the same criteria for both re-radiated and airborne noise. For airborne noise intrusion, higher noise levels are generally considered acceptable, of around 45dBA L_{Amax} in the case of residential buildings - corresponding to a low probability of sleep disturbance according to the general consensus of research into this field.

It is also generally accepted that people are more tolerant of noise from sources which can also be seen. Furthermore, where sources are visible, airborne noise intrusion through the façade in most cases masks the ground-borne noise which is re-radiated simultaneously.

For Positions 2 and 4, which do not face the railway lines, the measured worst-case levels of re-radiated noise detailed in Section 9.2 are around 32-36 dBA(L_{smax}) and likely to occasionally exceed the 35dBA(L_{smax}) criteria detailed in Section 6.2 at position 4 only.

Our predictions for this position indicate that worst-case levels of around 36 dBA(L_{smax}) are likely. We would, therefore, suggest that there would be a low impact on these residential premises resulting in train pass-by's probably being audible during quiet periods of background noise but not considered to be cause for complaint.

11.0 RECOMMENDATIONS

Having modelled various construction types and building foundation configurations, we conclude that the London Borough of Camden's internal re-radiated noise limit of 35db(A)$_{Lmax}$ is unlikely to be met without the use of building isolation.

Since the site is situated close to railway tracks, levels of airborne noise are likely to mask those created through ground-borne vibrations. Having modelled these vibrations, we predict that they are likely to cause a low-medium impact on residential properties proposed within the development.

We would, therefore, recommend that further discussions be held with the London Borough of Camden regarding their criteria on this matter as gains made through building isolation would be minimal.

12.0 CONCLUSIONS

Owing to the proposed new development at 59-61 Oak Grove, NW2 and its proximity to railway lines, a vibration survey has been undertaken to establish the existing levels of train induced vibration.

The survey results have subsequently been used to predict the likely levels of train induced noise and vibration, based upon our understanding of the proposed scheme.

The results of our assessment indicate that train induced vibration dose values should be below the London Borough of Camden's criteria and should be therefore deemed acceptable.

The predicted levels of ground-borne re-radiated noise at this site are in excess of Camden's criteria at points within the buildings most sensitive areas. These levels, however, are likely to be masked by airborne noise generated by passing trains.

We have, therefore, recommended that any improvements made by isolating the building would be minimal whereby possibly only benefitting half of the development. Further discussion with the London Borough of Camden regarding ground-borne noise, therefore, should be sought.

Generally, we would recommend that measures are taken to minimise amplification of vibration levels by the use of heavy, stiff constructions. We would advise against the use of lightweight wide span constructions as these are inherently prone to significant vibration amplification.

Prepared by
Richard P Booth
Assistant Consultant
HANN TUCKER ASSOCIATES

Checked by
John Ridpath
Director
HANN TUCKER ASSOCIATES

REFERENCES

(1) "A Prediction Procedure for Rail Transportation Ground-borne Noise and Vibration"
James Turner Nelson and High Saurenman
Transportation Research Record 1143.

(2) "Handbook of Urban Rail Noise and Vibration Control" Saurenman, Nelson, Wilson
US Department of Commerce
National Technical Information Services – February 1982.

(3) "Measurement and Assessment of Groundborne Noise and Vibration", The Association of Noise Consultants. ISBN 0-9539516-1-8

APPENDIX A

VIBRATION TERMINOLOGY

Vibration Units

The vibratory motion of a surface can be described by either:

(a) displacement (m),

(b) velocity (m/s), or

(c) acceleration (m/s^2).

Furthermore the vibration magnitude can be quantified in several ways:

peak to peak	:	This value gives the <u>total</u> excursion of the oscillation about the zero datum. The unit is often used where the vibratory displacement of a component is critical for maximum stress or mechanical clearance calculations.
peak	:	This value gives the maximum excursion of the oscillation above or below the zero datum. This value is useful for indicating the level of short duration shocks.
r.m.s	:	This value gives the root mean square of the time history over a specific time interval (time constant). This value is useful for indicating the energy content of the vibration.
dB	:	Decibel quantities are often encountered. A reference level of 10^{-6} m/s^2 r.m.s is typically used for acceleration.

<u>Vibration Dose Value</u> (V.D.V) ($m/s^{1.75}$)

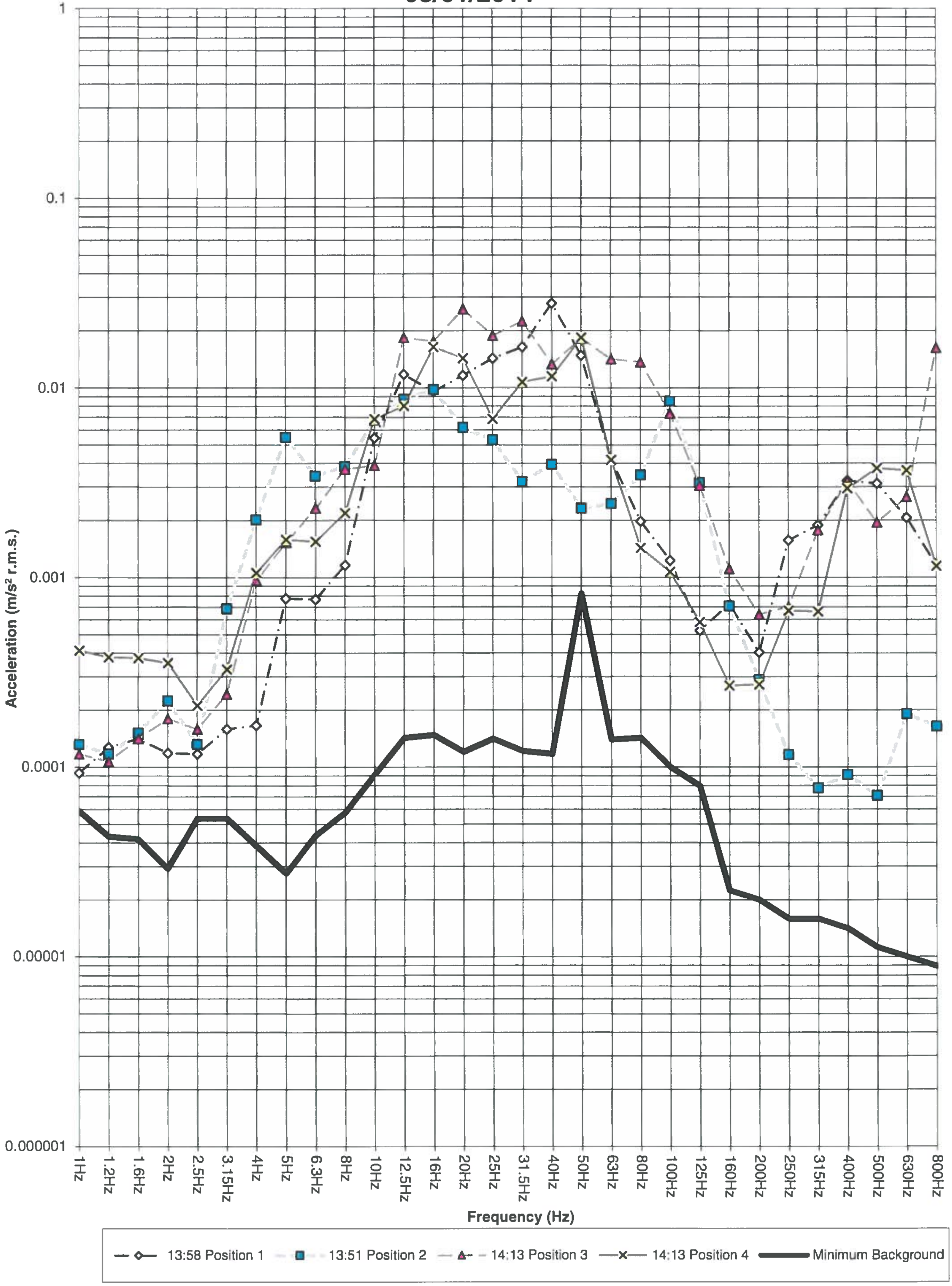
This value assesses both the magnitude of vibration and its duration. Where possible the vibration dose value should be determined over the full exposure to vibration. It is often estimated from the frequency weighted r.m.s value of the acceleration and its duration and is then referred to as e.V.D.V.

APPENDIX B

NOISE TERMINOLOGY

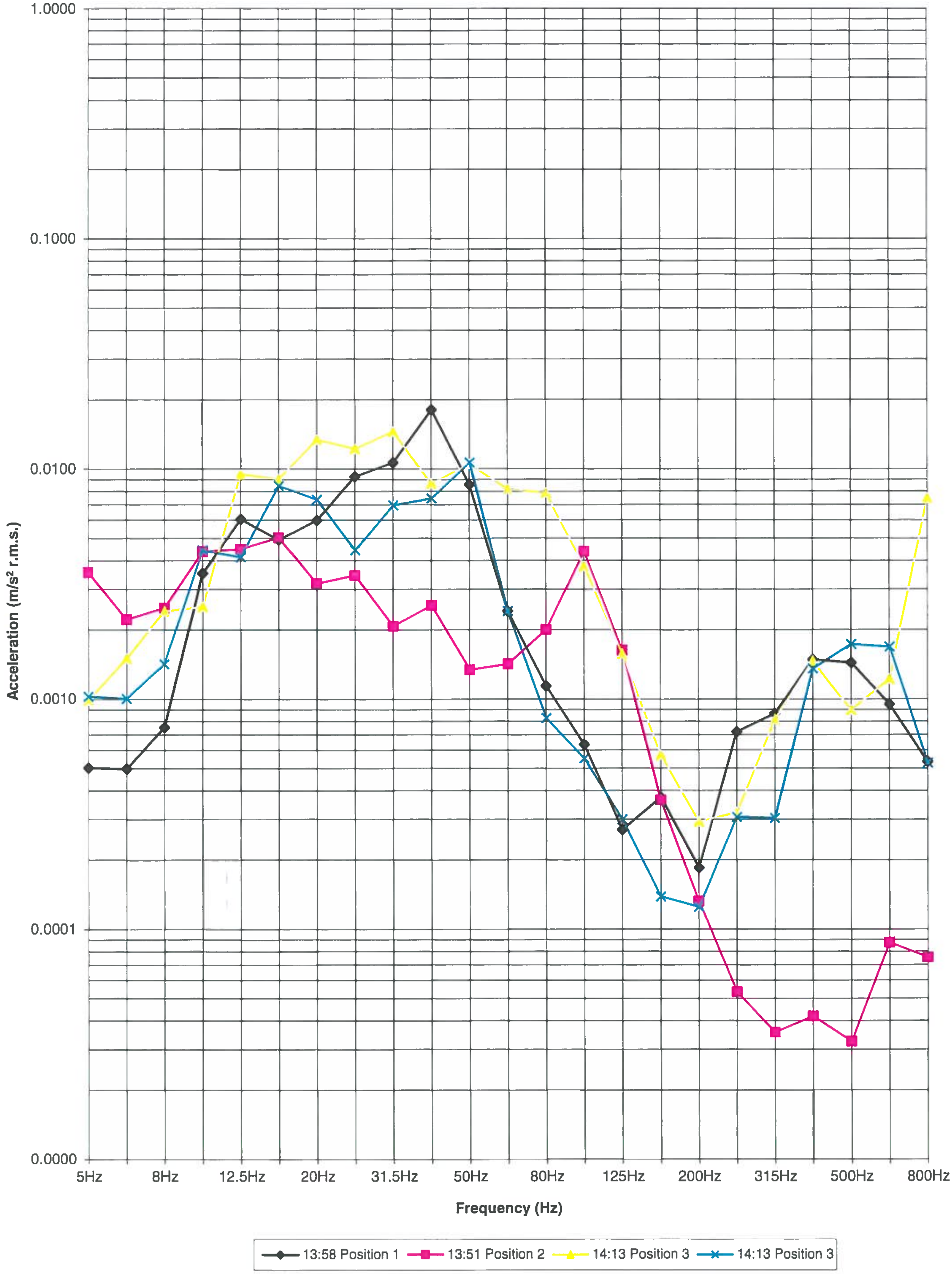
dB	:	Decibel - Used as a measurement of sound pressure level. It is the logarithmic ratio of the noise being assessed to a standard reference level.
dBA	:	The human ear is more susceptible to mid-frequency noise than the high and low frequencies. To take account of this when measuring noise, the 'A' weighting scale is used so that the measured noise corresponds roughly to the overall level of noise that is discerned by the average human. It is also possible to calculate the 'A' weighted noise level by applying certain corrections to an un-weighted spectrum. The measured or calculated 'A' weighted noise level is known as the dBA level. Because of being a logarithmic scale noise levels in dBA do not have a linear relationship to each other. For similar noises, a change in noise level of 10dBA represents a doubling or halving of subjective loudness. A change of 3dBA is just perceptible.
L_{max}	:	L_{max} is the maximum sound pressure level recorded over the period stated. L_{max} is sometimes used in assessing environmental noise where occasional loud noises occur, which may have little effect on the L_{eq} noise level.
L_{smax}	:	L_{smax} is the maximum sound pressure level recorded over the period stated where the meter has a slow response (1 second) as opposed to a fast response which is usually set to 0.125 seconds.

59-61 Oak Grove, NW2
Maximum Train Pass-by Bivration Measurements
03/01/2014

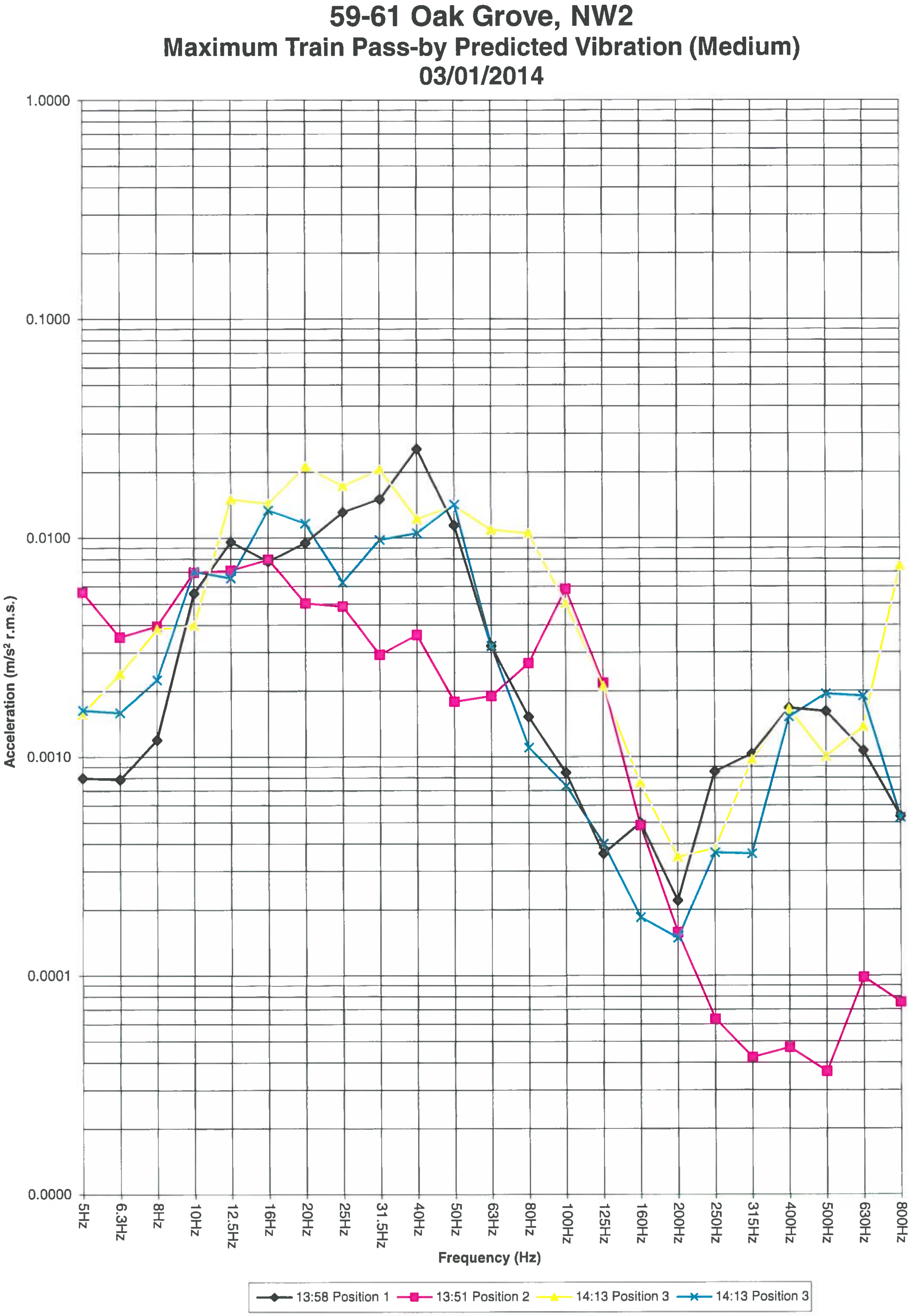


HT19861/G1

59-61 Oak Grove, NW2
Maximum Train Pass-by Predicted Vibration (Low)
03/01/2014

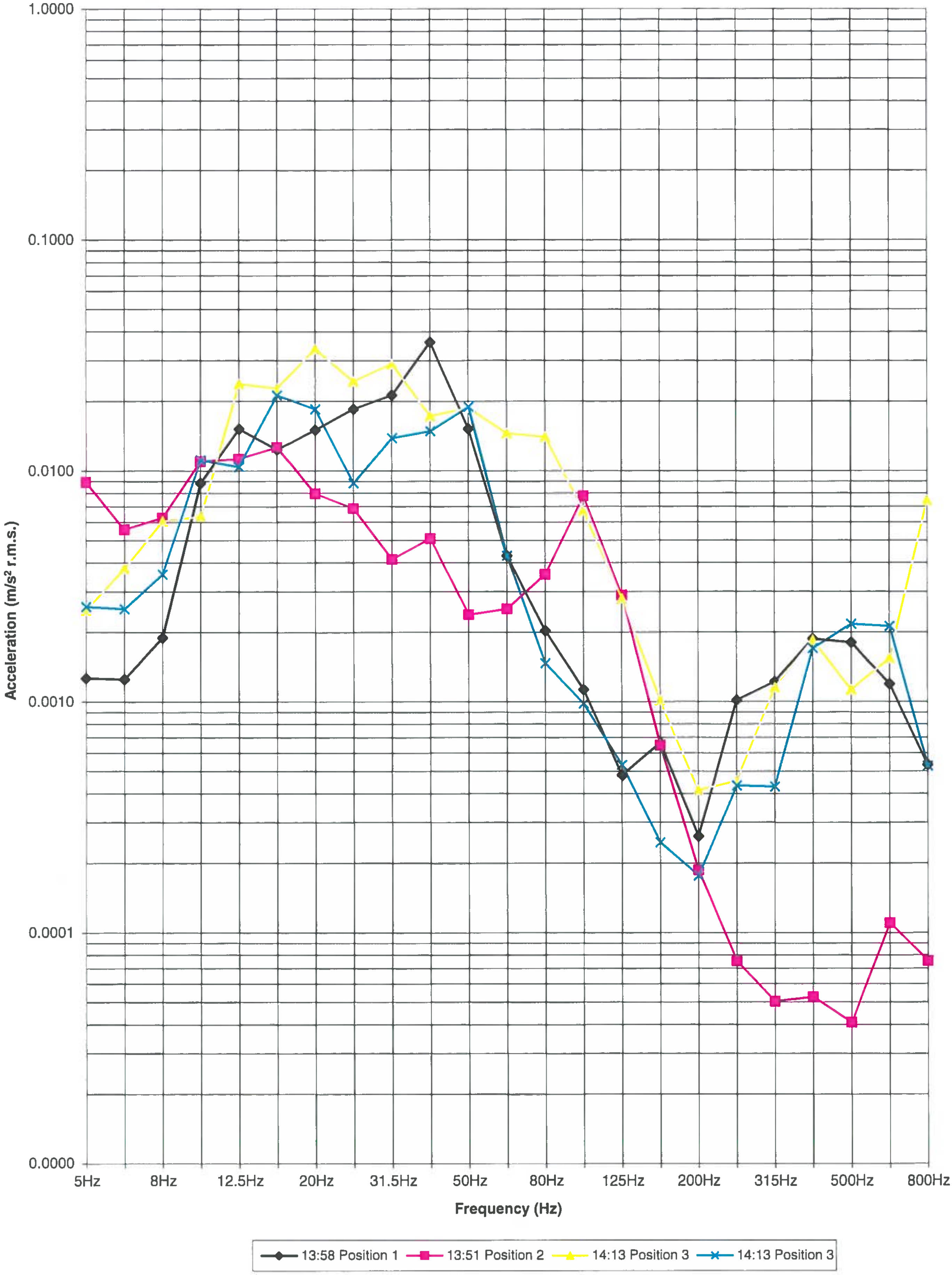


HT19861/PV1


59-61 Oak Grove, NW2
Maximum Train Pass-by Predicted Vibration (Medium)
03/01/2014
1.0000
0.1000
0.0100
0.0010
0.0001
0.0000
Acceleration (m/s² r.m.s.)
5Hz
6.3Hz
8Hz
10Hz
12.5Hz
16Hz
20Hz
25Hz
31.5Hz
40Hz
50Hz
63Hz
80Hz
100Hz
125Hz
160Hz
200Hz
250Hz
315Hz
400Hz
500Hz
630Hz
800Hz
Frequency (Hz)
13:58 Position 1
13:51 Position 2
14:13 Position 3
14:13 Position 3

HT19861/PV2

59-61 Oak Grove, NW2
Maximum Train Pass-by Predicted Vibration (High)
03/01/2014



HT19861/PV3