HUNTER DEVELOPMENT CORPORATION

HDC MAYFIELD SITE

Rail-Related Vibration Assessment

Report No. 29N-09-0003-TRP-2755046-0

Vipac Engineers & Scientists Ltd

Newcastle, NSW

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EXECUTIVE SUMMARY

This report provides the results, findings and recommendations arising from a revised vibration assessment of rail activities carried out within the boundaries of the former BHP Steel Closure Area at Mayfield, NSW. The assessment is in relation to a rail line associated with the development consent for Development Application No. DA 293-08-00 (File No. S99/00601) issued by the Minister for Planning on 6th April 2001, for a Multi-Purpose Terminal (MPT) and associated facilities.

The Hunter Development Corporation (HDC) are responsible for site remediation and key infrastructure provisions, including relocation of the existing rail line and remediation of the site. This revised assessment follows the State Government's decision to modify the rail alignment, in response to a request of the Newcastle Port Corporation (NPC), the entity responsible for management of the port lands within the MPT. HDC have therefore conducted these investigations to satisfy NPC's requests

The purpose of this assessment was to assess impact of rail-related ground vibration on off-site adjacent residences and also provide guidance on setbacks and design of future buildings located within the site, in terms of:

- Occupants discomfort; and
- Structural damage.

A number of options have been explored and it is our understanding that the preferred approach is as follows:

- Remove the existing One-Steel rail connection;
- Construct a new line on a revised alignment connecting the ARTC network to One-Steel and also service the proposed MPT.

This assessment highlights the following:

- Current rail-related vibration levels at 5-metres from the rail track centreline are well below the relevant criteria for structural damage and human perception;
- Whilst vibration levels on site are relatively low, calculations indicated that the future daily number of train movements might trigger adverse comments in occupants of buildings located within 5-metres from the track. Further calculations indicate that the minimum distance to the track should be 6-metres for workshop/industrial buildings and 15-metres for office/commercial buildings;
- Calculations show that the minimum distance to the track should be 52-metres for residential housing. As the closest resident is in excess of 400-metres, the potential for current and future structural damage and human perception for nearby residences is negligible;
- The low vibration levels are essentially due to the train's speed not exceeding 10-15km/h. This is certainly the most cost-effective measure to ensure the site is not adversely affected by train movements from a ground vibration point of view;
- Based on a 10-15km/h-train speed, the site is suitable for the construction of office, commercial and industrial buildings subject to the distance restrictions outlined above. Critical working areas, such as precision laboratories, should be located as far as possible from the rail corridor;
- It should also be noted that vibration could be amplified in the upper floors of multi-storey buildings. This issue should be considered at design stage if such a building was to be constructed close to the rail line.
- No significant off-site impacts in relation to vibration are anticipated as a result of the rail relocation, subject to conditions noted above.

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1. INTRODUCTION

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- Occupants discomfort; and
- Structural damage.

A number of options have been explored and it is our understanding that the preferred approach is as follows:

- Remove the existing One-Steel rail connection;
- Construct a new line on a revised alignment connecting the ARTC network to One-Steel and also service the proposed MPT.

The proposed rail alignment is illustrated in **Figure 1**, It was determined that the closest resident to the proposed rail network is in excess of 400m.

Figure 1: BHP Alternative Rail Design (WorleyParsons)

Vibration levels from train using the proposed rail line are subject to the Consent Condition outlined below:

5.13 Prior to construction of the railway linking the MPT to the Morandoo sidings inroad, the Applicant shall prepare a vibration assessment report identifying the predicted impacts of rail related vibration as a result of the development. The assessment report shall be prepared in consultation with the Rail Infrastructure Corporation and be submitted for the approval of the Director-General. The Report shall include measurements of predicted vibration associated with the new rail line connecting the MPT and identify mitigation measures to be incorporated into the detailed design of the rail line.

This study is substantially carried out under the requirements of Rail Infrastructure Corporation (RIC) *Consideration of Rail Noise and Vibration in the Planning Process* Interim Guidelines for Applicants.

2. VIBRATION CRITERIA

2.1 HUMAN PERCEPTION

As outlined in the RIC guidelines, floor vibration levels in habitable rooms should comply with the criteria in British Standard BS 6472:1992 *Evaluation of Human Exposure to Vibration in Buildings (1Hz to 80Hz).* This is the vibration standard recommended by Department of Planning (DoP) and Department of Environment and Climate Change (DECC).

BS 6472 provides general guidance on human exposure to building vibration in the frequency range 1Hz to 80Hz. The standard defines curves of equal annoyance for humans for various types of building occupancy. **Figure 2, Figure 3** and **Table 1** detail BS 6472 criteria curves.

In addition to the above, BS 6472 introduces the concept of Vibration Dose Value (VDV), which addresses people response to the frequency of train movements. The VDV depends on acceleration levels and exposure time (relative to the number of train pass-by), and relate the severity of intermittent vibration to that for continuous vibration. **Table 2** outlines acceptable VDV values for various types of buildings, based on 16-hour days and 8-hour nights.

Figure 2: - x-axis and y-axis criteria curves (BS 6472)

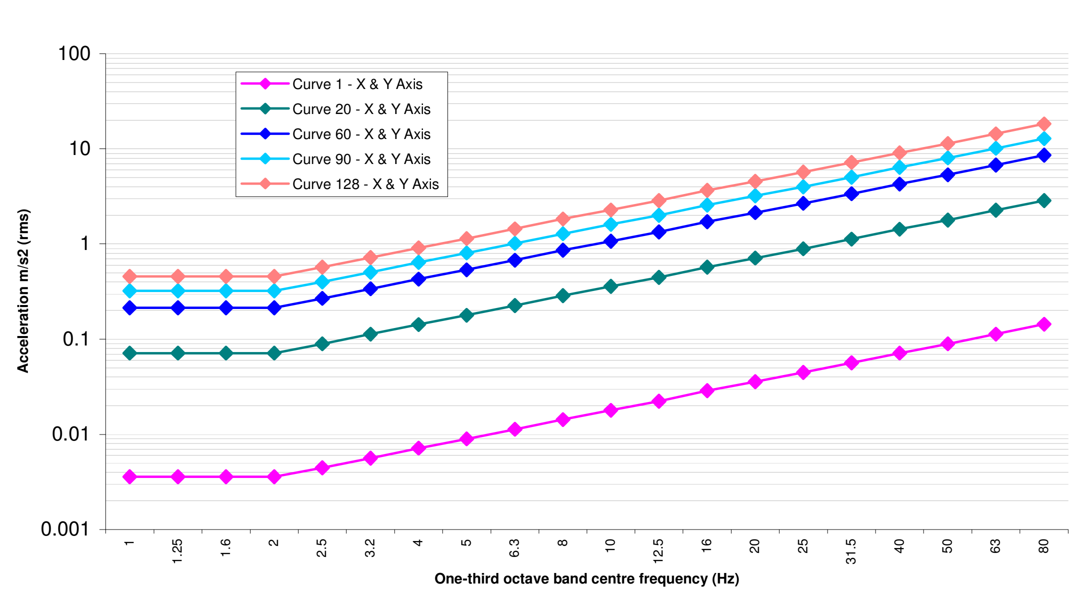


Figure 3: - z-axis criteria curves (BS 6472)

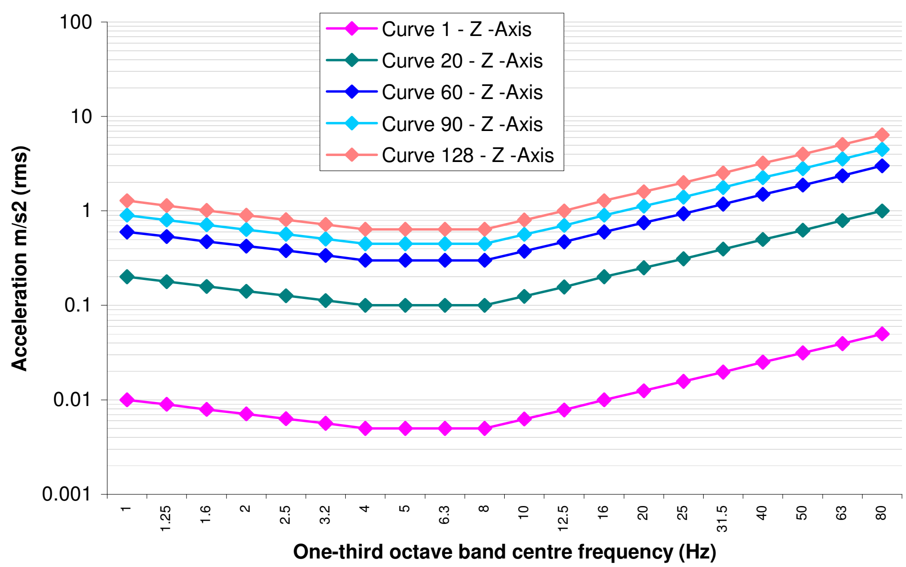


Table 1: Multiplying factors used to specify satisfactory magnitudes of building vibration with respect to human response

Place	Time	Multiplying Factors[1]	
		Exposure to continuous vibration (16h day, 8 h night)	**Impulsive vibration excitation with up to 3 occurrences**
Critical working areas (eg. Precision laboratories)	Day	1	1
	Night	1	1
Residential	Day	2 to 4	60 to 90
	Night	1.4	20
Office	Day	4	128
	Night	4	128
Workshops	Day	8	128
	Night	8	128

Table 2: VDV ($m/s^{1.75}$) above which various degrees of adverse comment may be expected

Place	Time	Low probability of adverse comment	Adverse comment possible	Adverse comment probable
Critical working areas (eg. precision laboratories)	Day	0.10	0.20	0.40
	Night	0.09	0.18	0.36
Residential	Day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
	Night	0.13	0.25	0.51
Office	Day	0.40	0.80	1.60
	Night	0.36	0.73	1.46
Workshops	Day	0.80	1.60	3.20
	Night	0.73	1.46	2.91

[1] The multiplying factors lead to magnitudes of vibration below which the probability of adverse comments.

2.2 STRUCTURAL DAMAGE

In the absence of any Australian Standard addressing the issue of structural damage from ground vibration, German Standard DIN 4150:1999 *Structural Vibration – Part 3: Effects of vibration on structures* is normally used as a reference. DIN 4150 recommends maximum peak particle velocity (PPV) vibration limits in mm/s for different frequency ranges to be associated with transient vibration sources. According to DIN 4150, if the recommended criteria are not exceeded, damage that reduces the serviceability of a building should not occur.

The minimum "safe limits" of for short –term vibration for different types of buildings and intermittent vibrations is presented in **Table 3** below.

Table 3: DIN 4150 – Minimum "safe limits"

Type of Structure	Peak particle velocity guide values PPV (mm/s)			
	At Foundation			At plane of floor of uppermost full storey (all frequencies)
	< 10 Hz	10 to 50 Hz	50 to 100 Hz * and above	
1.Buildings used for commercial purposes, industrial buildings or similar design	20	20 – 40	40 – 50	40
2.Dwellings and buildings of similar design and/or use	5	5 – 15	15 – 20	15
3.Structures that, because of their particular sensitivity to vibration do not correspond to those listed in 1 and 2 and are of great intrinsic value (e.g. buildings that are under a preservation order).	3	3 – 8	8 – 10	8

3. METHODOLOGY

Vibration measurements were taken on site along the straight section of the OneSteel line, 5m from the rail centreline on the 5th February 2007 between 7am and 2pm.

The following train pass-by's were monitored.

Table 4: Monitored Pass-by's

Measurement ID	Time	Train Description
1	11:59am	Single Diesel Locomotive
2	1:38pm	Diesel Locomotive and 30 Freight Cars

Measurements were conducted with a Blastronics μmx vibration monitor (Serial Number 0258).

The µ0258 Model vibration monitor was set up so as to monitor instantaneous particle velocity levels, triggering and recording particle velocity for levels once the set threshold was exceeded.

The monitor was used to measure the velocity in 3 directions. Data signals were recorded digitally at a sample rate of 1000Hz and ViewW Software used to analyse the data.

Data processing and analysis followed the sequence below:

- Analysis of the velocity time waveforms and conversion of particular events in the frequency domain (if required);
- Differentiation of the velocity time waveforms into acceleration time waveforms;
- FFT analysis of the acceleration waveforms to identify the measurements frequency content and comparison against BS6472 criteria curves. FFT analysis was conducted on sections of the time signal showing outstanding peaks. This analysis was utilised to simulate the vibration produced by the rail system for both the current and future proposed scenarios.

VDV levels were calculated based on the following **daily** train volumes and exposure times, using the maximum acceleration as determined from the FFT analysis.

Table 5: Current and future daily Train Volumes

Serviced premises	Current	350,000 TEU per annum container facility
OneSteel	11	11
Proposed container facility	0	6
Total	11	17

Note: Daily train volumes for the Container Facility take account for the 60:40 split between rail and road traffic and assume 90 TEU per train.

Measurements of current train pass-bys were used as a basis for simulation of the vibration produced by the future rail scenario. This was based on discussion with pacific national, which determined that the locomotives currently operating on site would be similar to those utilised in a container terminal operation and may represent a conservative case due to likely improvement in locomotive produced vibration.

To provide a measure of conservatism, all trains were assumed to be representative of the ‘likely container train’ which consists of two diesel locomotives dragging 45 freight cars with a pass-by time of 4 minutes and the highest acceleration levels occurring for 10% of the time, as witnessed on site with the larger train.

4. RESULTS & DISCUSSION

4.1 STRUCTURAL VIBRATION

The figures below present the velocity waveforms for each pass-by in all 3 directions (relative to the rail line axis).

Figure 4: Pass-by 1 – Longitudinal peak particle velocity (mm/s)

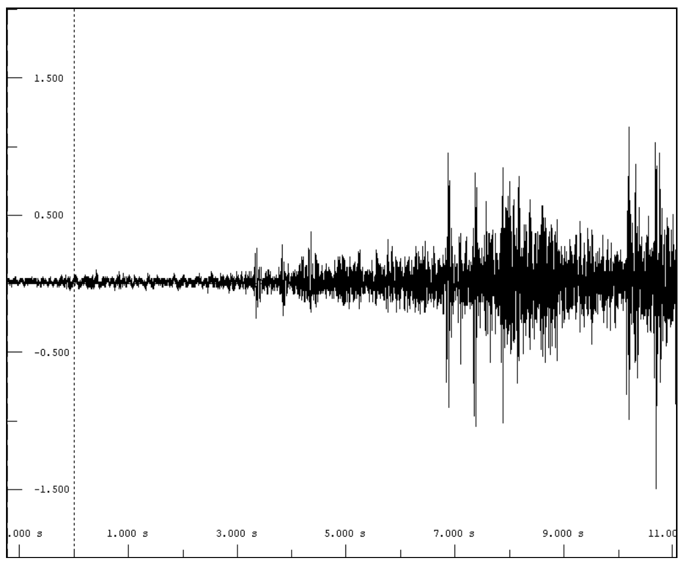


Figure 5: Pass-by 1 – Lateral peak particle velocity (mm/s)

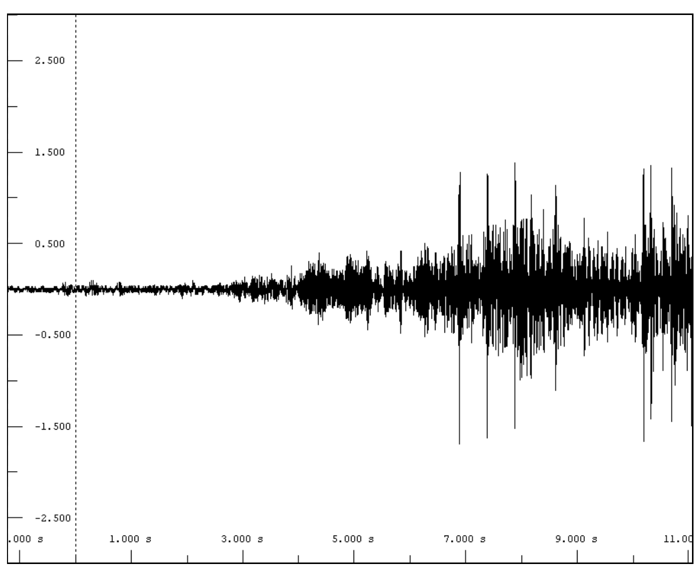


Figure 6: Pass-by 1 – Vertical peak particle velocity (mm/s)

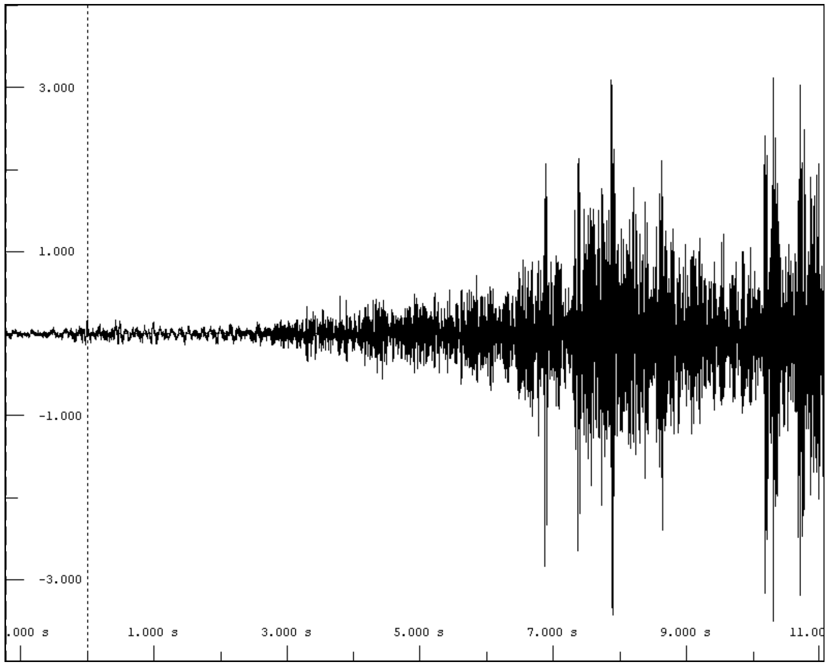


Figure 7: Pass-by 2 – Longitudinal peak particle velocity (mm/s)

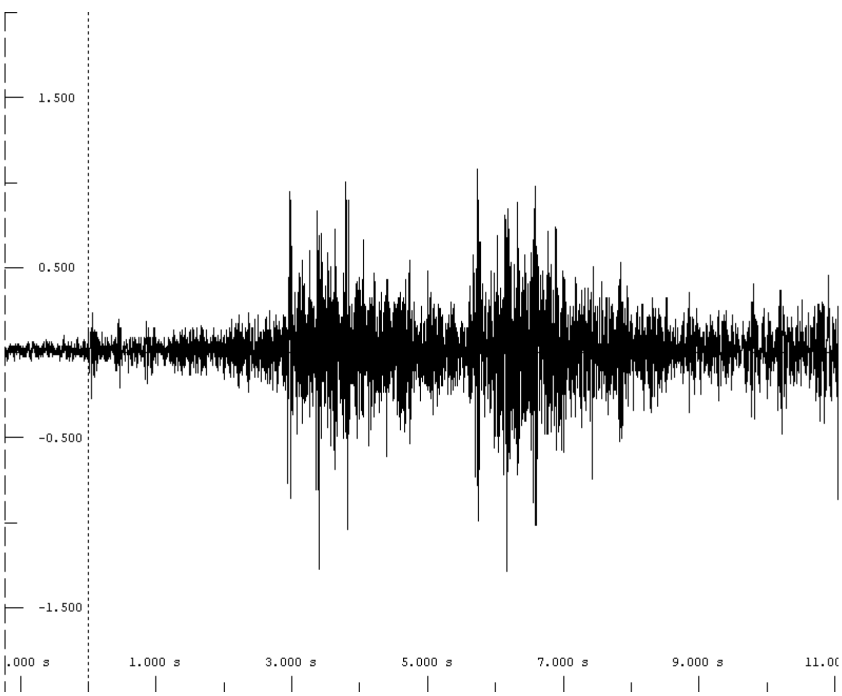


Figure 8: Pass-by 2 – Lateral peak particle velocity (mm/s)

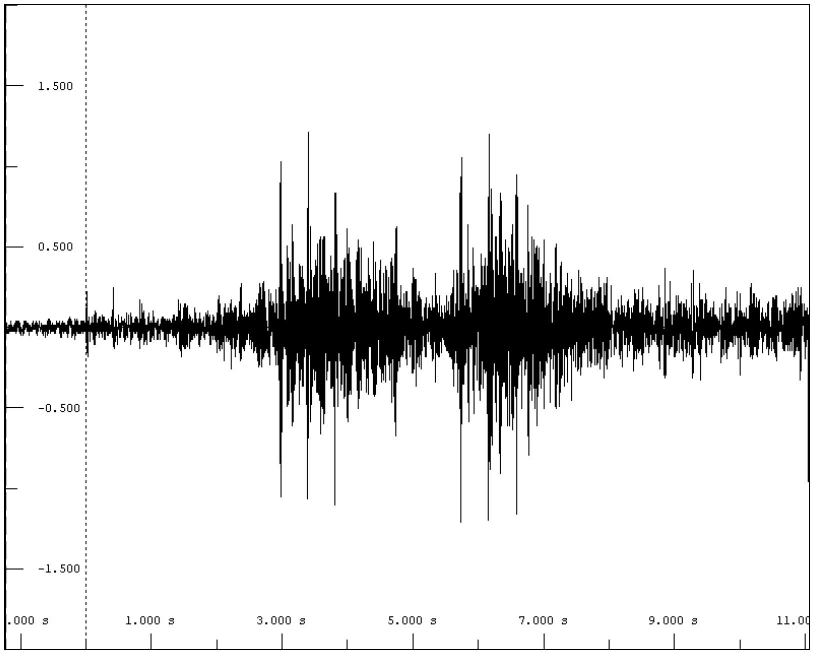
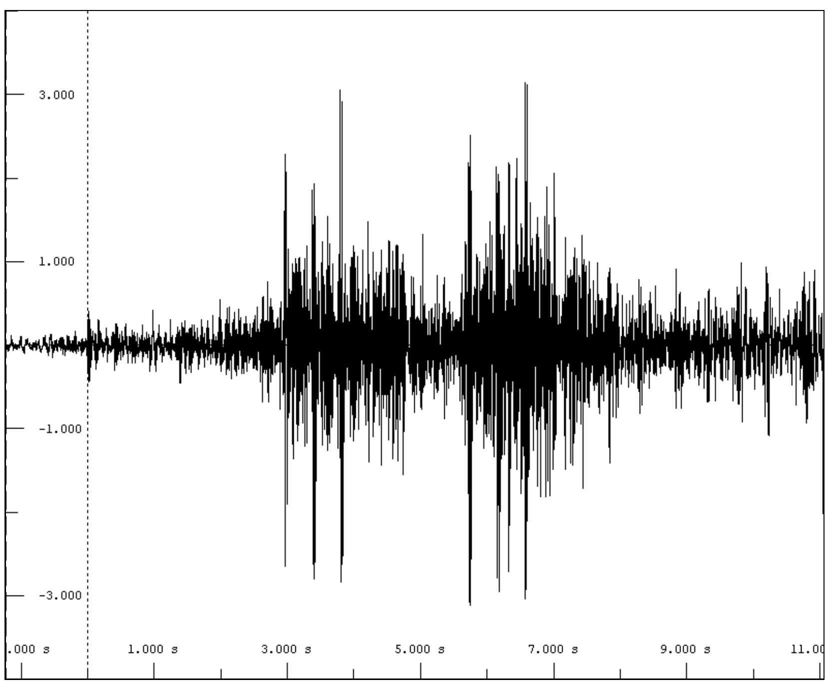


Figure 9: Pass-by 2 – Vertical peak particle velocity (mm/s)



The above waveforms raise the following comments:

- Due to the low train speed on site (10-15km/h), measured vibration levels were relatively low. The highest peaks were gathered as the diesel locomotive passed by the monitor. This is explained by the fact that the locomotive would be substantially heavier than the freight cars;

- The highest peaks are generally experienced in the vertical direction. Regardless of the frequency content of the waveforms, peaks are generally below 3mm/s with marginal exceptions in the order of 3-3.5mm/s (vertical direction only);

- With reference to Table 3, the velocity waveforms show that vibration levels are well below the structural damage criteria for residential, commercial and industrial buildings at 5 metres from the track centreline. Vibration levels will decrease as the distance from the track increase. Provided that the train speed on site remains limited to 10-15km/h, it is our opinion that there is no risk for structural damage for buildings located at distances greater than 5 metres from the track;

- The structural damage criteria are based on instantaneous peak particle velocity levels and are therefore not dependent on the number of trains using the rail line over a given period. As a result, compliance with these criteria will not be affected by the fact that additional trains are brought on the site to service the proposed container facility.

4.2 HUMAN PERCEPTION

Results for both pass-by are summarised in **Table 6** below, showing the magnitudes of the highest detected spikes (RMS acceleration) and corresponding frequencies. Corresponding acceleration spectra (peak acceleration) are provided in **Appendix A**.

The table and spectra raise the following comments:

- Spectra show that vibrational energy is consistently comprised between 40Hz and 80Hz, with negligible components at frequencies below 40Hz. With reference to BS 6472 criteria curves, this frequency range corresponds to less stringent criteria regardless of the vibration direction;

- RMS levels do not exceed 0.134m/s^2 at any given frequency, measured in the vertical direction;

- Human perception criteria are based on either continuous or intermittent/impulsive vibration. In this case, even with substantially more trains passing through the site, rail-related vibrations will remain intermittent;

- As a result, it is our opinion that train vibration will not have an adverse impact on the occupants of future office, commercial and industrial buildings on site provided that the distance between the buildings and the track is greater than 5-meters. However, critical work areas (such as precision laboratories) should be systematically located as far as possible from the rail track.

Table 6: Summary of acceleration peak levels (m/s^2 rms)

Frequency (Hz)	Longitudinal	Frequency (Hz)	Lateral	Frequency (Hz)	Vertical
39.063	0.016	50.781	0.012	39.062	0.029
53.711	0.016	51.758	0.017	40.039	0.033
54.687	0.011	53.711	0.040	41.016	0.025
56.641	0.022	54.687	0.027	41.992	0.032
63.477	0.011	56.641	0.030	47.852	0.033
64.453	0.015	56.57	0.025	49.805	0.055
67.383	0.018	60.547	0.016	50.781	0.041
69.336	0.013	61.523	0.014	52.734	0.035
70.312	0.029	62.5	0.026	53.711	0.063
71.289	0.031	63.477	0.019	71.289	0.060
73.242	0.017	67.383	0.018	72.266	0.047
74.219	0.019	69.336	0.014	73.242	0.035
75.195	0.012	70.312	0.035	75.195	0.100
76.172	0.027	71.289	0.039	**76.172**	**0.134**
79.102	0.015	72.266	0.019	77.148	0.091
82.031	0.017	75.195	0.039	79.102	0.047
82.031	0.012	76.172	0.034	81.055	0.086
89.844	0.016	77.148	0.030	82.031	0.060
		78.125	0.024	83.984	0.028
		82.031	0.015	86.914	0.045
				88.867	0.040

Based on a maximum RMS peak of $0.134 m/s^2$ and the assumptions outlined in Section 3, **Table 7** presents the estimated VDV's for the current and future (350,000 TEU container facility) rail activities on site.

Table 7: Estimated VDV's

Scenario	Estimated VDV
Current Situation	0.76
350,000 TEU per annum container facility	0.84

With reference to Table 2, results suggest that adverse comments are possible for both office and workshop buildings located 5-metres from the track.

On this basis, it is preferable to provide a buffer zone between the track and the nearest buildings. Vibration magnitude relation to the distance from the source varies from a site to another. However, field data suggest that the distance (d) relationship to vibration attenuation generally varies between $d^{-0.8}$ and $d^{-1.6}$.

Vibration propagation calculations aimed at determining the minimum distance (based on a conservative $d^{-0.8}$ attenuation factor outlined in the State Rail Authority Interim Guidelines For Councils document) enabling compliance with acceptable VDV's for residential, office, and workshop buildings. Results suggest that residential, office, and workshop buildings should be 52-metres, 15-metres, and 6-metres respectively from the rail track to ensure a low probability of adverse comments.

5. CONCLUSION

This assessment highlights the following:

- Current rail-related vibration levels at 5-metres from the rail track centreline are well below the relevant criteria for structural damage and human perception;

- Whilst vibration levels on site are relatively low, calculations indicated that the future daily number of train movements might trigger adverse comments in occupants of buildings located within 5-metres from the track. Further calculations indicate that the minimum distance to the track should be 6-metres for workshop/industrial buildings and 15-metres for office/commercial buildings;

- Calculations show that the minimum distance to the track should be 52-metres for residential housing. As the closest resident is in excess of 400-metres, the potential for current and future structural damage and human perception for nearby residences is negligible;

- The low vibration levels are essentially due to the train's speed not exceeding 10-15km/h. This is certainly the most cost-effective measure to ensure the site is not adversely affected by train movements from a ground vibration point of view;

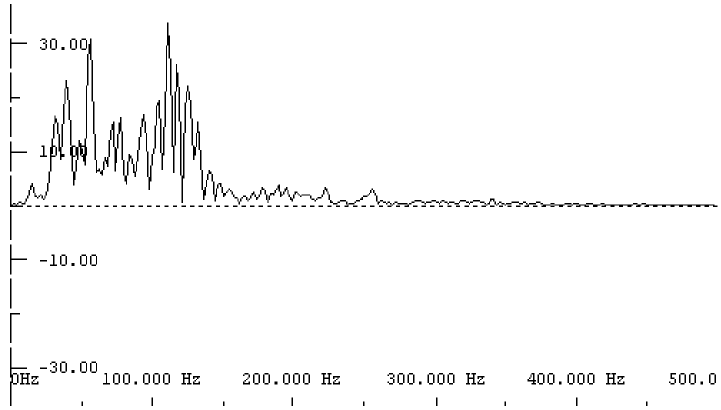
- Based on a 10-15km/h-train speed, the site is suitable for the construction of office, commercial and industrial buildings subject to the distance restrictions outlined above. Critical working areas, such as precision laboratories, should be located as far as possible from the track;

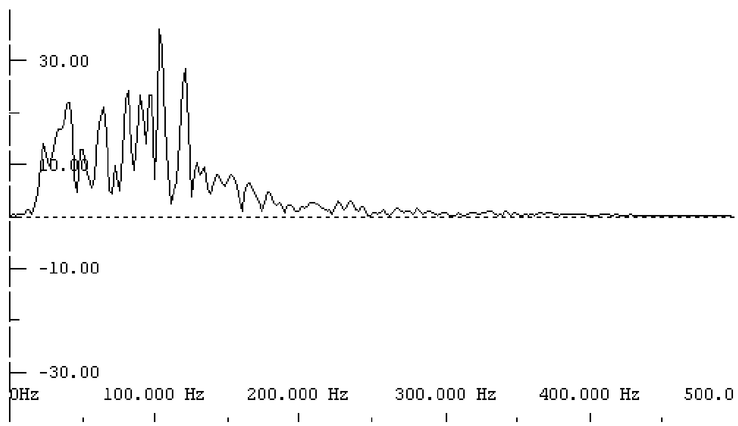
- It should also be noted that vibration could be amplified in the upper floors of multi-storey buildings. This issue should be considered at design stage if such a building was to be constructed close to the rail line.

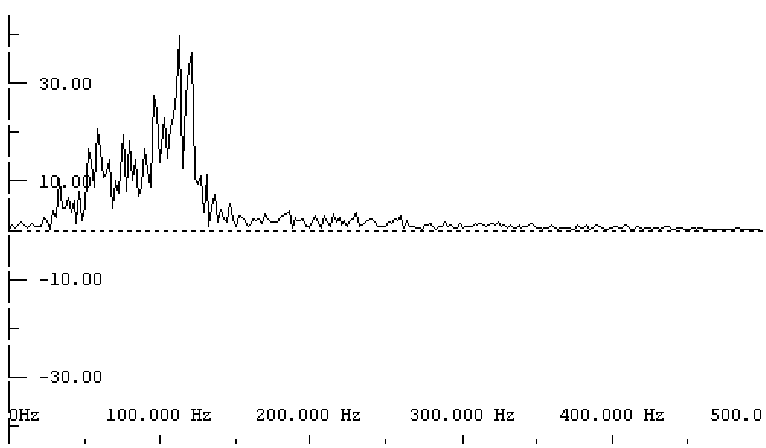
- No significant off-site impacts in relation to vibration are anticipated as a result of the rail relocation, subject to conditions noted above.

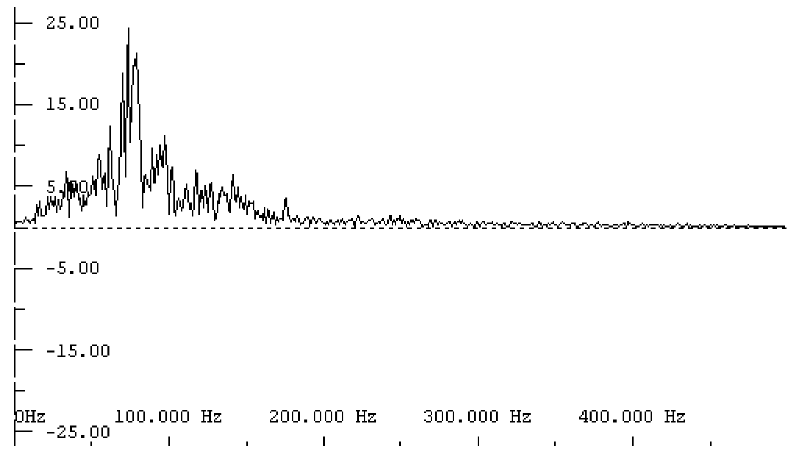
APPENDIX A – PEAK ACCELERATION SPECTRA – LONGITUDINAL DIRECTION

All charts are scaled in mm/s².





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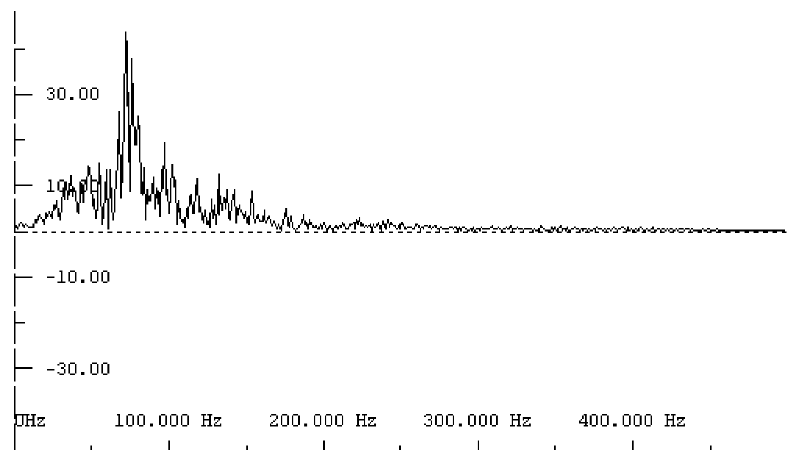
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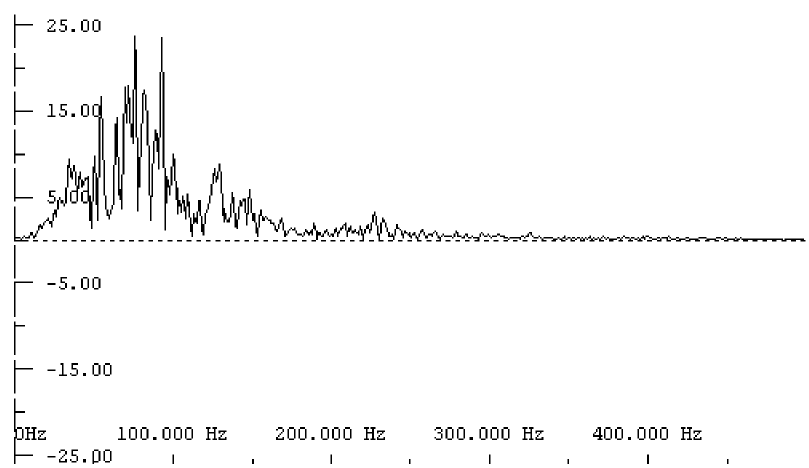
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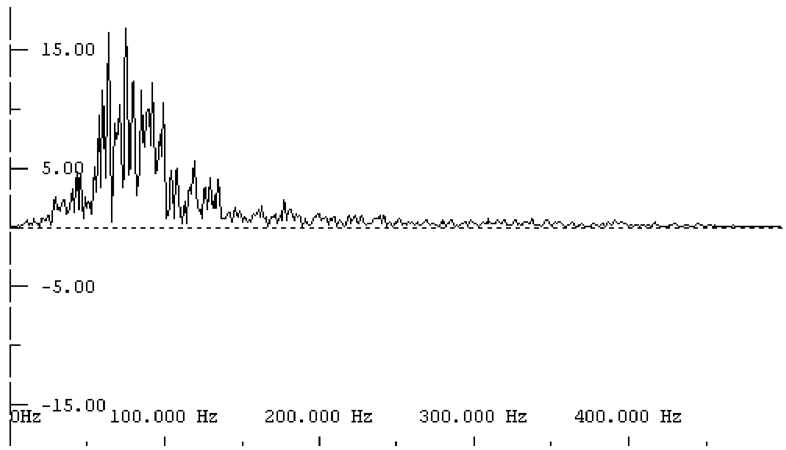
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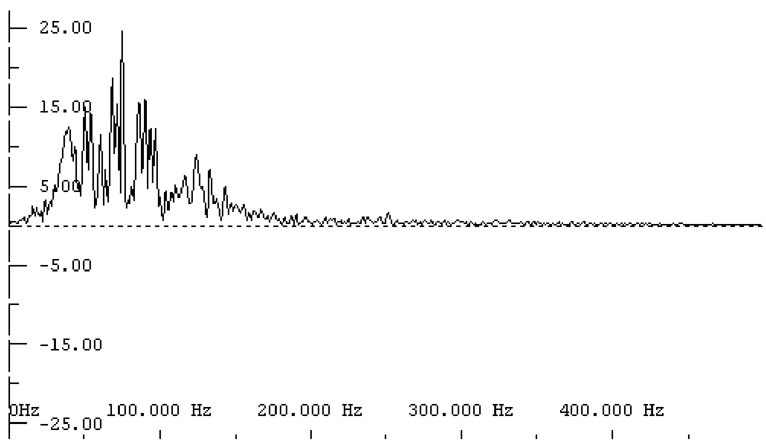
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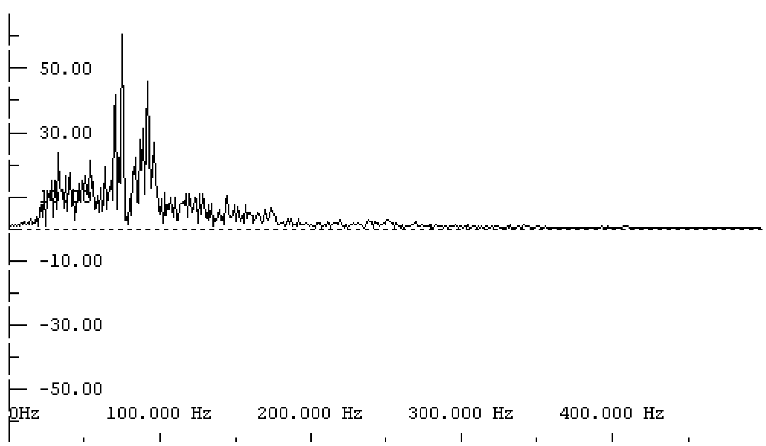
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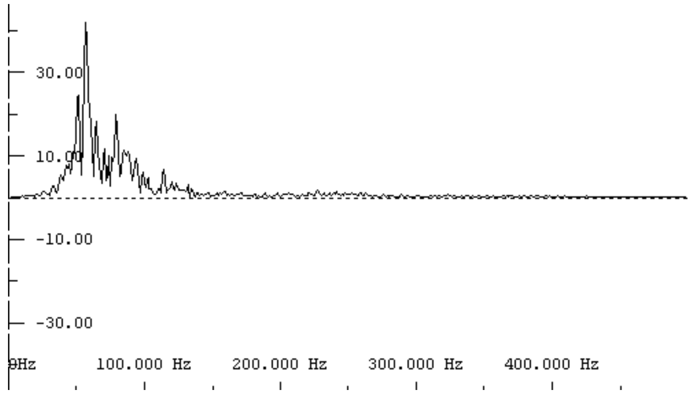
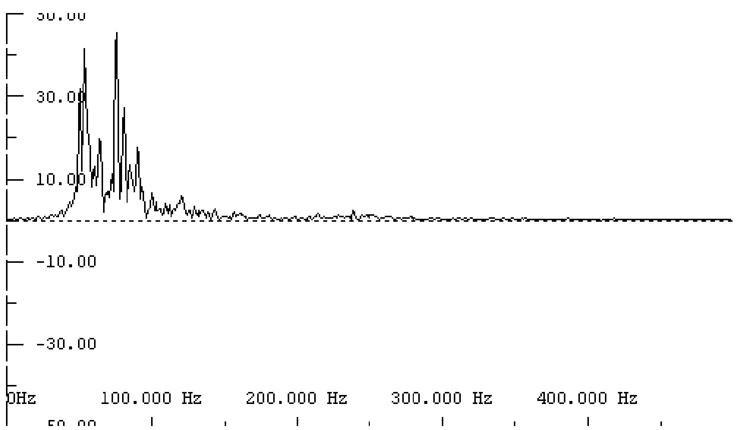
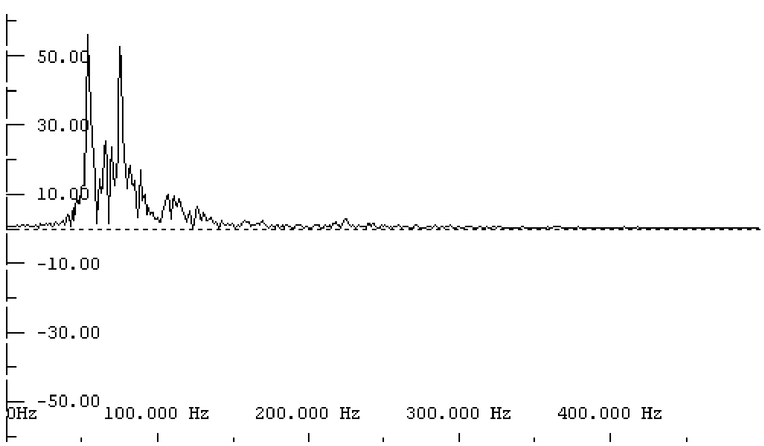
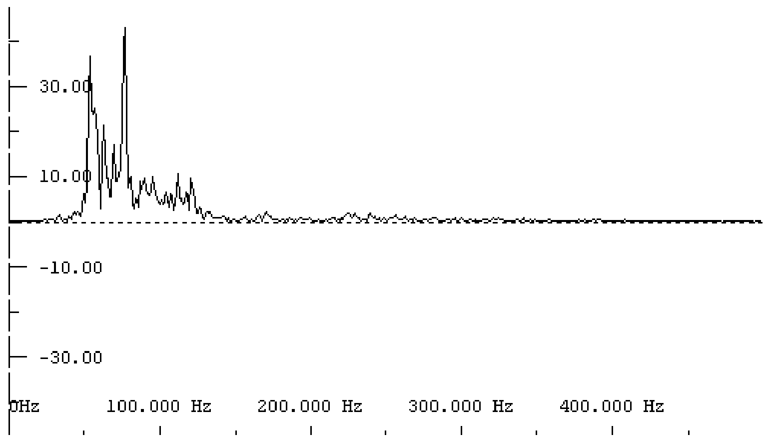
APPENDIX B – PEAK ACCELERATION SPECTRA – LATERAL DIRECTION

All charts are scaled in mm/s^2.





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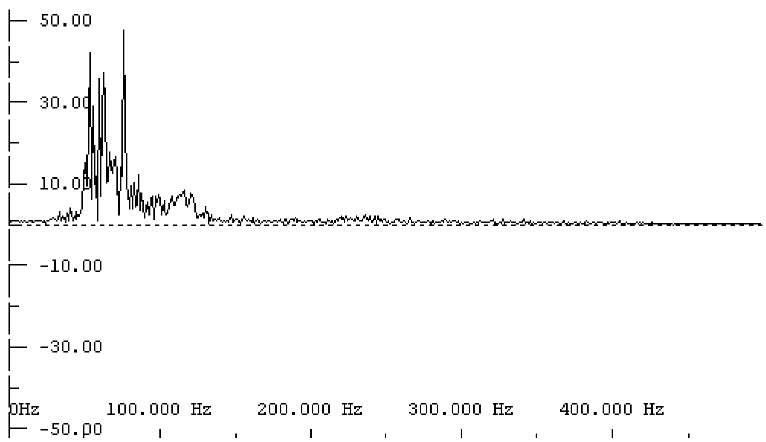
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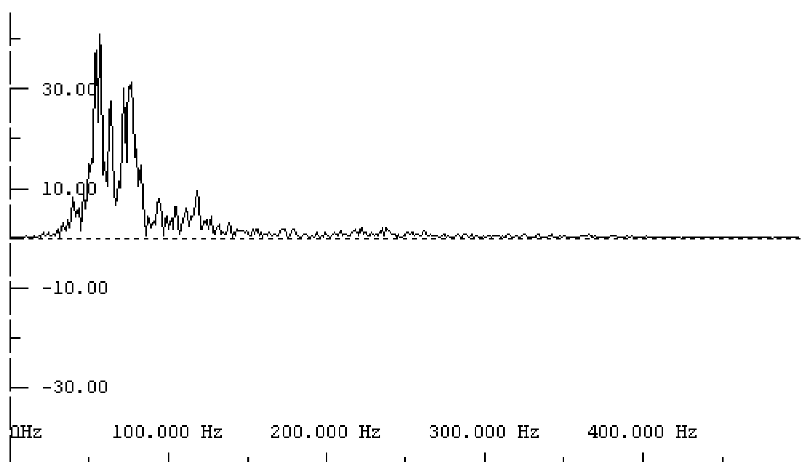
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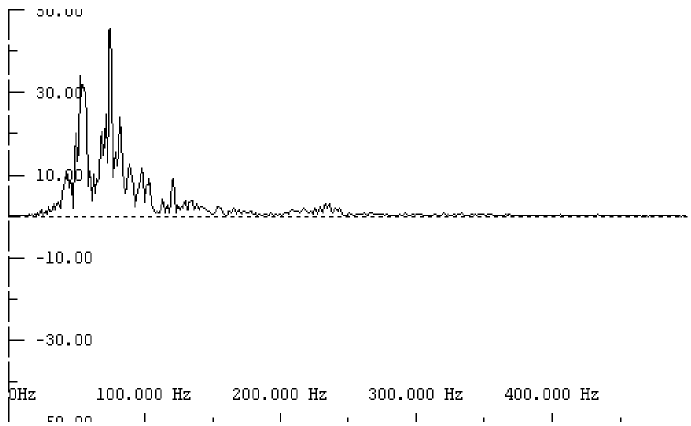
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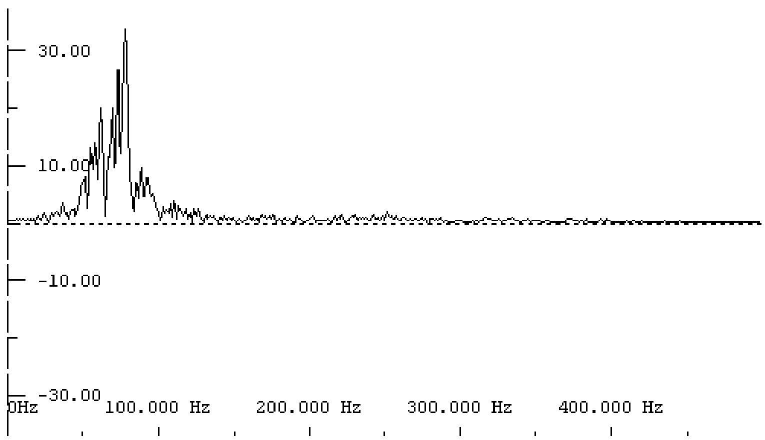
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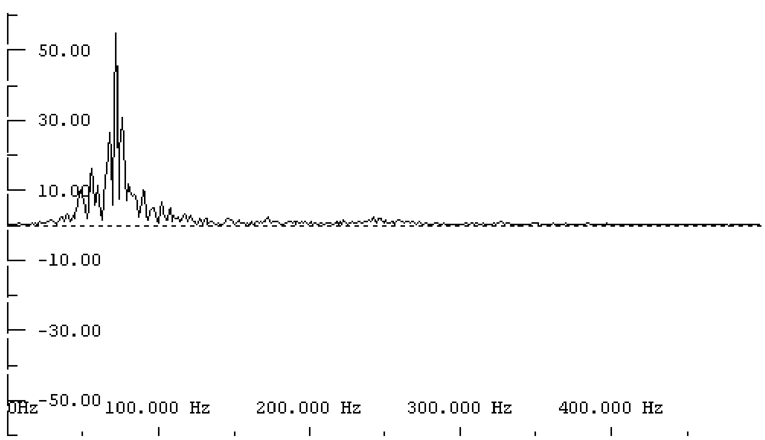
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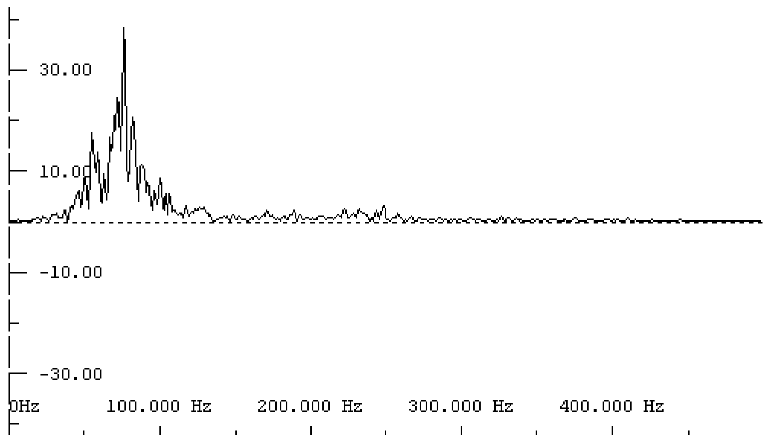
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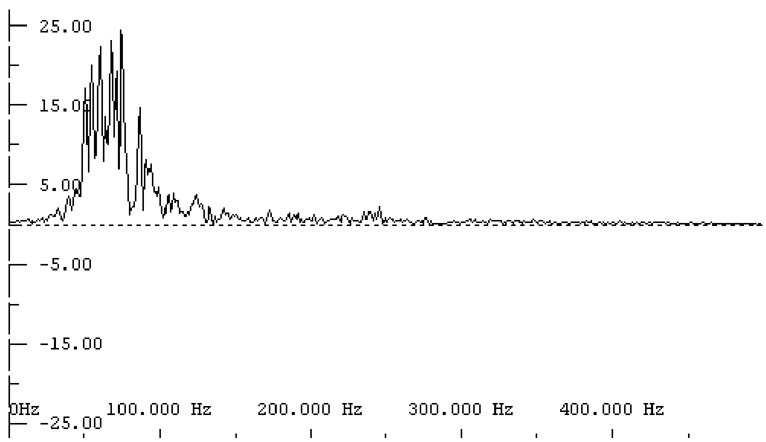
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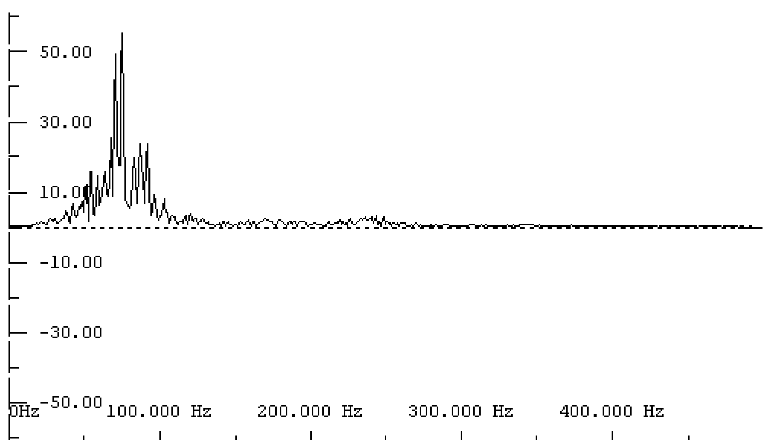
50.00
30.00
10.00
-10.00
-30.00
-50.00
0Hz
100.000 Hz
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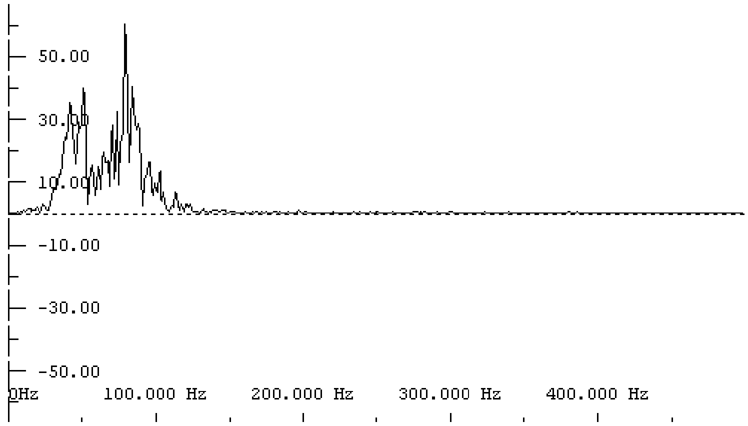
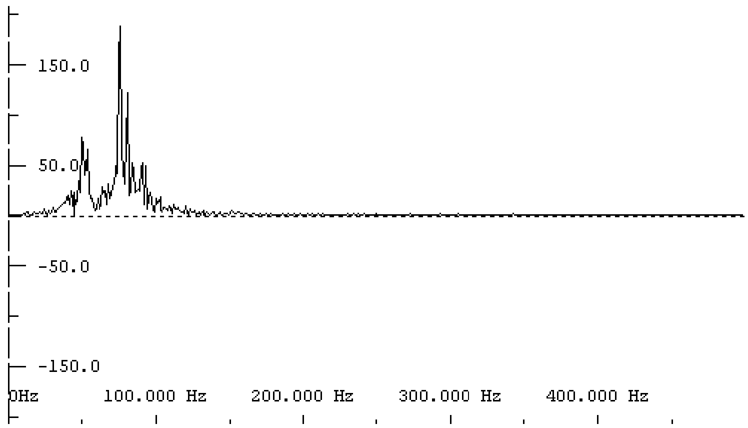
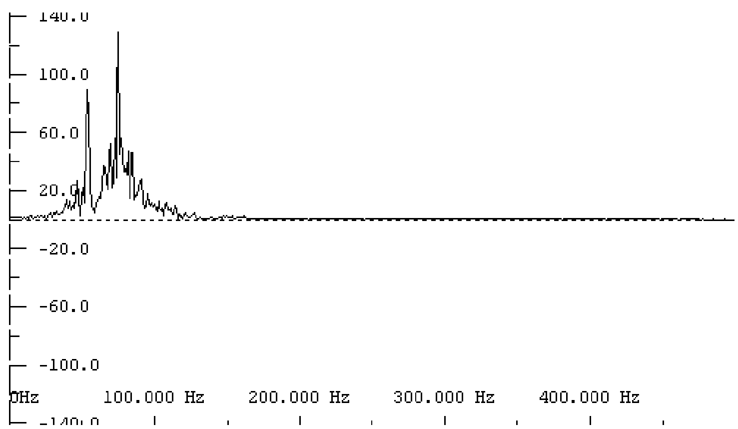
300.000 Hz
400.000 Hz

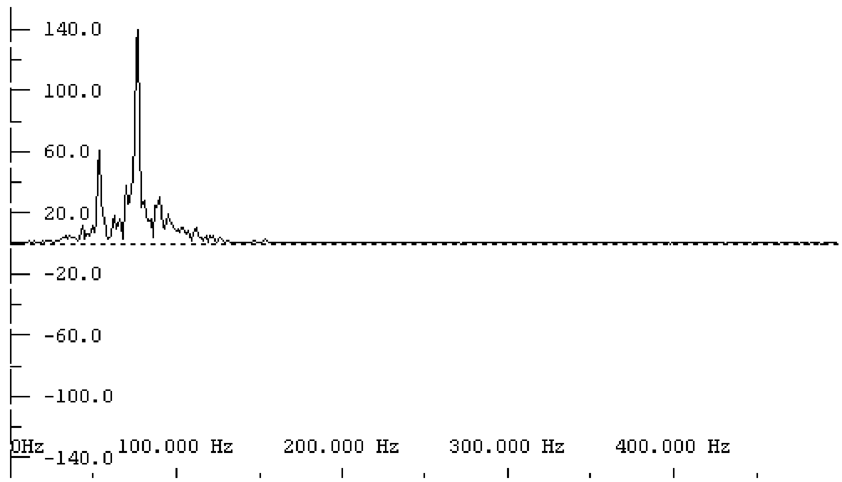
APPENDIX C – PEAK ACCELERATION SPECTRA – VERTICAL DIRECTION

All charts are scaled in mm/s^2.





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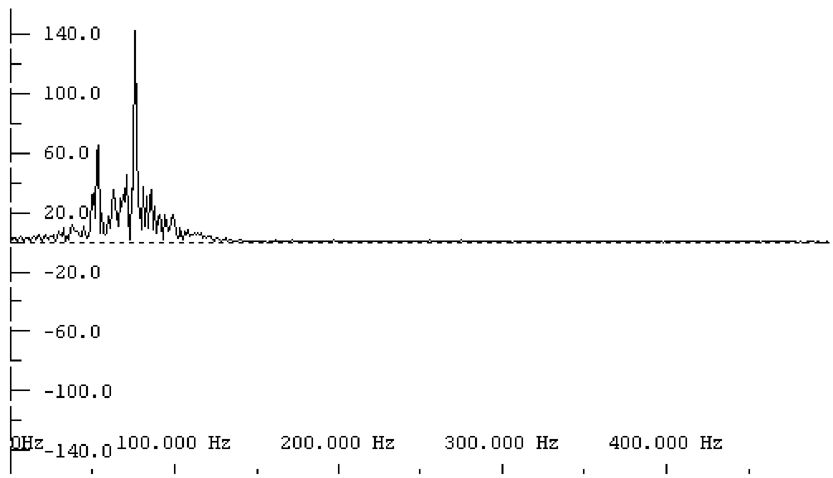
100.0
60.0
20.0
-20.0
-60.0
-100.0
-140.0
0Hz
100.000 Hz
200.000 Hz
300.000 Hz
400.000 Hz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100.0
60.0
20.0
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-60.0
-100.0
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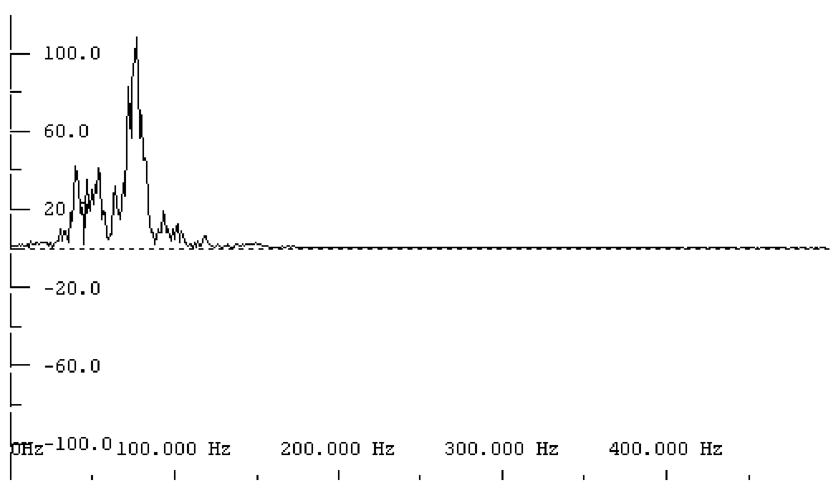
0Hz
100.000 Hz
200.000 Hz
300.000 Hz
400.000 Hz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-20.0
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0Hz
100.000 Hz
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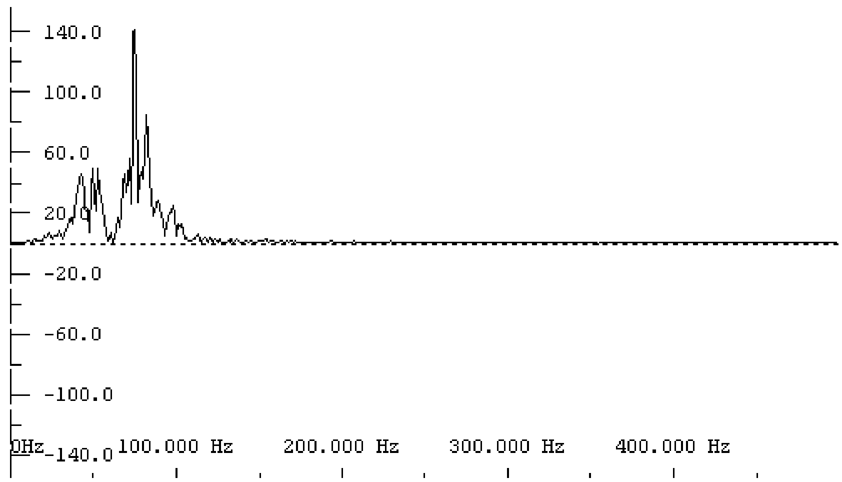
300.000 Hz
400.000 Hz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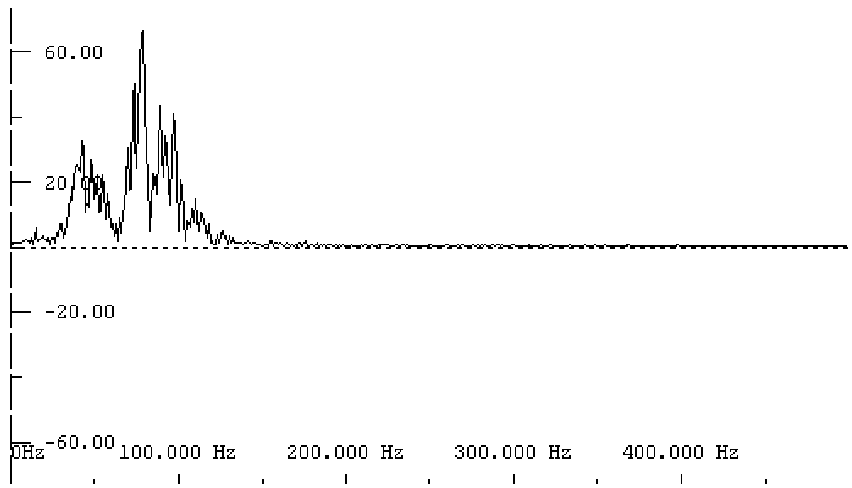
100.000 Hz
200.000 Hz
300.000 Hz
400.000 Hz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100.000 Hz
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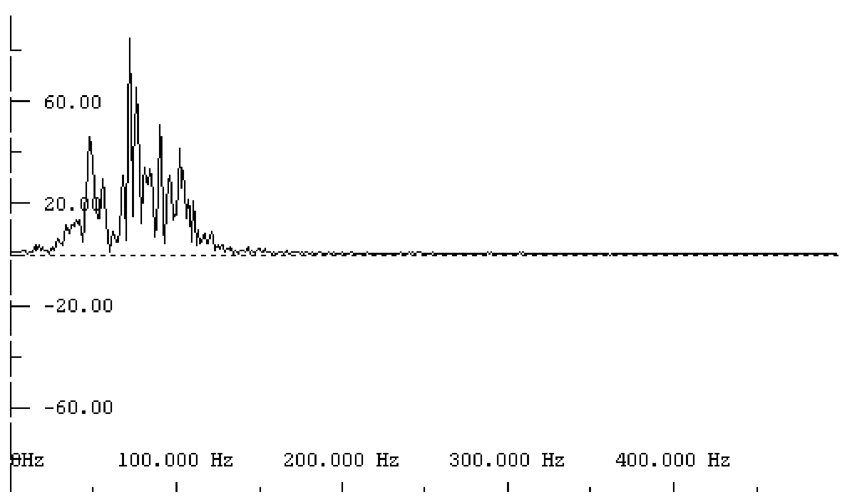
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100.000 Hz
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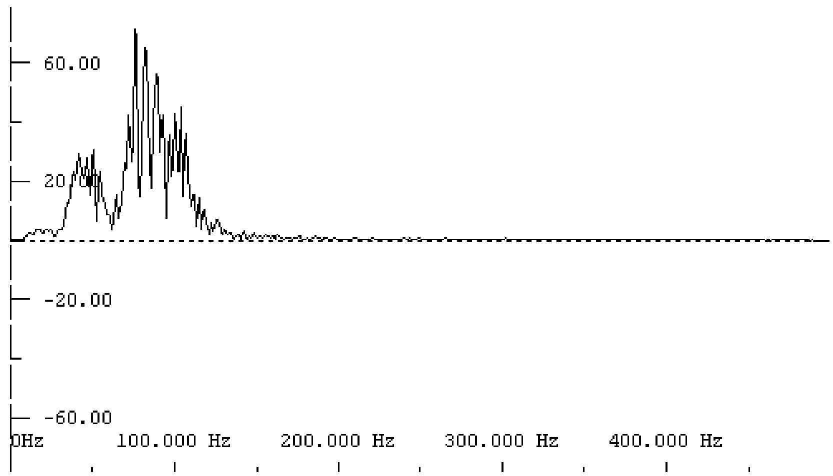
300.000 Hz
400.000 Hz


60.00
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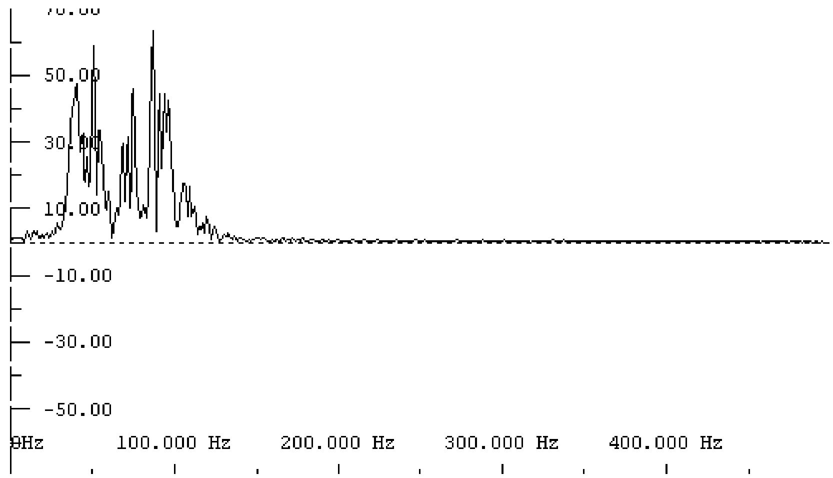
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100.000 Hz
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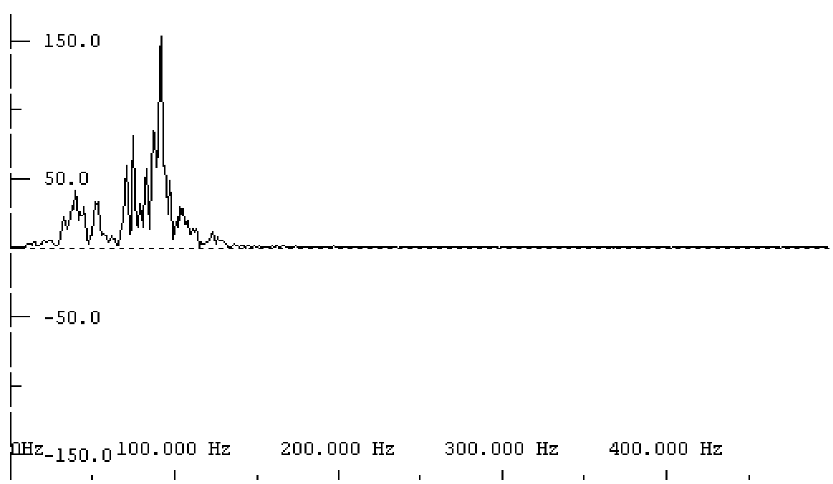
400.000 Hz


150.0
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-50.0
-150.0
0Hz
100.000 Hz
200.000 Hz
300.000 Hz
400.000 Hz