Appendix 4.5

Force Density Level (FDL)

Description of Measurements at Heng Fa Chuen Depot & Po Lam Station

In accordance with the determination of the Force Density Level (FDL) given in Section 4, vibration measurements were made on 24-25 October 2005 during Metro-Cammell EMU (M-stock) passbys and during impact hammering on the Ballast & Sleeper trackform at nearby Heng Fa Chuen Depot between Heng Fa Chuen Station and Chai Wan Terminus on the up track of Island Line (ISL) main line. The second vibration measurement was held on 27 October 2005 during the M-stock train passbys and during impact hammering on the LVT trackform inside the tunnel between Po Lam Terminus and Hang Hau Station (King Lam Estate) and impact hammering on the ground level above the same location of the tunnel on the down track of Tseung Kwan O Line (TKL) at CH64.063.

Eight car MTR Urban Line M-stock EMU used for the measurement, there were no audible wheel flats observed during the train passbys. The tangent track at the measurement location is UIC 60 plain line continuous rail on ballast and sleepers.

The impact hammer located along the track centreline is shown in Photo 1. For both Hang Fa Chuen and Po Lam measurement location, measurements during train passbys and hammer impacting were taken with the same linear array of geophones and accelerometers located transverse to the track alignment, as shown in Photos 2 to 5. At Hang Fa Chuen, during each impact or train passby, as shown in Figures 11 & 12, surface vibration measurements were simultaneously taken at setback locations of 4.2 m, 13.6 m, 20.3 m, 28.9 m, 38.5 m, 49.4 m, and 62.5 m, respectively. Sensors also put under the Rails at the impact point and on the centre of sleeper 4.2m from the impact point. The sensor setback location at Po Lam were 12 m, 24 m, 27 m, 34 m, 44 m, 54 m, 64m, and 74 m, respectively. Appendix 4.7: Figures 2 & 3 shows the schematic drawings of measurement location. The measurement details are presented in Appendix 4.7: Table 1 and Appendix 4.7: Photos 1 to 6. For the impact measurements, the magnitude of the hammer force impact was also measured, allowing the determination of the point and line source responses at these setbacks.

Vibration measurements at Hang Fa Chuen were taken at train speeds of 20 kph, 30 kph, 40 kph, and 60 kph. In the projection of ground borne noise and vibration at sensitive receivers along the WIL, the FDL is determined by interpolation of these data in 1/3 octave bands to the maximum passby speed which occurs within a eight car train length centred on the track adjacent to the receiver.

At Hang Fa Chuen, the rail had grinding marks present from previous rail grinding which had not worn smooth at the time of the measurements (Photos 7 & 8).

Instrumentation

Low sensitivity accelerometres (0.1 V/g Wilcoxon M408) were used in measurement of rail vibration. The other vibration sensor equipment used for the measurements is given in Table 1. Medium sensitivity accelerometres (Geospace Digiphones) were used for near locations from the trackform, and high sensitivity accelerometres (10 V/g Wilcoxon 731A) were used at locations distant from the trackform.

Other instruments used in the performance of tests are shown in Table 2 and Photo 6. Signal conditioning and amplification was performed during measurements by either WIA Type 222 or B%K Nexus Type 2693 A 014 multi channel Conditioning Amplifiers. All measurement data was recorded with 8 channel Teac RD135T & RD130TE DAT recorder. Impact and train passby vibration measurements were analysed with a B&K Pulse 22 Channel Spectrum Analyser, Model 3560D, Serial #2382079 in 1/3 octave bands.

The vacuum assisted impact tool (WHAMMY), as shown in Photo 1, is used for impacts on the ground surface. It was manufactured by Wilson, Ihrig & Associates, Inc. (WIA) of Oakland CA USA. This tool drops a 20 kg steel slug thru 1.2 m to provide an impact force to the ground. A vacuum system with a flow reverser: 1) augments the impact by a minimum factor of 1.2 by providing a back pressure in the downward direction; and 2) lifts the metal slug to the top position by reversing the back pressure to the up direction just after impact, which also prevents double or multiple bounces. A strain gauge is built into its base in order to determine the imparted force provided by the impact. Power supply is provided by the WIA strain gauge amplifier, Model # 140, Unit #3.

Measurement Data Analysis and Results

Train Passbys

At each speed, between three and seven train passbys in both directions on the Up track at Hang Fa Chuen and the morning train passby at Po Lam were recorded and analysed for the measurement locations. The equivalent vibration level in 1/3 octave bands from 3.15 Hz to 500 Hz was determined for each passby from the passage of the front and rear end of the train. The passbys levels for each speed were arithmetically averaged, with select results given in Figures 1-4 at different setbacks.

Additional analysis showed that unlike noise levels during at grade train passbys, wherein a significant leading and trailing effect is evident, the vibration levels drop off almost as soon as the train is past – thus, in the calculation of the FDL for the 30 minute equivalent A-weighted noise level, the rms passby level is assumed, with impact period determined from the length of the train and the train velocity.

Hammer Impacting

Twenty hammer blows or more were time averaged for signal to noise enhancement with square windowing applied to the force and modified (quarter sine wave) square windowing applied to the vibration measured at each setback. The transfer function (vibration divided by force or point source response (PSR)) narrow band spectrum of the result was determined from 0 Hz to 500 Hz using an 800 line Fast Fourier Transformation, not including aliasing lines. The narrow band PSR was summed to 1/3 octave bands, with select results given in Figures 2 and 4.

Determination of the LSR and the FDL

The train passby vibration level at Hang Fa Chuen Depot and Po Lam for various setback distances are shown in Figures 1 and 3. The Line Source Response for each setback distance were obtained from the 1/3 octave band Point Source Response (PSR) by incoherent integration along the length of the train, as described in Appendix 4.8. The results are given in Figures 2 and 4.

The vibration source strength of the SP1900, or Force Density Level (FDL) is obtained at a particular speed and setback by subtracting, in decibels, line source response from the vibration level resulting from the train passby. Results are linearly interpolated in speed and setback. Figures 5 to 7 give the FDLs of Metro-Cammell EMU at Hang Fa Chuen Depot and Po Lam with and without plus a 2 standard deviation of data value.

Figure 7, at higher frequencies, the FDL level is quite high on account of the rail and wheel roughness, the rail as shown in Photo 7 and 8. Thus wheel and rail condition can be considered to correspond to a somewhat deteriorated condition.

Comparison to FDLs Determined for Other Transit Trains

Figure 8, the FDL obtained for the Metro-Cammell EMU is compared to results obtained on four other heavy rail transit trains. It can be seen that we use what could be considered an upper bound on the FDL for the trains considered in this analysis for WIL

References

1. Nelson, J.T. and H.J. Saurenman, “Procedures for Prediction of Ground-Borne Noise and Vibration from Rail Transit Trains”, May 1986. Preliminary Draft prepared by Wilson, Ihrig & Associates, Inc., Oakland, CA for the Transportation Systems Centre of the USDOT.

Tables

Table 1 Location of Vibration Measurements at Hang Fa Chuen Depot FDL Measurements and Equipment Used

Setback (m)	Accelerometer/ Geophone	Charge Amp/ Preamp
4.2	Geospace Digiphone #1	WIA Geophone Preamp Unit #1
4.2	Geospace Digiphone #5	WIA Geophone Preamp Unit #5
13.6	Geospace Digiphone #2	WIA Geophone Preamp Unit #2
20.3	Geospace Digiphone #3	WIA Geophone Preamp Unit #3
28.9	Geospace Digiphone #4	WIA Geophone Preamp Unit #4
38.5	Wilcoxon Seismic Accelerometer Model 731A Serial # 2181	Wilcoxon P31 Power Unit/ Amplifier Serial #1504
49.4	Wilcoxon Seismic Accelerometer Model 731A Serial # 2182	Wilcoxon P31 Power Unit/ Amplifier Serial #1505
62.5	Wilcoxon Seismic Accelerometer Model 731A Serial # 2183	Wilcoxon P31 Power Unit/ Amplifier Serial #1506

Table 2 Instrumentation Used for Recording and Analysis

Instrument	Model No.	Serial Number
22-Channel Spectrum Analyser,	B&K Pulse, Model 3560D,	2382079
8-channel DAT Recorder	Teac RD130TE	512826
8-channel DAT Recorder	Teac RD135T	731107
4-channel Conditioning Amplifier	B&K Nexus, Type 2693 A 014	2407019
2-Channel Conditioning Amplifier	WIA Type 222	-

Photos

PHOTO 1 WHAMMY IMPACTING WITH A HAMMER PLATFORM INSTALLLED ON TOP OF A CONCRETE SLEEPER TO TRANSMIT THE IMPACT FORCE TO THE BALLAST TRACK

PHOTO 2 **WILCOXON ACCELEROMETRE INSTALLED UNDER THE HIGH AND LOW RAIL**

PHOTO 3 **GEOPHONE MOUNTED ON THE SLEEPER 4.2m AWAY FROM THE IMPACT LOCATION**

PHOTO 4 **GEOPHONE MOUNTED ON THE SPIKE INSERTED INTO SOIL NEARBY THE TRACK**

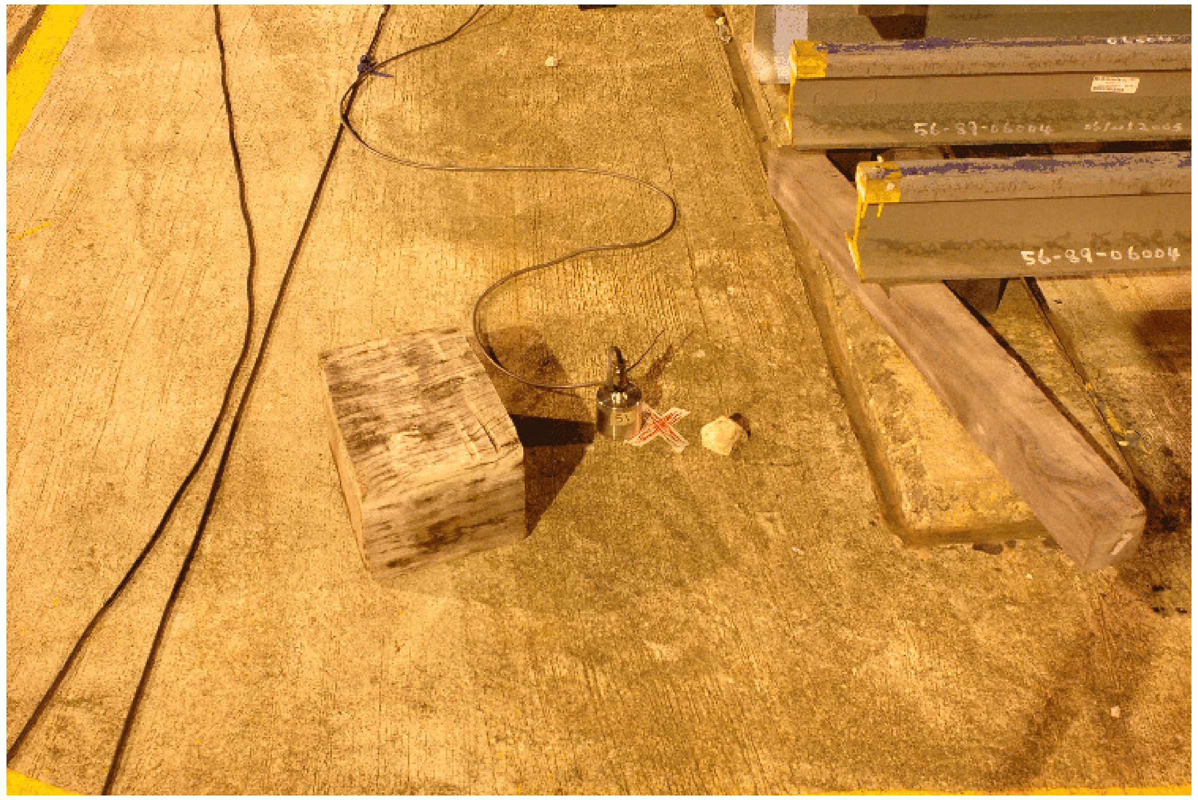

PHOTO 5 **HIGH SENSITIVITY, LOW NOISE SEISMIC ACCELEROMETRE**

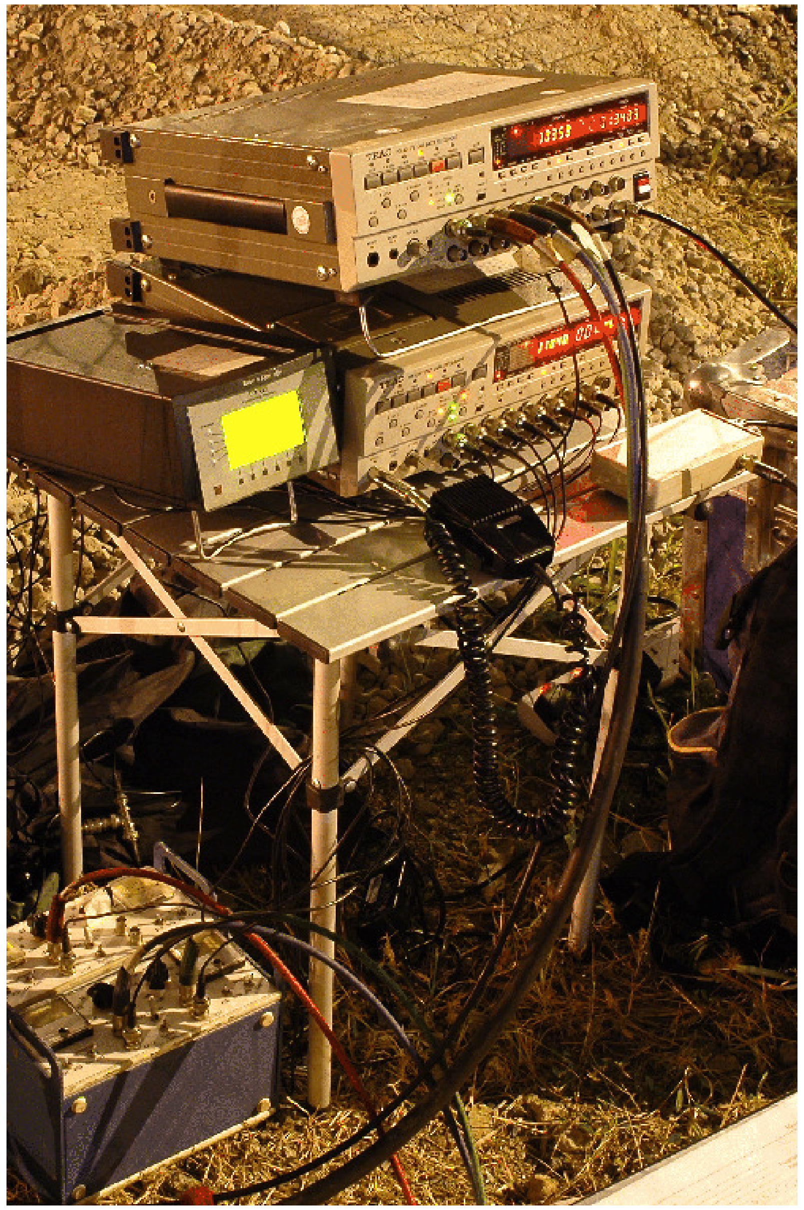

PHOTO 6 DATA ACQUISITION SYSTEM AND DIGITAL AUDIO TAPE RECORDER USED TO RECORD MEASUREMENT DATA PLACED NEARBY THE TRACK

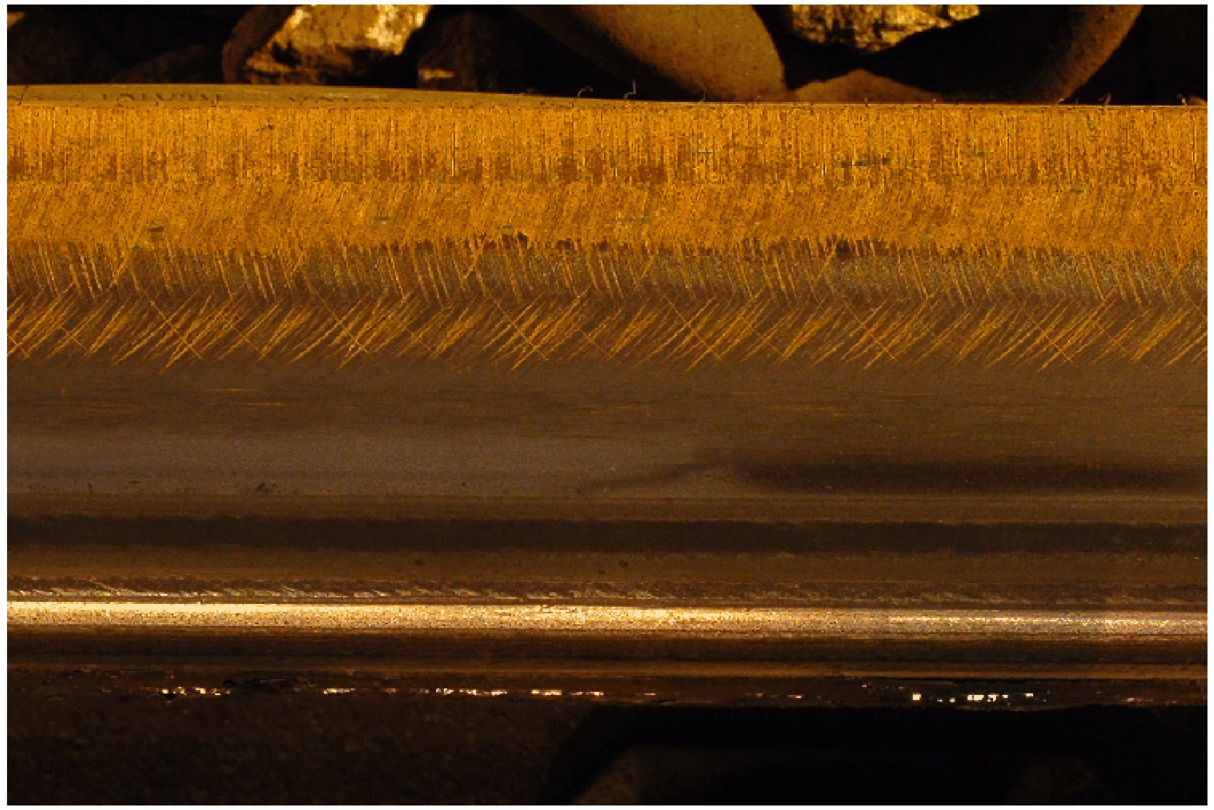

PHOTO 7 RUNNING SURFACE OF HIGH RAIL

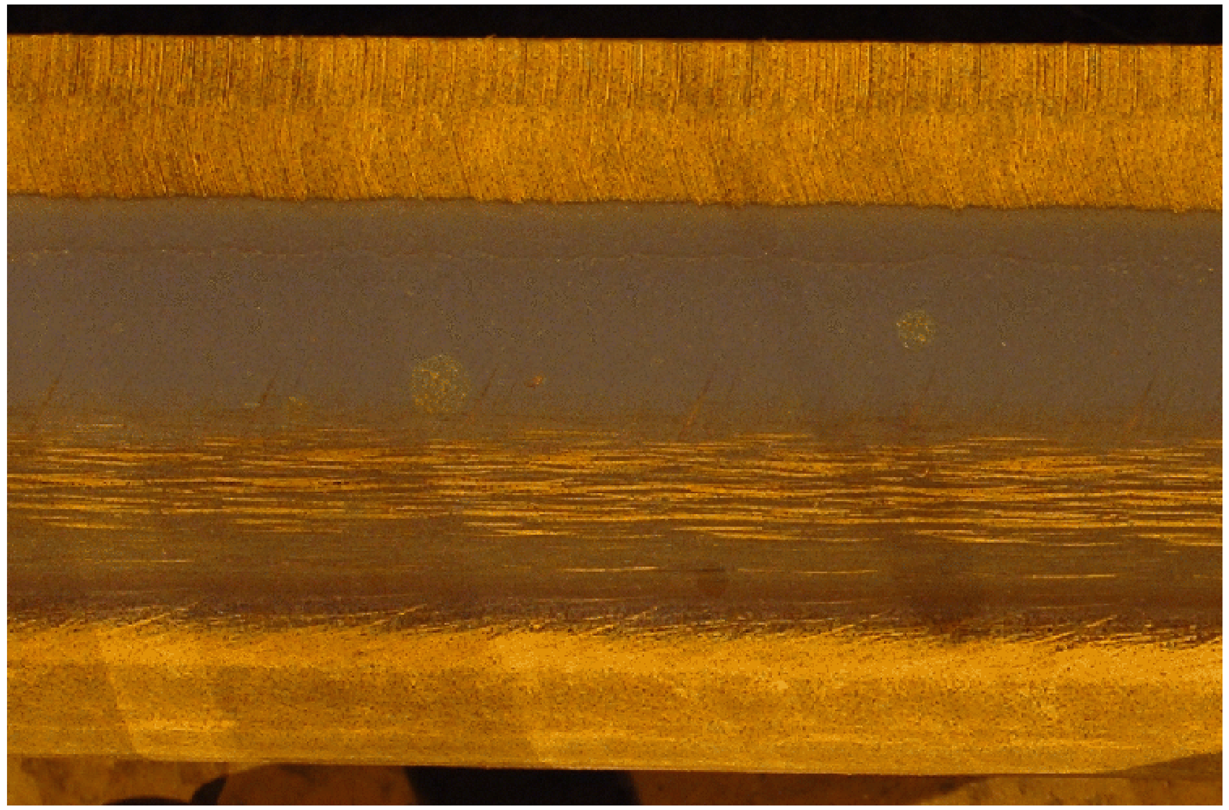

PHOTO 8 RUNNING SURFACE OF LOW RAIL

Figures

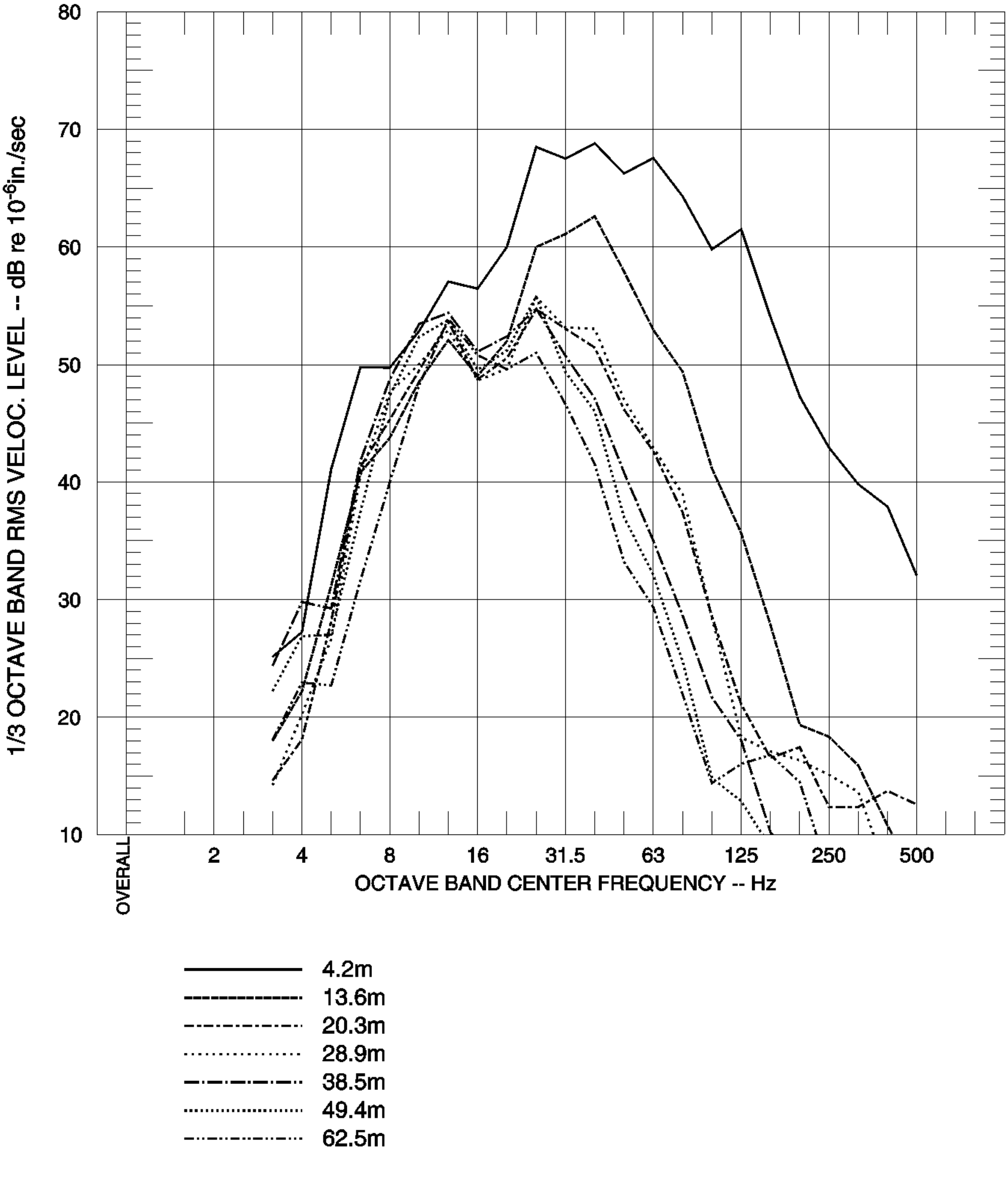

FIGURE 1 HEUNG FA TSUENG DEPOT TRAIN PASSBY VIBRATION LEVELS AT DIFFERENT SETBACK

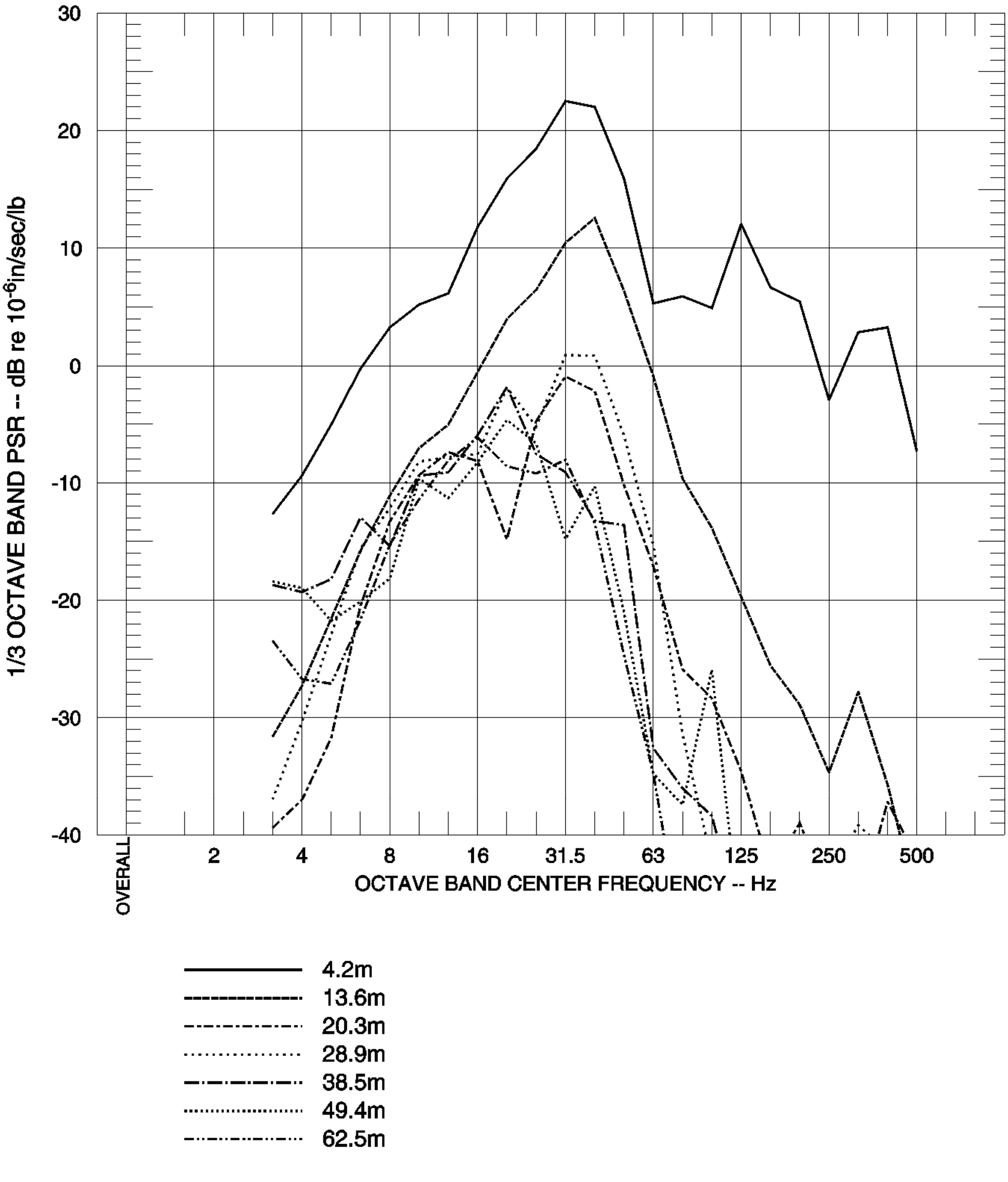

FIGURE 2 **HEUNG FA TSUENG DEPOT POINT SOURCE RESPONSE AT DIFFERENT SETBACK**

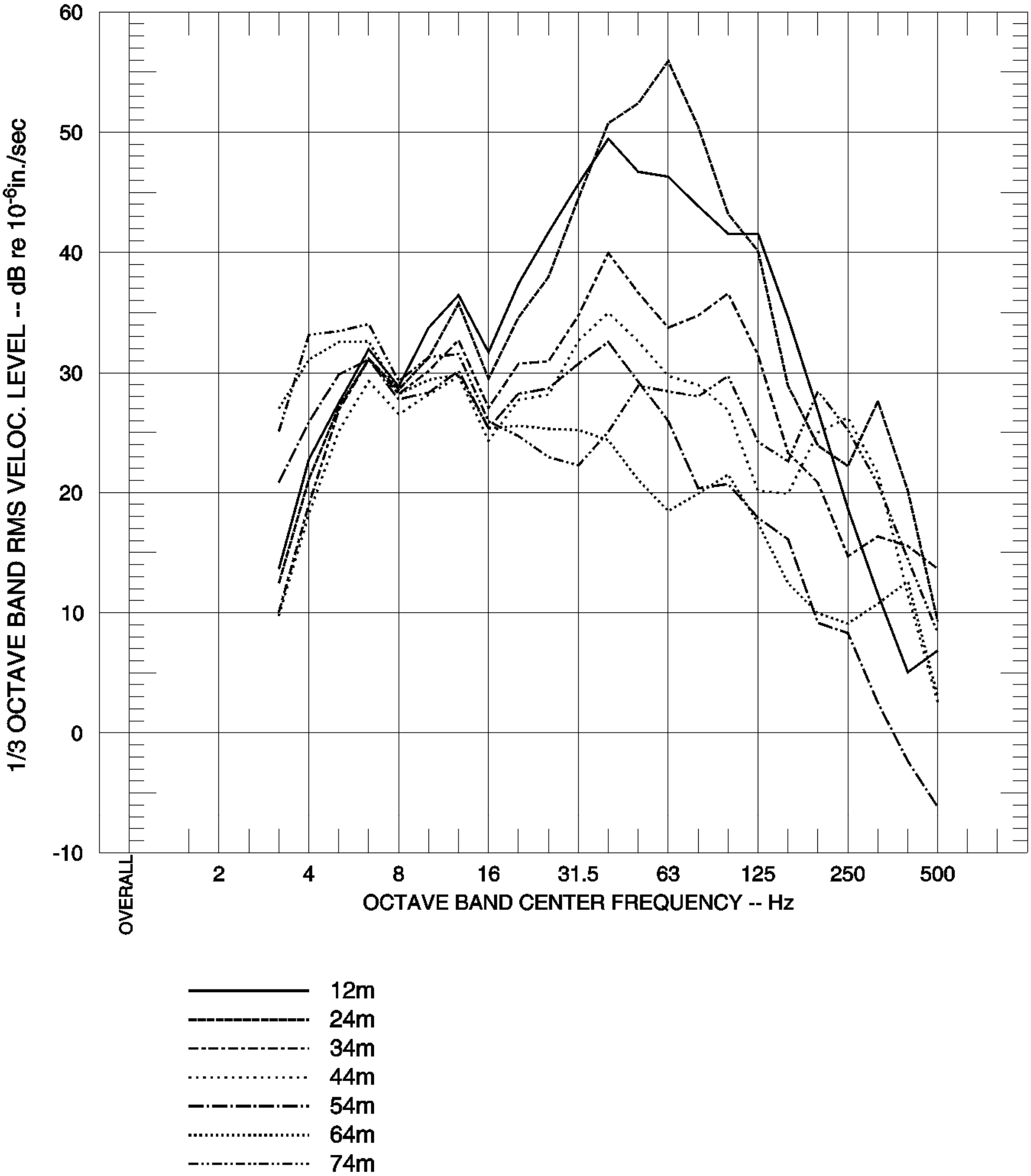

FIGURE 3 PO LAM STATION TRAIN PASSBY VIBRATION LEVELS AT DIFFERENT SETBACK

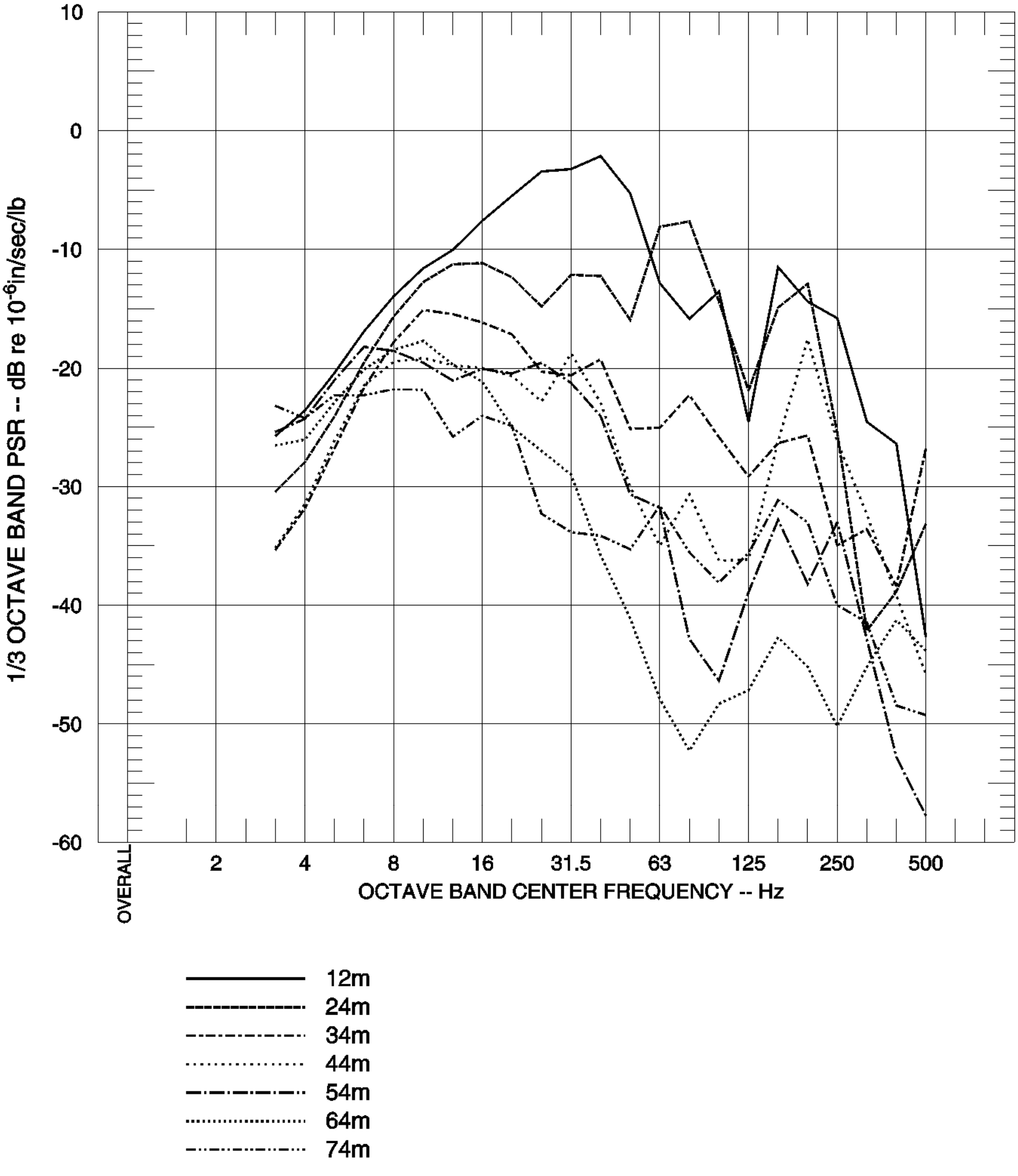

FIGURE 4 PO LAM STATION POINT SOURCE RESPONSE AT DIFFERENT SETBACK

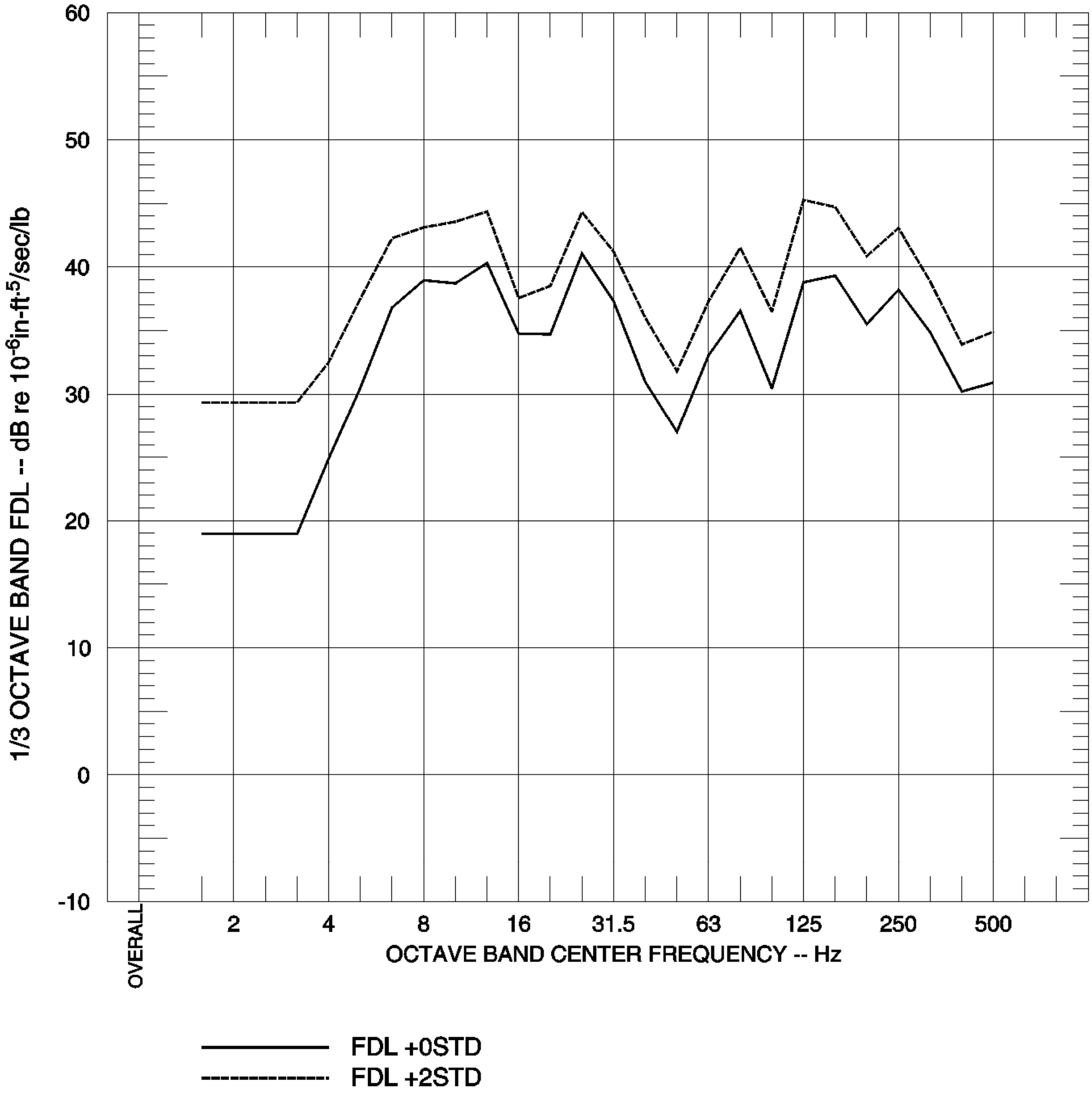

FIGURE 5 HEUNG FA TSUENG DEPOT FORCE DENSITY LEVEL

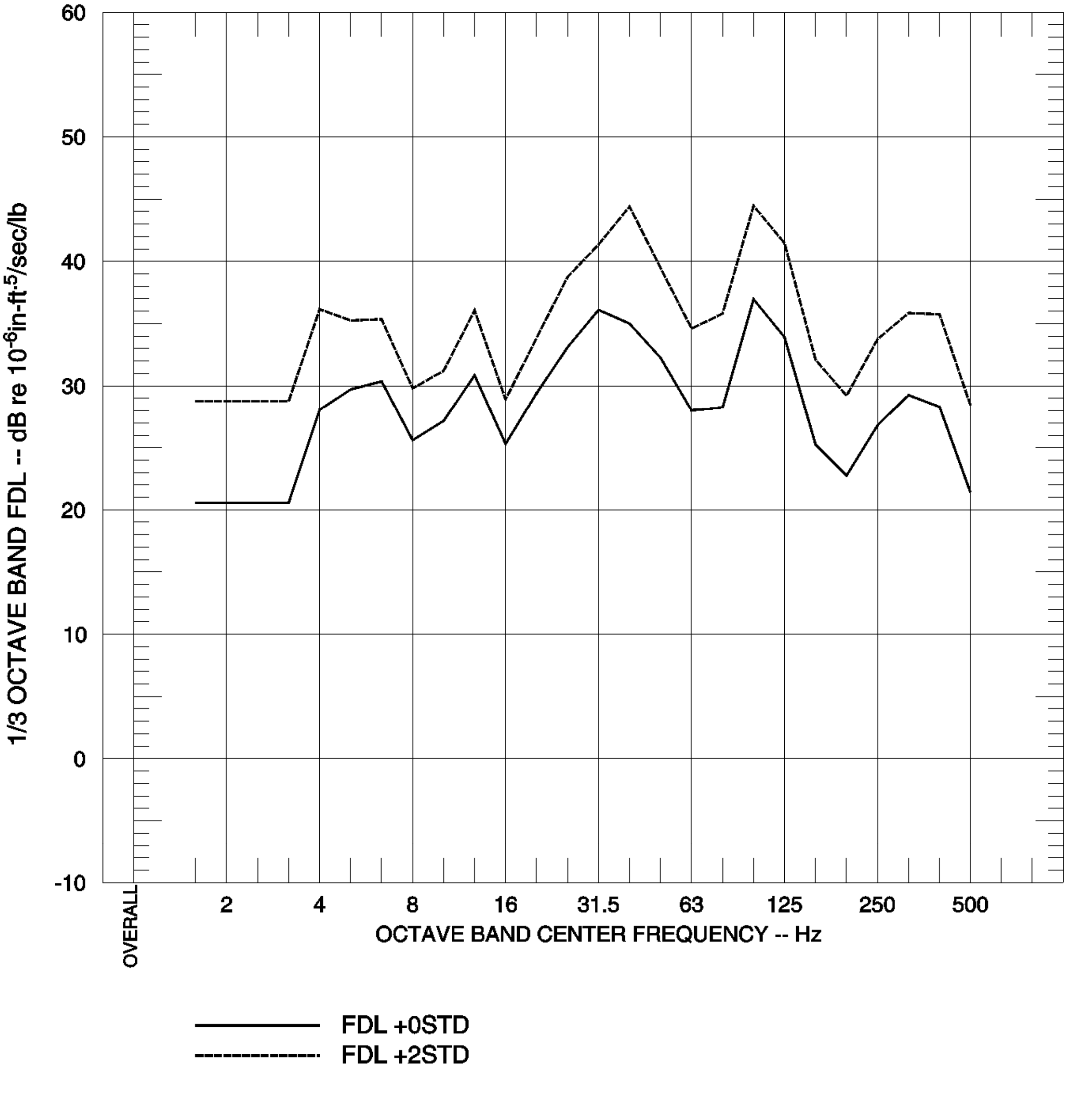

FIGURE 6 PO LAM STATION FORCE DENSITY LEVEL

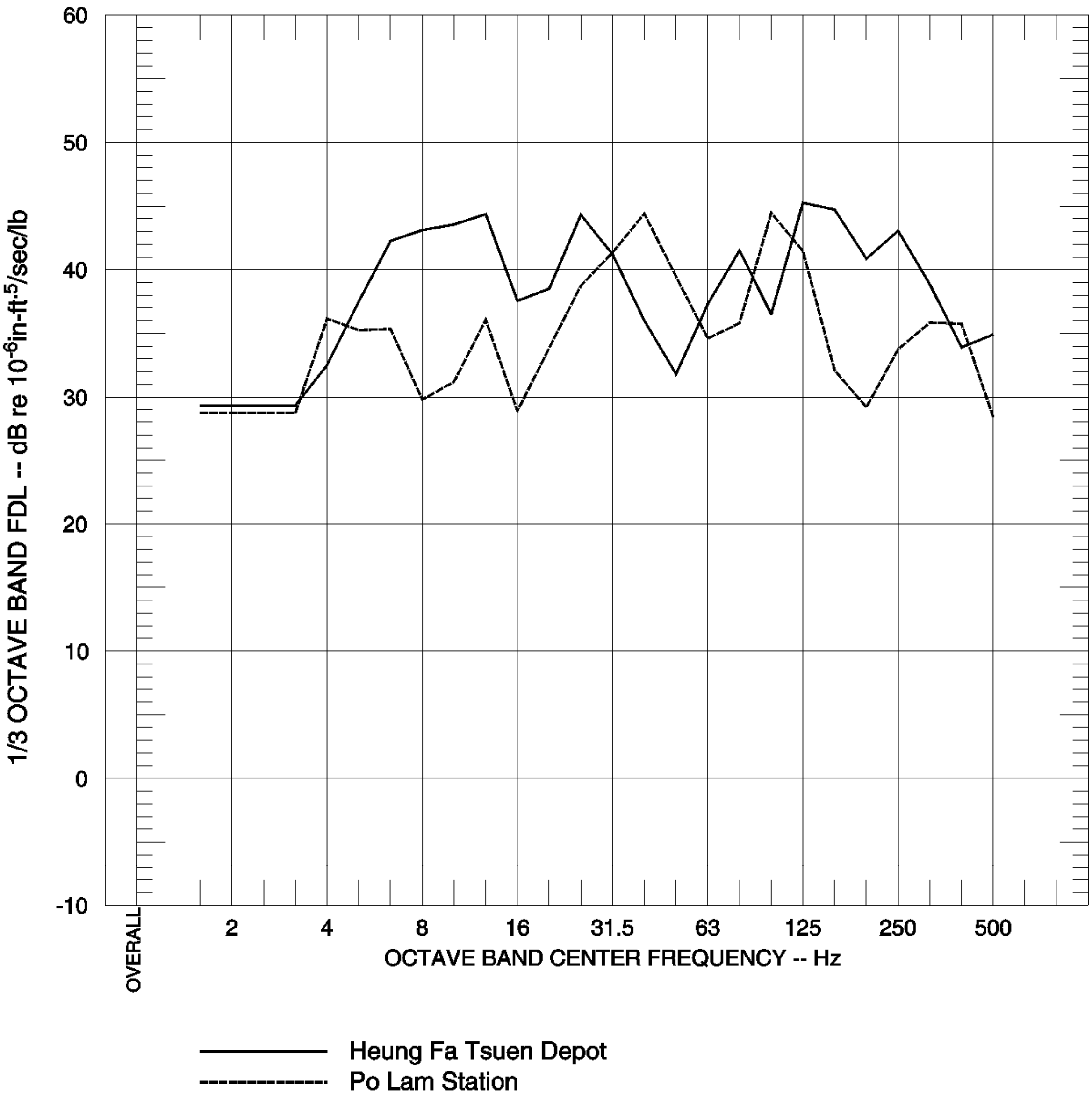

FIGURE 7 FORCE DENSITY LEVEL +2STD AT DIFFERENT LOCATION

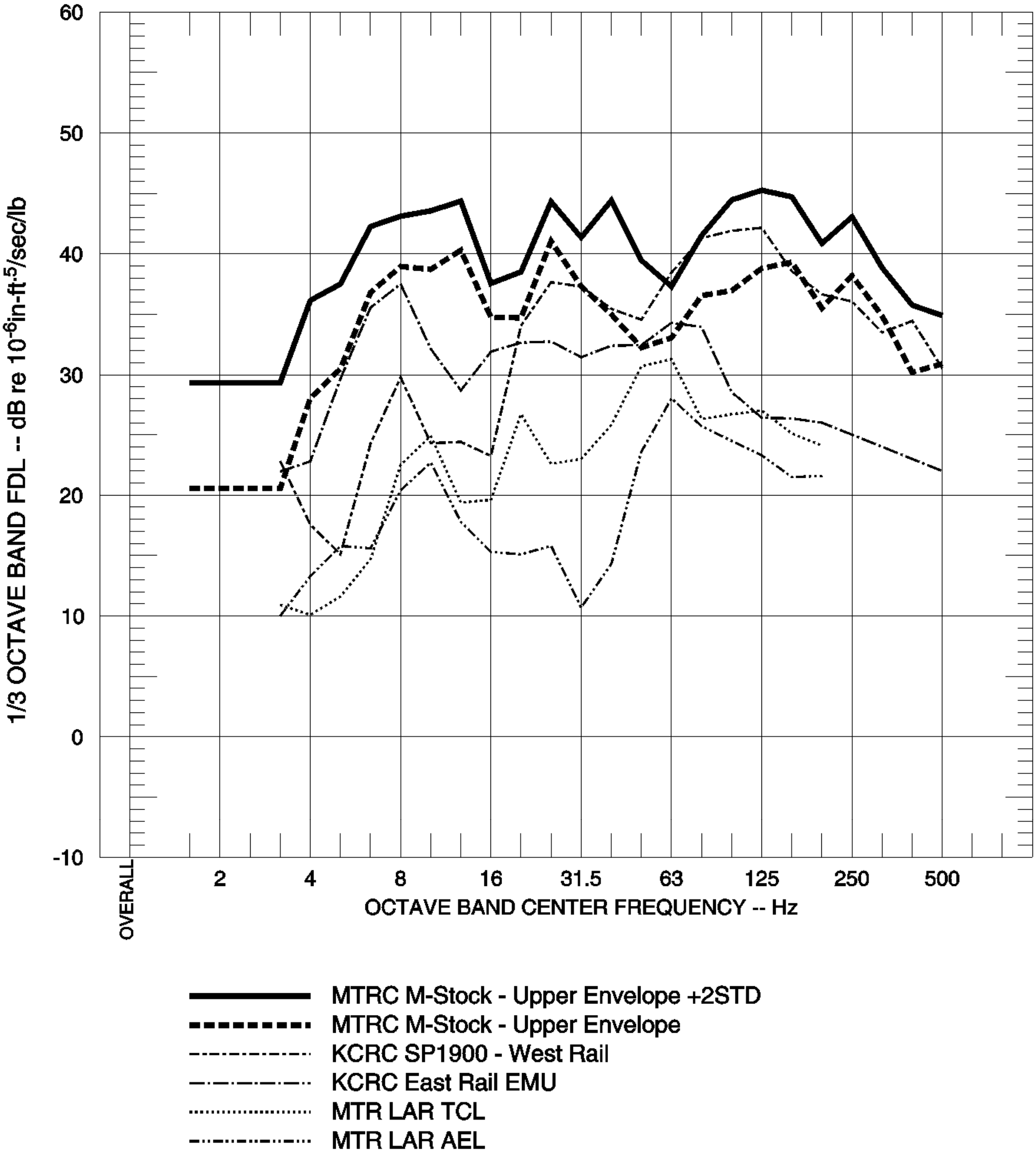

FIGURE 8 COMPARSION OF FORCE DENSITY LEVEL AT DIFFERENT LOCATION

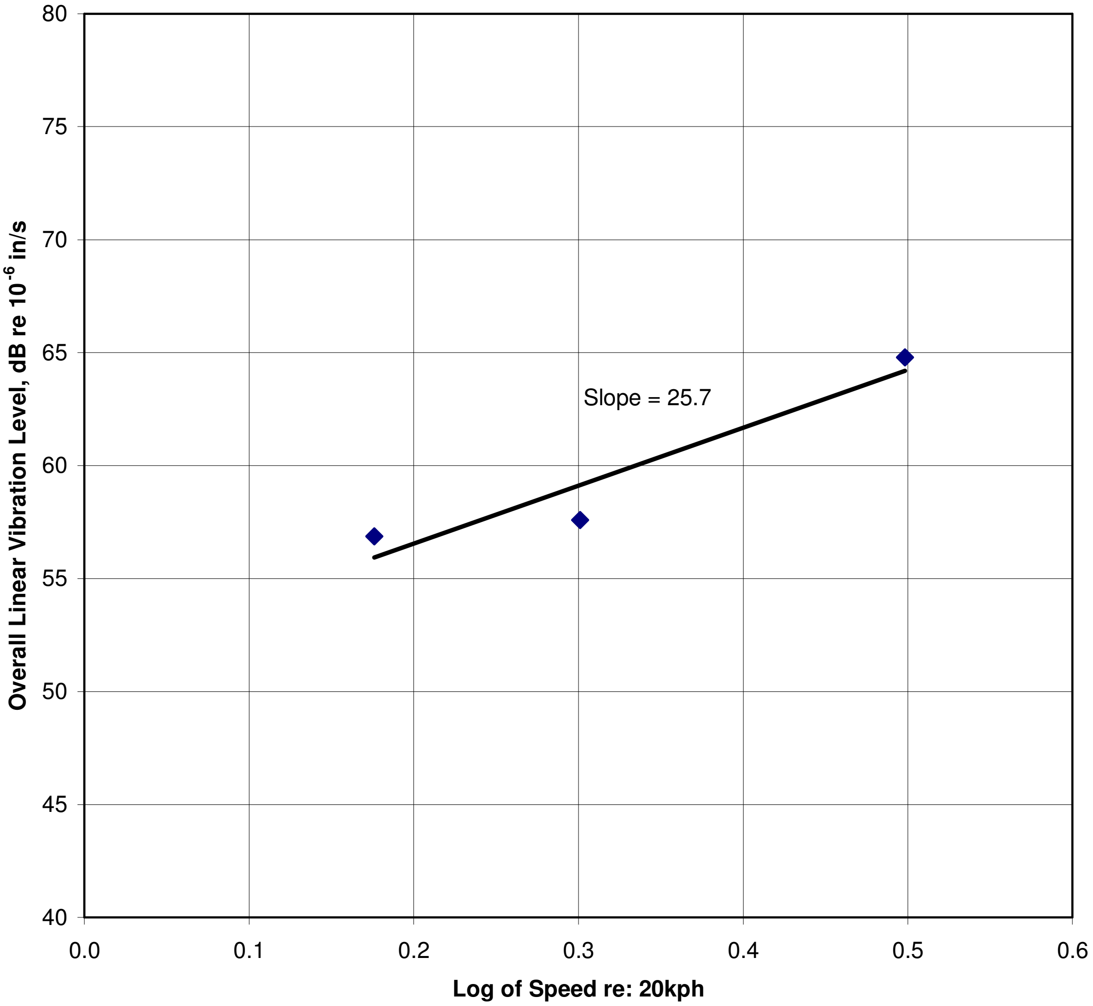

FIGURE 9 SPEED CORRECTION FOR OVERALL LINEAR VIBRATION LEVEL

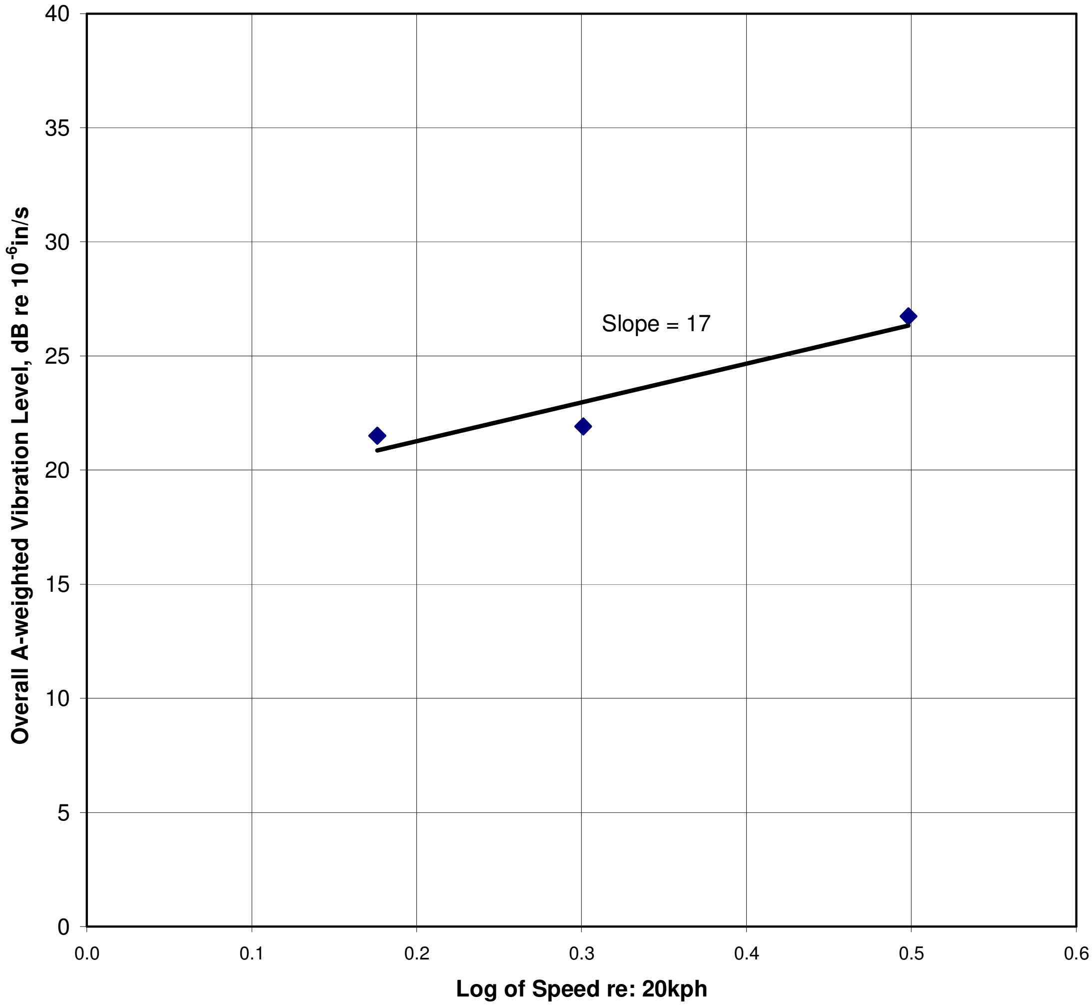

FIGURE 10 SPEED CORRECTION FOR OVERALL A-WEIGHTED VIBRATION LEVEL

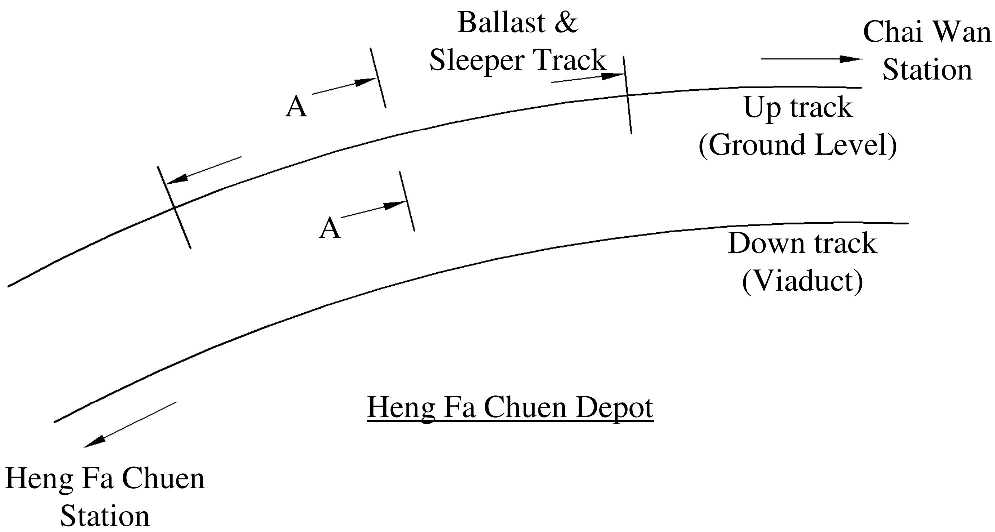

FIGURE 11 SCHEMATIC ARRANGEMENT OF HENG FA CHUEN DEPOT FDL MEASUREMENT

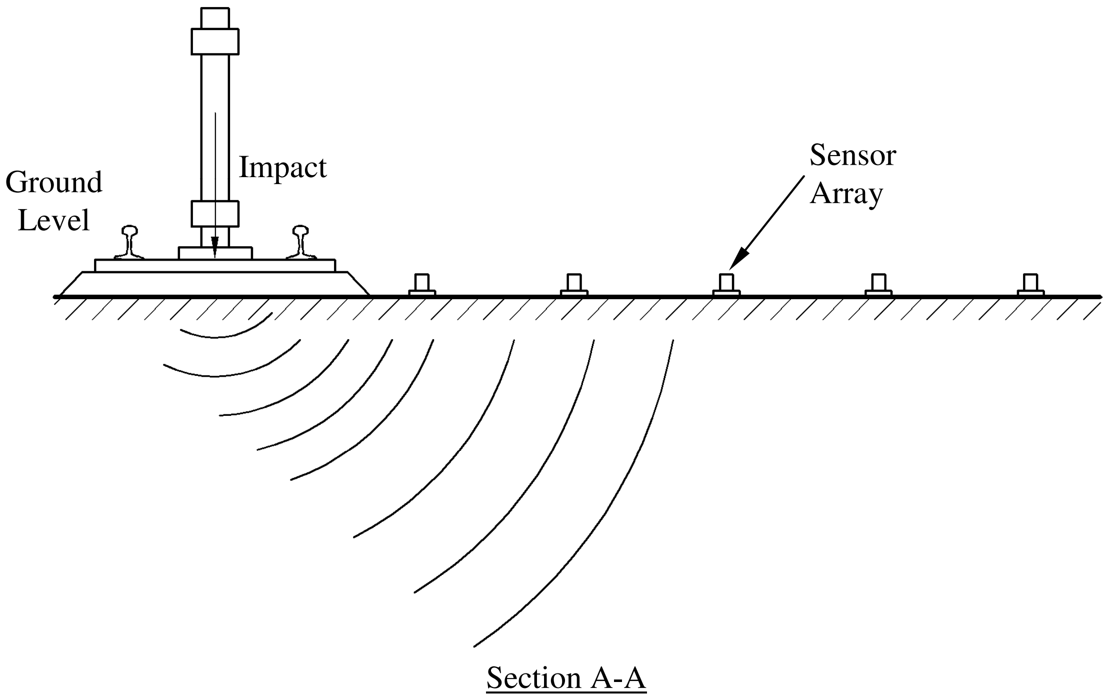

FIGURE 12 SECTION VIEW OF HENG FA CHUEN DEPOT FDL MEASUREMENT