WILSON, IHRIG & ASSOCIATES, INC.
ACOUSTICAL CONSULTANTS

5776 BROADWAY
OAKLAND, CA
U.S.A. 94618-1531
Tel: (510) 658-6719
Fax: (510) 652-4441
E-mail: swolfe@wiai.com
www.wiai.com

SLAC SECTOR 20 OFF-AXIS INJECTOR PROJECT

VIBRATION MEASUREMENT RESULTS

29 April 2004

Submitted to:

Mr. Steven Hill
Project Manager
Jacobs Civil, Inc.
5757 Plaza Drive, Suite 100
Cypress, CA 90630

By:

William A. Pritchard
Associate

Reviewed By:

James T. Nelson, Ph.D., P.E.
Vice President

INTRODUCTION

Vibration data were collected at three positions for the Sector 20, Off-Axis Injector Laser project at the Stanford Linear Accelerator Center (SLAC) on April 8, 2004. Vibration velocity data for ambient and single-event conditions were analyzed and compared with vibration velocity criteria presented in our March 7, 2004 letter, "Vibration Criteria for SLAC LCLS Project."

MEASUREMENT LOCATIONS

The three vibration measurement positions for the Sector 20 project are shown in Figure A-1 (street level) and A-2 (lower level) in Appendix A, and described in Table I below. Measurements were made on the concrete slab of the existing street-level room and lower-level vault.

TABLE I MEASUREMENT POSITIONS FOR SECTOR 20 VIBRATION SURVEY

Position Designation	Position Description	Sector 20 Level	Distances from East & South Walls (Ch.1-3)**	Distances from East & South Walls (Ch.4)**
Pos.1	Street Level - East	Upper - Roadway	125 in & 117 in	125 in & 195 in
Pos.2	Street Level - West	Upper - Roadway	240 in & 116 in	240 in & 194 in
Pos.3	Lower Level - Injector Hall	Lower - Injector Hall	76 in from S. Wall, Centered on N. Penetration	38 in from S. Wall, Centered on N. Penetration

** See Figures A-1 and A-2 for visual comparison. Note also the difference in locations at street level of the building's East Wall at the time of measurements and for the proposed new building.

INSTRUMENTATION

Simultaneous measurements were made with four Wilcoxon Research Seismic Accelerometers (Types 731 and 731A). The accelerometers were individually mounted inside aluminum brackets and then adhered to the concrete floor with wax. The accelerometer signals were amplified with WIA Type 222, 2-channel, decade amplifiers. The output of each channel from the decade amplifier was recorded on a Teac Model RD 135T, 8-channel digital audio tape (DAT) recorder. The decade amplifier outputs were also split and integrated with WIA Type 402, 2-channel, selectable high-pass filter integrators to provide a direct recording of vibration velocity on the remaining four channels of the 8-channel recorder.

The four channels of recorded vibration velocity data were analyzed simultaneously with two, 2-channel Larson Davis Laboratories Type 2900B Real Time Analyzers, which generated 1/3 octave band, RMS velocity levels and statistics for comparison with appropriate criteria. The analyzed data were stored on a Pentium based personal computer for further processing and plotting of the data.

Appendix B presents specific details on the vibration instrumentation and calibrations used for these measurements. Calibrations were made using a reference accelerometer that is tested annually at a NIST-certified calibration facility.

FIELD PROCEDURE

Four-channel measurements were made at all measurement positions. First, a tri-axial array was positioned according to the right-hand rule, with vertical, longitudinal (parallel to the beam, pointing east), and transverse (horizontally perpendicular to the beam, pointing north) orientations for the transducers. Then, a fourth transducer, also with vertical orientation, was positioned 1 or 2 meters from the first vertical transducer, along a line perpendicular to the beam, to provide comparative data and allow more complex future analysis if necessary.

Minimum 10-minute, ambient recordings were made at each of the three positions shown in Figure A-1 and A-2. While these recordings included passage of light vehicles and the occasional heavy vehicle, additional single-event sources were recorded separately. These sources included foot steps, banging/opening of doors and gates, and passes by a tractor cab and loaded dump truck. Analyses of all recordings were performed in the WIA laboratory and included computation of statistical vibration velocity levels for the 10-minute ambient samples (using a one-second integration time). Single-event sources were analyzed by computing the equivalent continuous RMS velocity level, averaged over two to four seconds, for each event.

Statistical levels are reported according to the Ln level, which represents the vibration velocity level exceeded during n% of the sample period. For example the L1, L10, L50, and L90 give the velocity level exceeded during 1%, 10%, 50%, and 90% of the sample period, respectively. Single-event plots show only the equivalent continuous rms level for each event, averaged over two to four seconds, depending on the event's duration.

More detailed definitions for these and other acoustical and vibration terms can be found in the Glossary in Appendix C.

CRITERIA

Measurement data are compared with several criteria curves discussed in our March 7, 2004 letter "Vibration Criteria for SLAC LCLS Project." Three curves, labeled IES VC-C (500 micro-in/sec), IES VC-D (250 micro-in/sec), and IES VC-E (125 micro-in/sec), originate from the Institute of Environmental Sciences (IES) publication *Recommended Practice IES-RP-CC012.1*. A fourth curve, below the other three and labeled "Sub VC-E (40 micro-in/sec)," is custom for this project and is the most restrictive of the presented criteria. All plots of the measurement data show these four criteria curves for comparison.

RESULTS AND DISCUSSION

The results of the statistical ambient and single-event vibration analyses are presented in Figures 1A to 9D, with single-event, overall vibration levels also summarized in Table II below. Figures show spectral plots of 1/3 octave band vibration velocity level verses 1/3 octave band center frequency. Each figure number, 1 to 9, has four corresponding letter designations, A to D, for data from Channel 1 - vertical (A), Channel 2 - parallel to beam (B), Channel 3 - horizontally perpendicular to beam (C), and Channel 4 - vertical at 1 or 2 m from Channel 1 (D). For ease of comparison, all plots also have the same full scale (70 dB) and show the four criteria curves discussed above.

Results from Statistical Analyses

Statistical vibration levels from the 10-minute, ambient recordings are shown in Figures 1 to 3, for Positions 1 to 3, respectively. See Figures A-1 and A-2 and Table I above for details of the measurement positions.

For sources including mechanical and electrical equipment and vehicle passbys, street-level Positions 1 and 2 show greater vibration levels than does Position 3 on the lower level. Vehicle passbys, including mini-vans and light trucks, show up most clearly in the L1 curves in the figures, because the L1 most closely resembles the maximum event vibration level during the sample period. Levels for the horizontal accelerometers (in figures labeled B and C, or CH.2 and CH.3) were substantially below those for the vertical accelerometers for all measurements.

At Positions 1 and 2, the Channel 4 accelerometer location was 2 m closer to the roadway than the Channel 1 location. Higher resulting vibration levels from vehicle passbys at Channel 4 are shown in the figures for both of these positions.

Overall, exceedances of the of the IES VC-E (125 micro-in/sec) curve are unusual within the statistical results. Only Figures 2A and 2D, which present vertical data from Position 2, show spectra exceeding the IES VC-D curve. Sources of these exceedances are vehicles striking the steal plates crossing the service roadway west of the Sector 20 building, and several pumps in the area. Similarly, all exceedances of even the “Sub VC-E (40 micro-in/sec)” curve appear to be caused by these same two sources.

Results from Single-Event Analyses

Data were captured for several single-event sources, including repeated passes by a medium-sized dump truck loaded with gravel and a semi-truck tractor cab (no trailer attached). Both of these vehicles had a single rear axle. Data were also collected for rolling and slamming of a large door, labeled 20-5, located immediately east of the Sector 20 building, along the north wall of the beam hall structure. Vibration data from walking on the upper- and lower-level slabs and connecting stairs were also collected. Other sources were measured, but not reported here because of very low corresponding vibration levels or because the source will be removed as part of the Sector 20 project.

Table II below presents a summary of single-event vibration levels collected by the Channel 1 accelerometer at each measurement position. See Figures A-1 and A-2 for position details. Spectral data for the sources of greatest interest - the dump truck and tractor cab - are shown in Figures 4A to 9D. Separate figures are shown for each measurement channel and measurement position. Spectra are shown for individual samples of the trucks passing the Sector 20 building and for the same trucks striking the steal plates crossing the service roadway west of the Sector 20 building. Note that spectra in Figures 4, 6, and 8 do not include influence from the steal plates, and instead show only the highest vibration levels created by the vehicles passing directly in front of the Sector 20 building. In contrast, Figures 5, 7, and 9 show only the vibration levels created as the trucks struck the steal plates, which are to be removed as part of the Sector 20 project.

All single-event figures show vertical vibration levels that are consistently higher than those from horizontal measurement channels. For Positions 1 and 2, maximum levels from truck passbys (not including the effects of the steal plates) typically equaled IES VC-E at Channel 1 and IES VC-D at Channel 4, which was 2 m closer to the roadway than Channel 1. Single-event levels from Position 3 (lower level) were lower than those from Positions 1 and 2 (street level).

TABLE II MAXIMUM RMS VIBRATION VELOCITIES FROM SINGLE-EVENT SOURCES - OVERALL LEVELS (Data from Channel 1 Accelerometer Only)

Ch.1 Position	**Description of Single-Event Source** (Figure Referenced Parenthetically where Applicable)	**Overall Vibration Velocity Level** (dB re: 10^{-6} in/sec)
Pos.1	Dump Truck and Tractor Cab Passing Building (Fig.4A)	44-51
	Dump Truck and Tractor Cab Striking Steal Plates (Fig.5A)	64-72
	Large Door (20-5), Rolling	50-55
	Large Door (20-5), Slamming Shut	67-69
	Walking, Small Doors, Footsteps on Stairs, etc.	43-48
Pos.2	Dump Truck and Tractor Cab Passing Building (Fig.6A)	43-58
	Dump Truck and Tractor Cab Striking Steal Plates (Fig.7A)	59-70
	Large Door (20-5), Rolling	43-45
	Large Door (20-5), Slamming Shut	55-56
	Walking, Small Doors, Footsteps on Stairs, etc.	43-49
Pos.3	Dump Truck and Tractor Cab Passing Building (Fig.8A)	33-45
	Dump Truck and Tractor Cab Striking Steal Plates (Fig.9A)	47-53
	Walking on Lower Level, Footsteps on Stairs, Jumping	42-49

CONCLUSION

The highest 1/3 octave band vibration velocities from both statistical and single-event data analyses are typically between the IES VC-D (250 micro-in/sec) and IES VC-E (125 micro-in/sec) criteria curves for sources that will remain after completion of the Sector 20 project. Higher levels were generated by a loaded dump truck and semi-truck tractor cab striking the existing steal plates located west of the project building, but this source is to be eliminated as part of the project.

Equipment that can withstand vibration velocities of IES VC-C (500 micro-in/sec) or greater can thus be used without significant concern for vibration. However, occasional sources of vibration associated with construction, repair, or other unusual activities in the immediate vicinity could certainly exceed this criteria. If equipment requiring a vibration limit below IES VC-C will be used, vibration mitigating design features should be considered and developed as part of the equipment's installation.

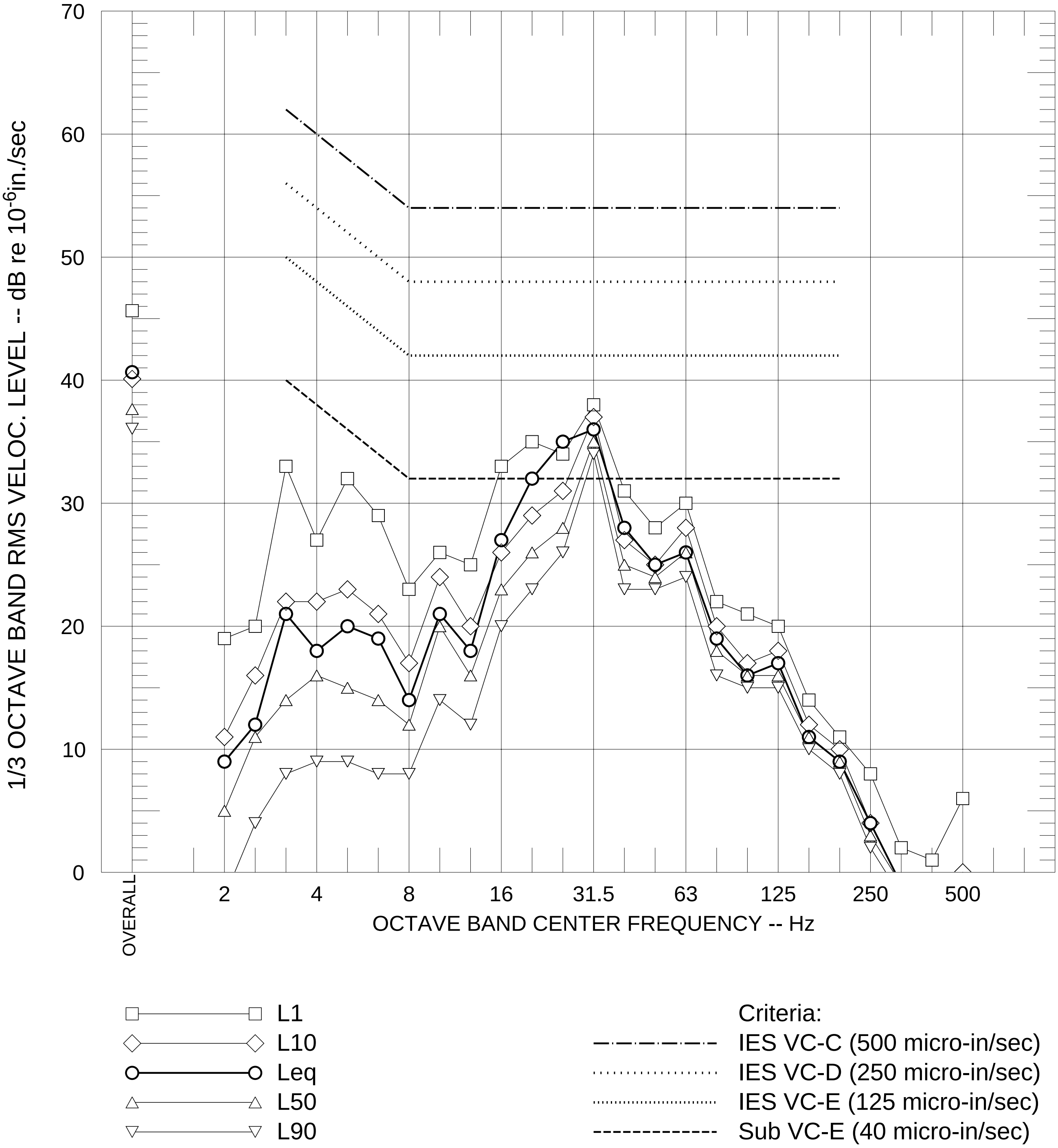

FIGURE 1A STATISTICAL VIBRATION LEVELS AT POSITION 1
CH.1 - VERTICALLY PERPENDICULAR TO BEAM HALL
STREET LEVEL - EAST

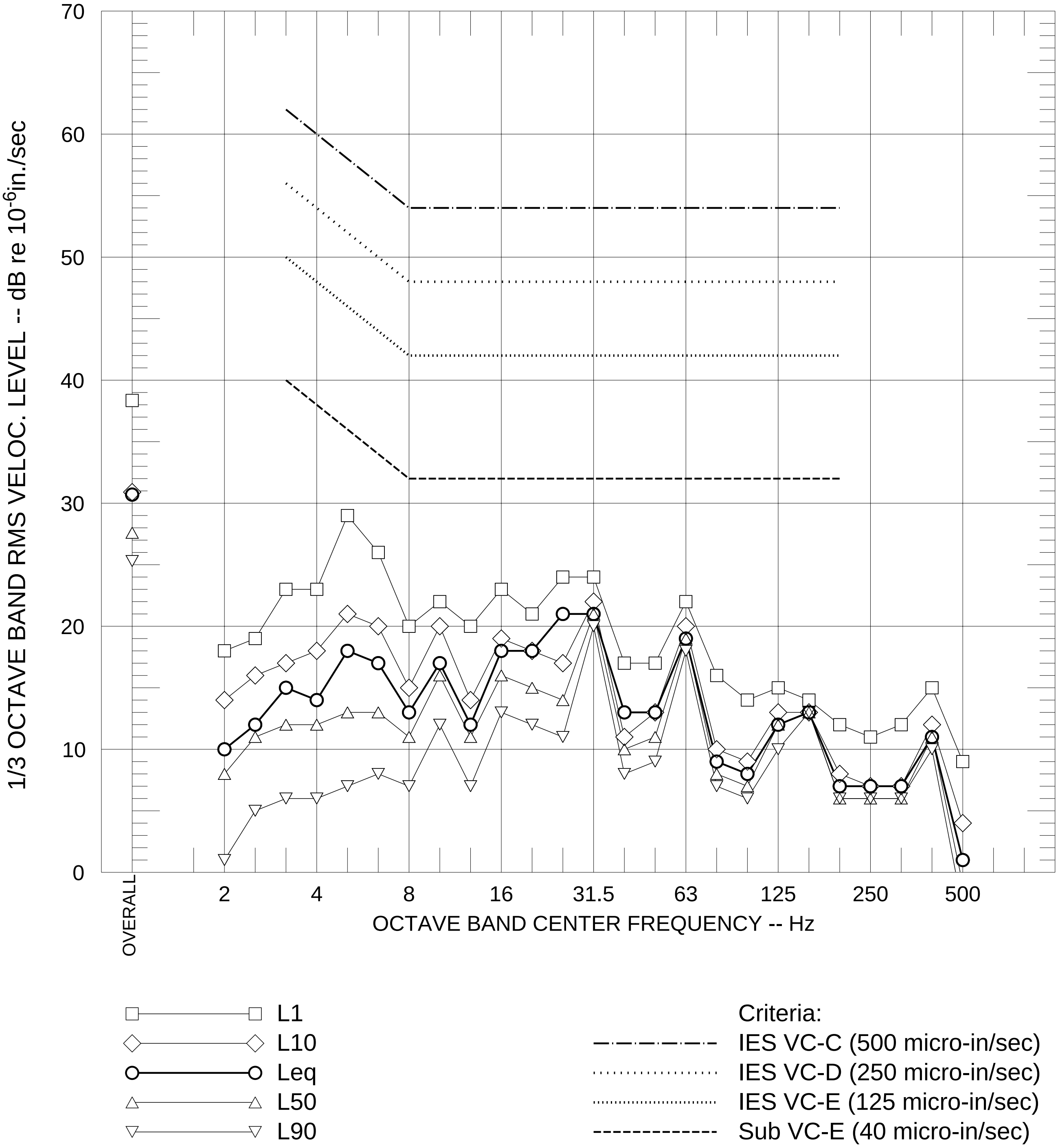

FIGURE 1B STATISTICAL VIBRATION LEVELS AT POSITION 1
CH.2 - PARALLEL TO BEAM HALL
STREET LEVEL - EAST

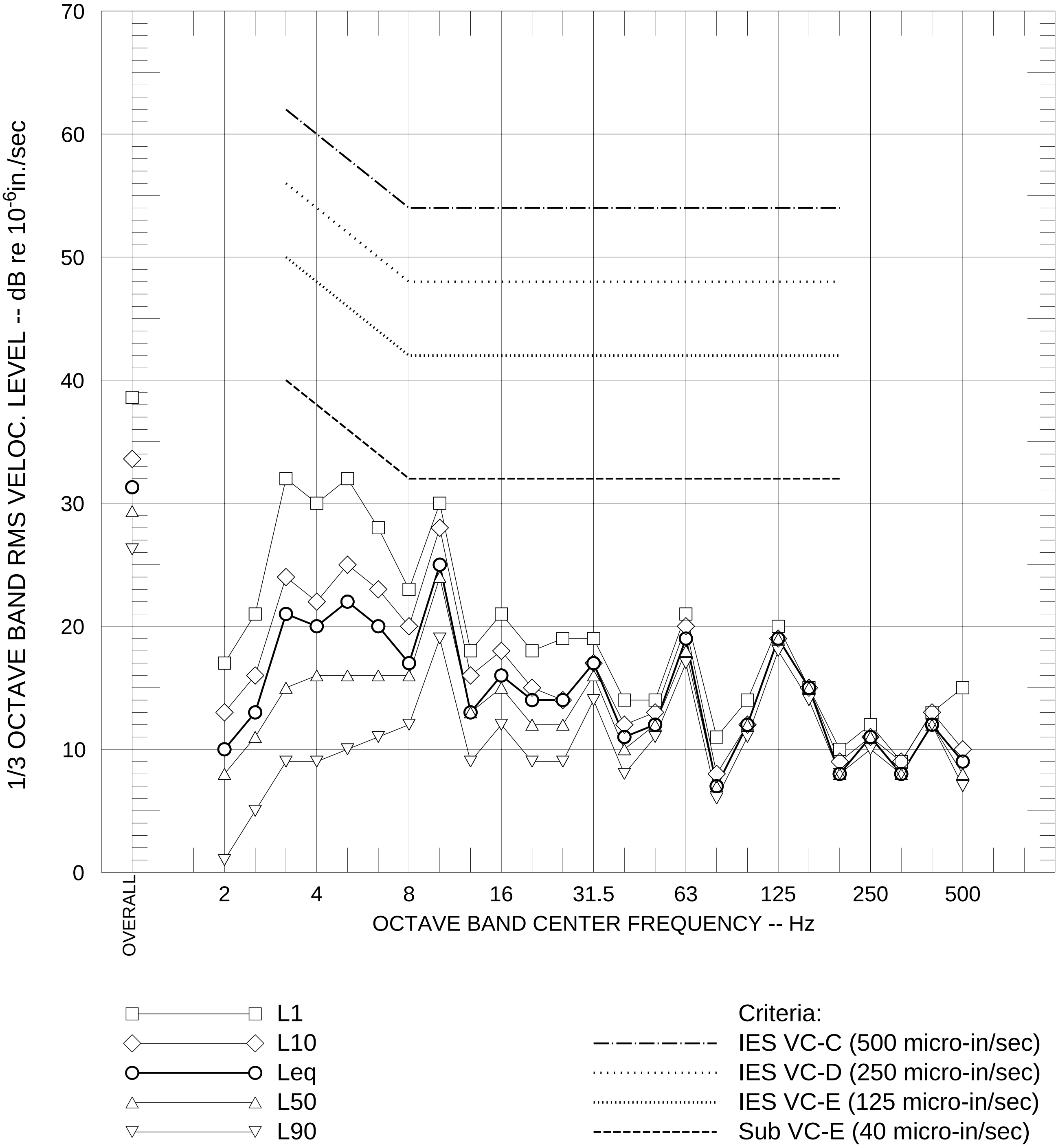

FIGURE 1C STATISTICAL VIBRATION LEVELS AT POSITION 1
CH.3 - HORIZONTALLY PERPENDICULAR TO BEAM HALL (TRANSVERSE)
STREET LEVEL - EAST

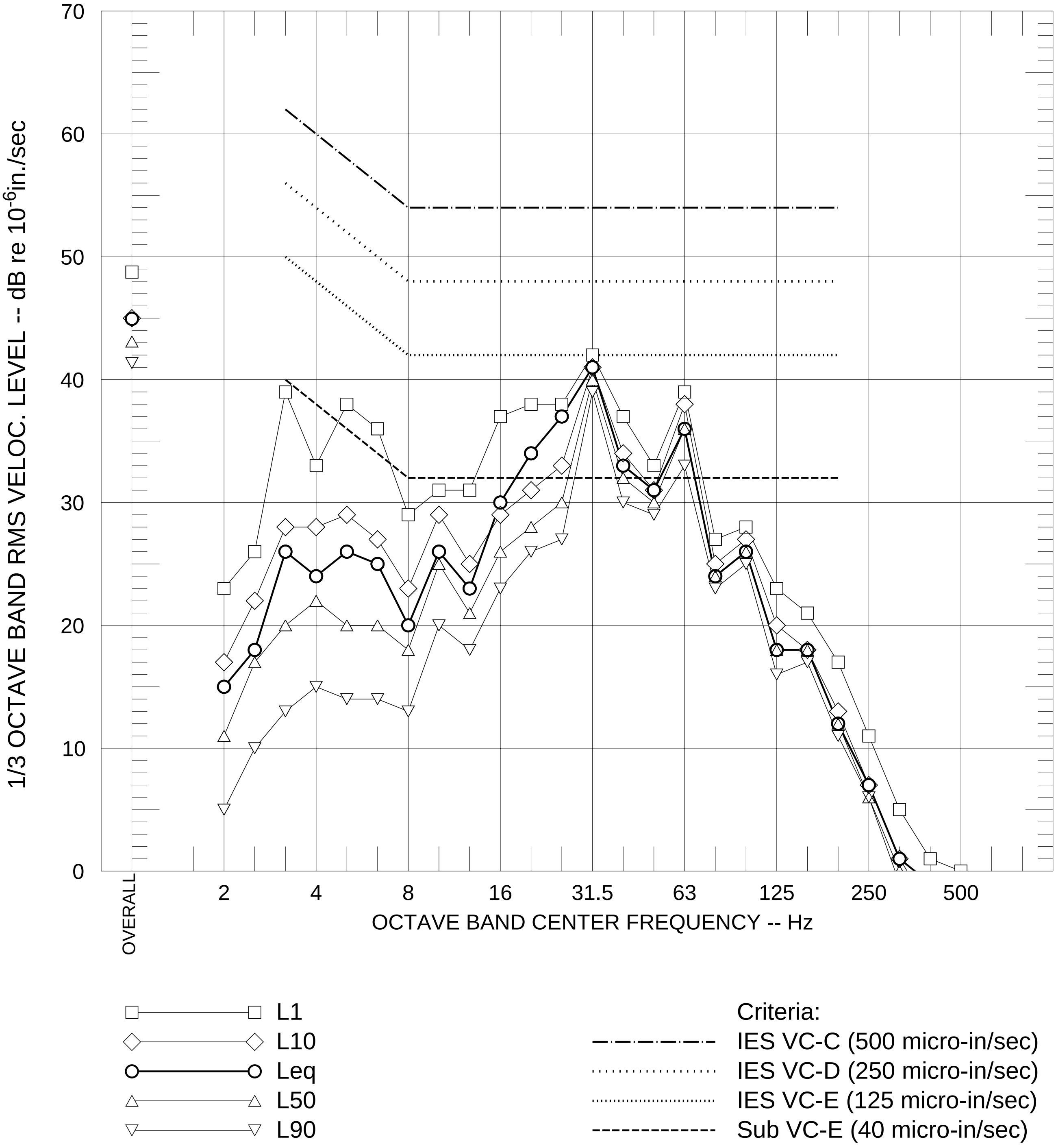

FIGURE 1D STATISTICAL VIBRATION LEVELS AT POSITION 1
CH.4 - VERTICALLY PERPENDICULAR TO BEAM HALL (at 2 m)
STREET LEVEL - EAST

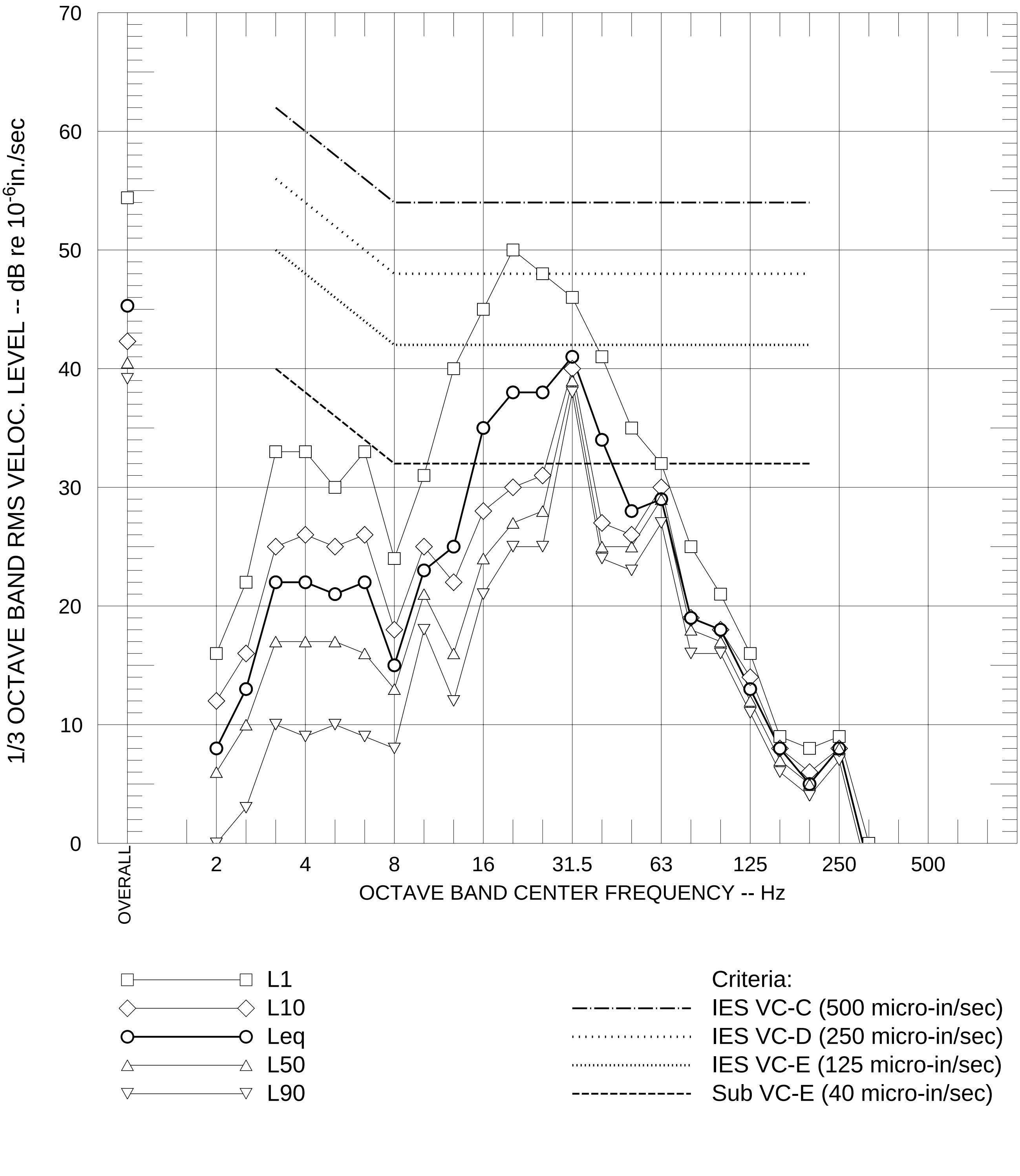

FIGURE 2A STATISTICAL VIBRATION LEVELS AT POSITION 2
CH.1 - VERTICALLY PERPENDICULAR TO BEAM HALL
STREET LEVEL - WEST

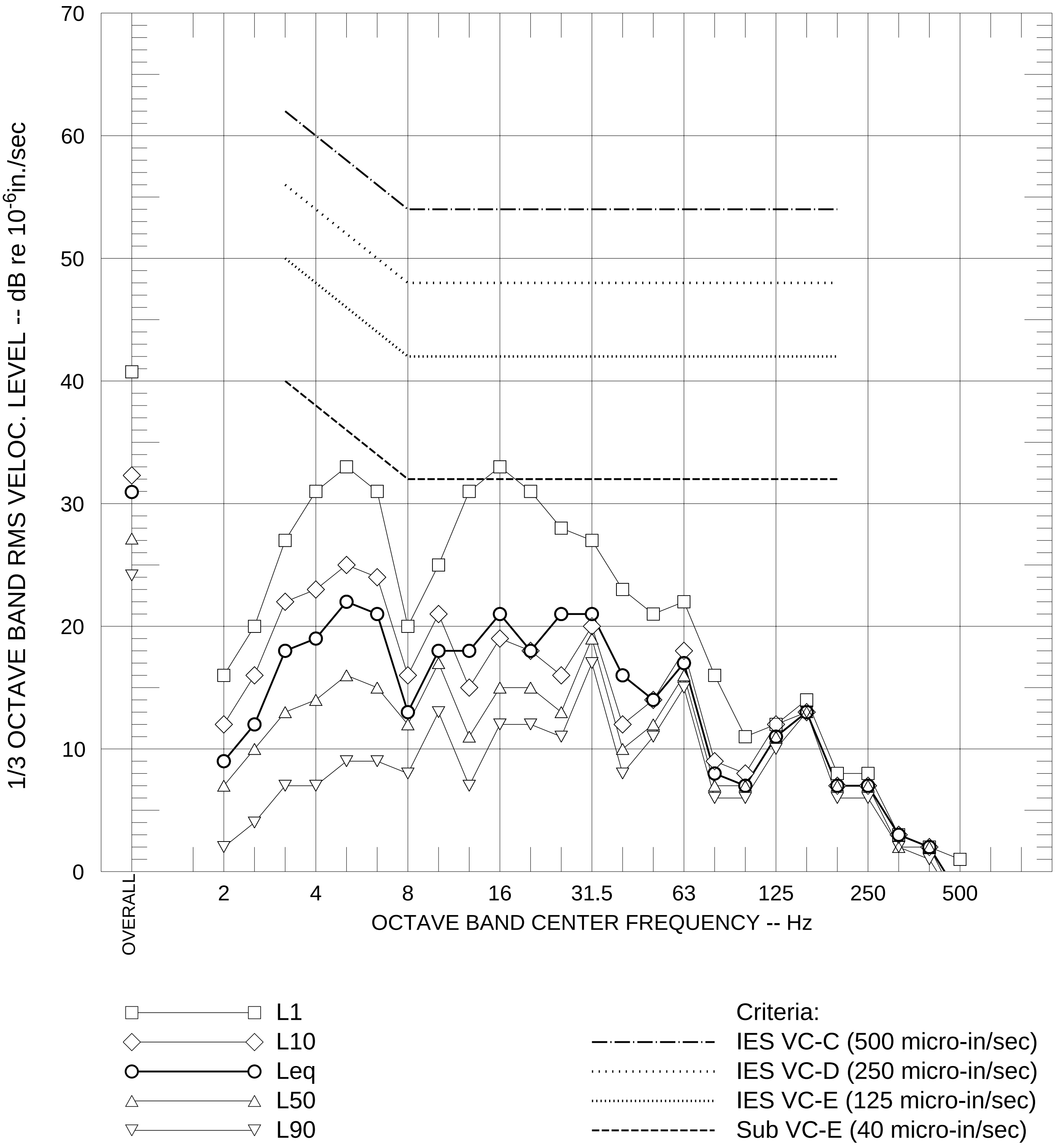

FIGURE 2B STATISTICAL VIBRATION LEVELS AT POSITION 2
CH.2 - PARALLEL TO BEAM HALL
STREET LEVEL - WEST

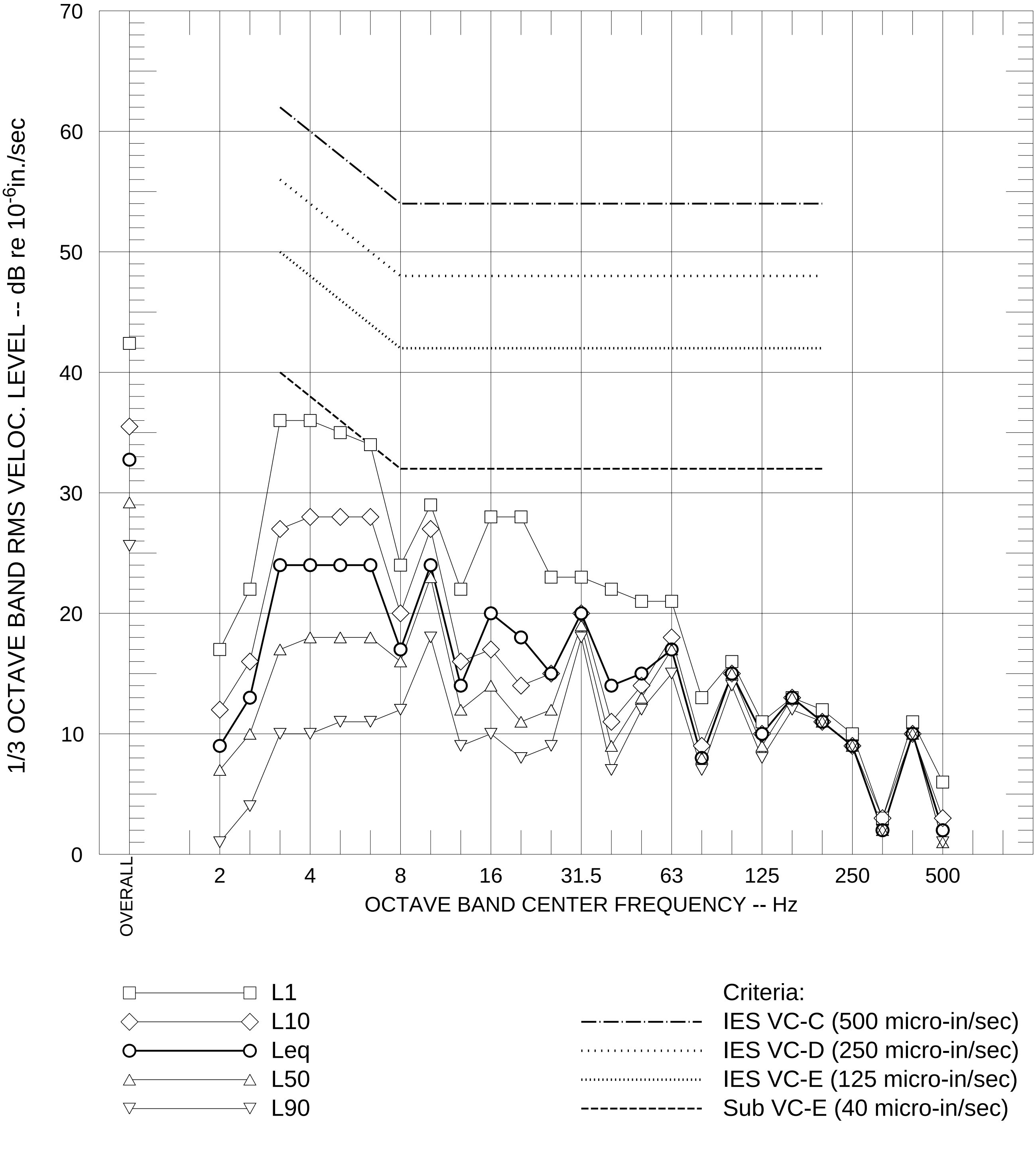

FIGURE 2C STATISTICAL VIBRATION LEVELS AT POSITION 2
CH.3 - HORIZONTALLY PERPENDICULAR TO BEAM HALL (TRANSVERSE)
STREET LEVEL - WEST

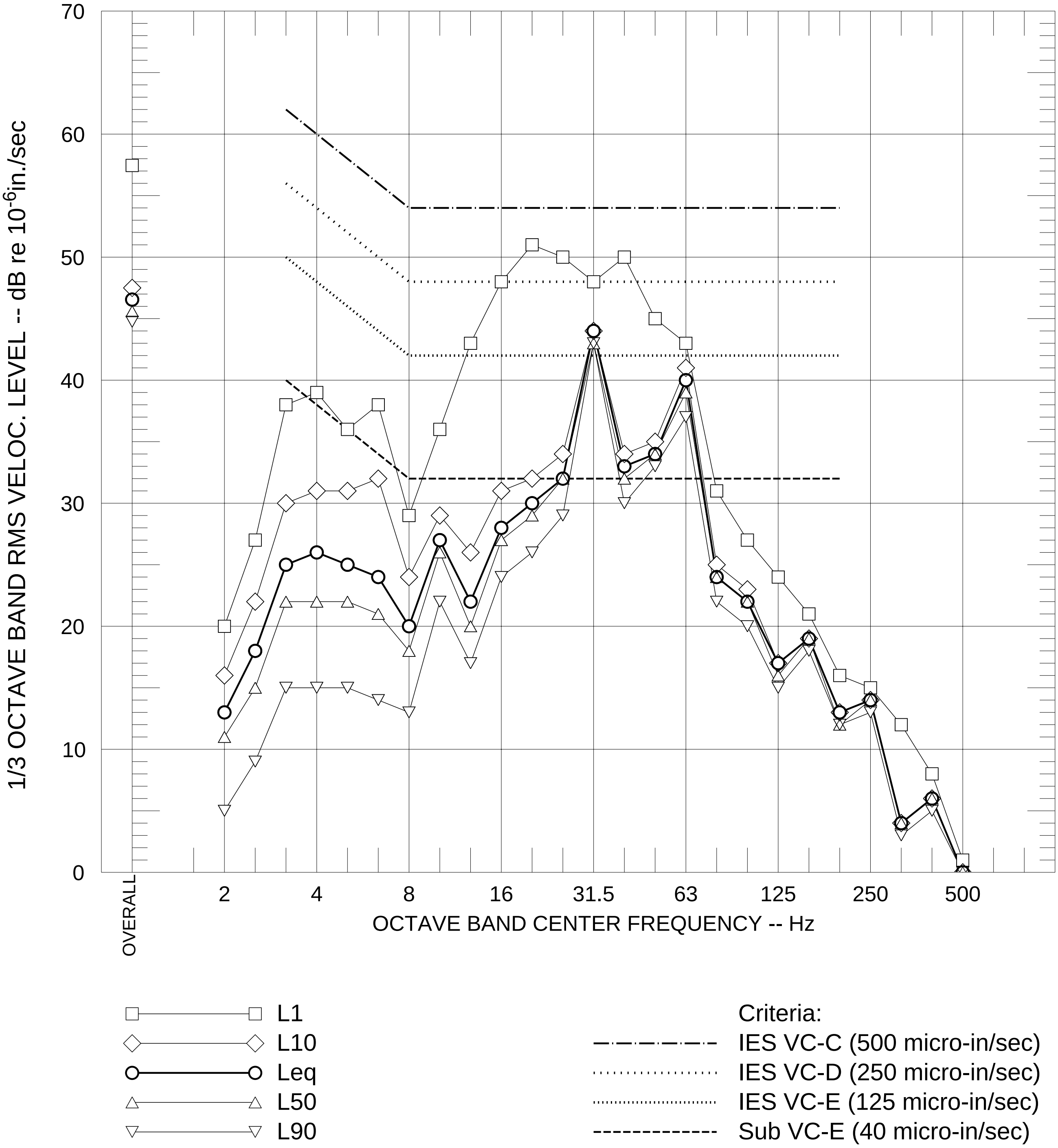

FIGURE 2D STATISTICAL VIBRATION LEVELS AT POSITION 2
CH.4 - VERTICALLY PERPENDICULAR TO BEAM HALL (at 2 m)
STREET LEVEL - WEST

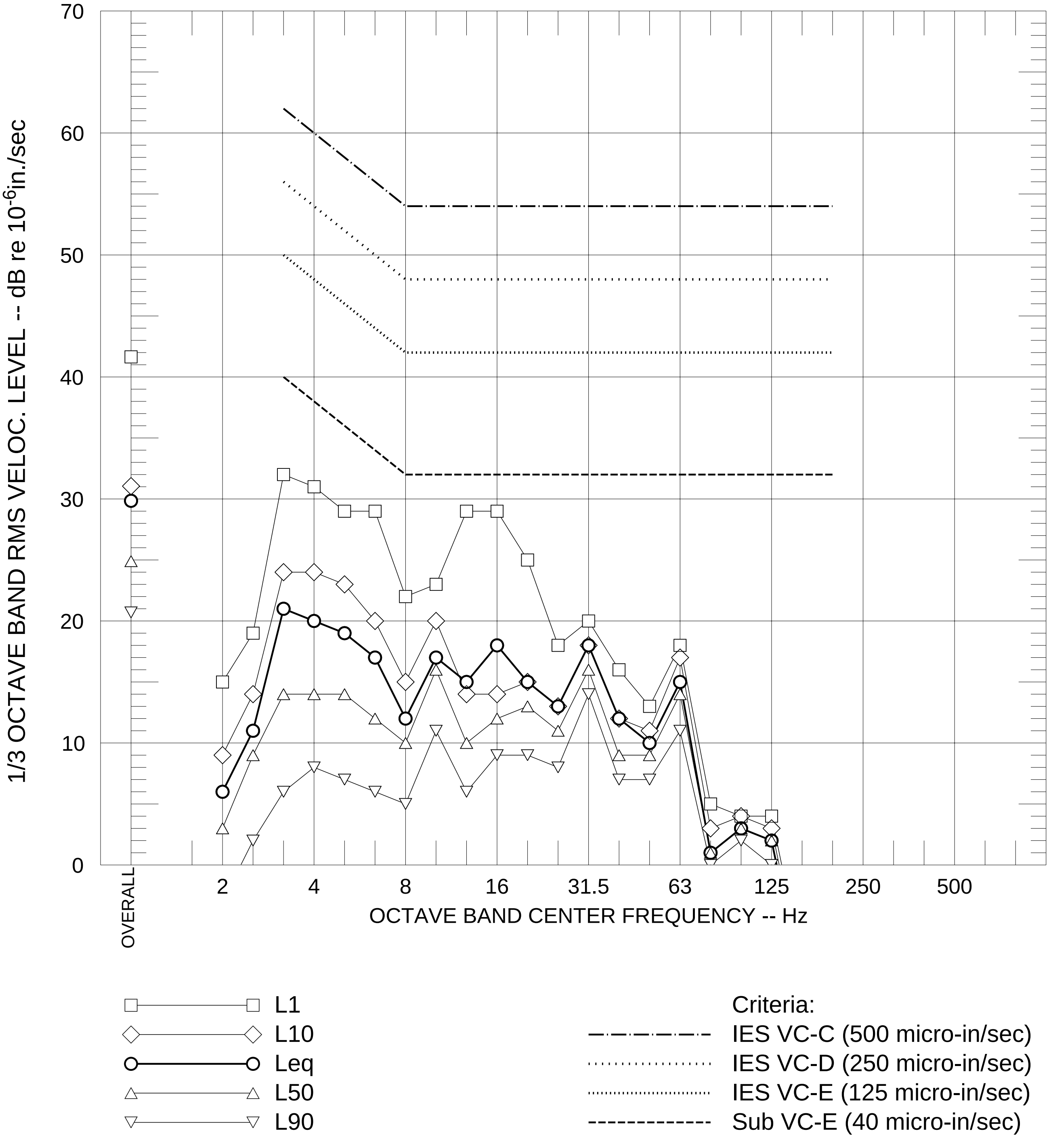

FIGURE 3A STATISTICAL VIBRATION LEVELS AT POSITION 3
CH.1 - VERTICALLY PERPENDICULAR TO BEAM HALL
LOWER LEVEL - INJECTOR HALL

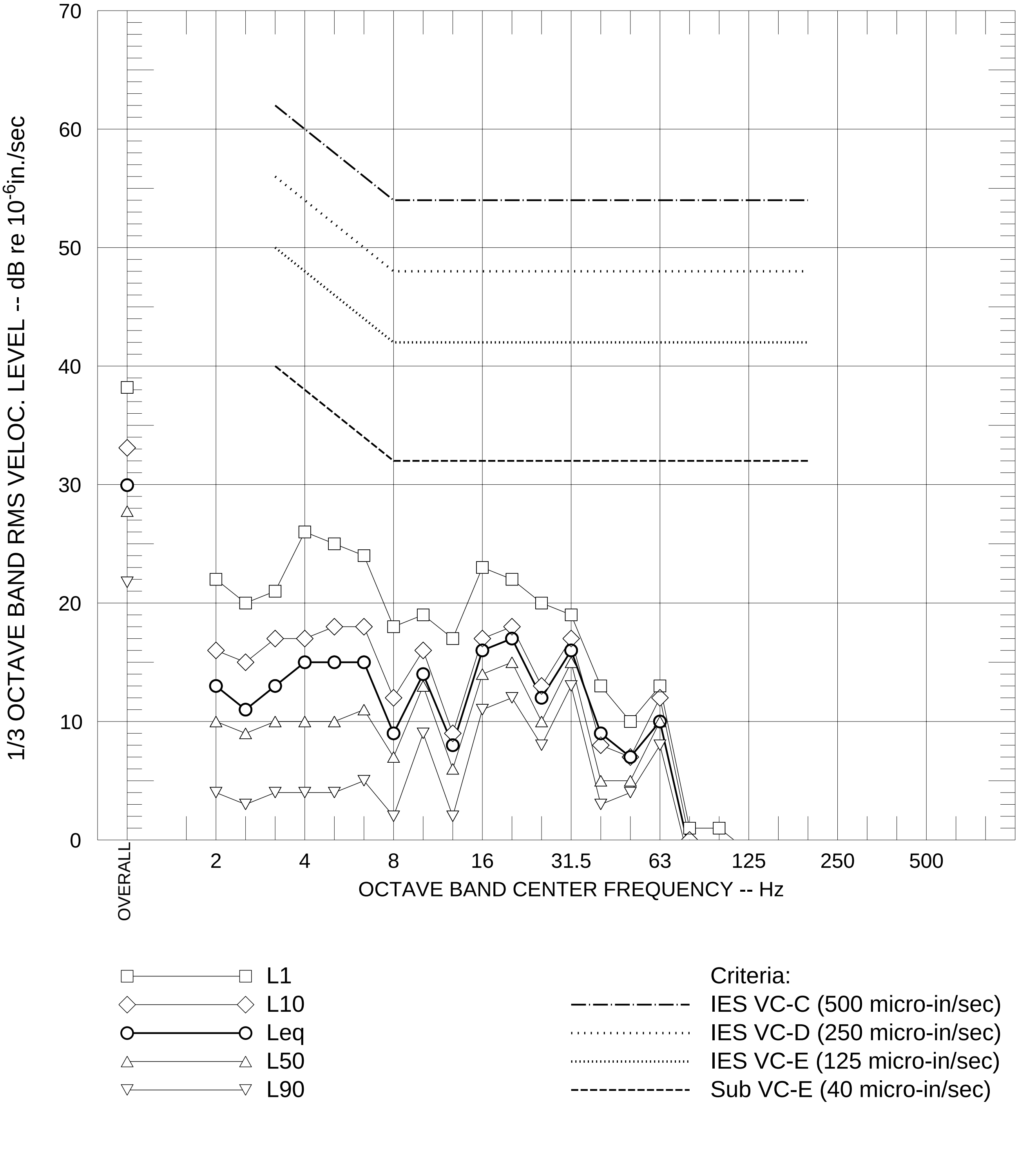

FIGURE 3B STATISTICAL VIBRATION LEVELS AT POSITION 3
CH.2 - PARALLEL TO BEAM HALL
LOWER LEVEL - INJECTOR HALL

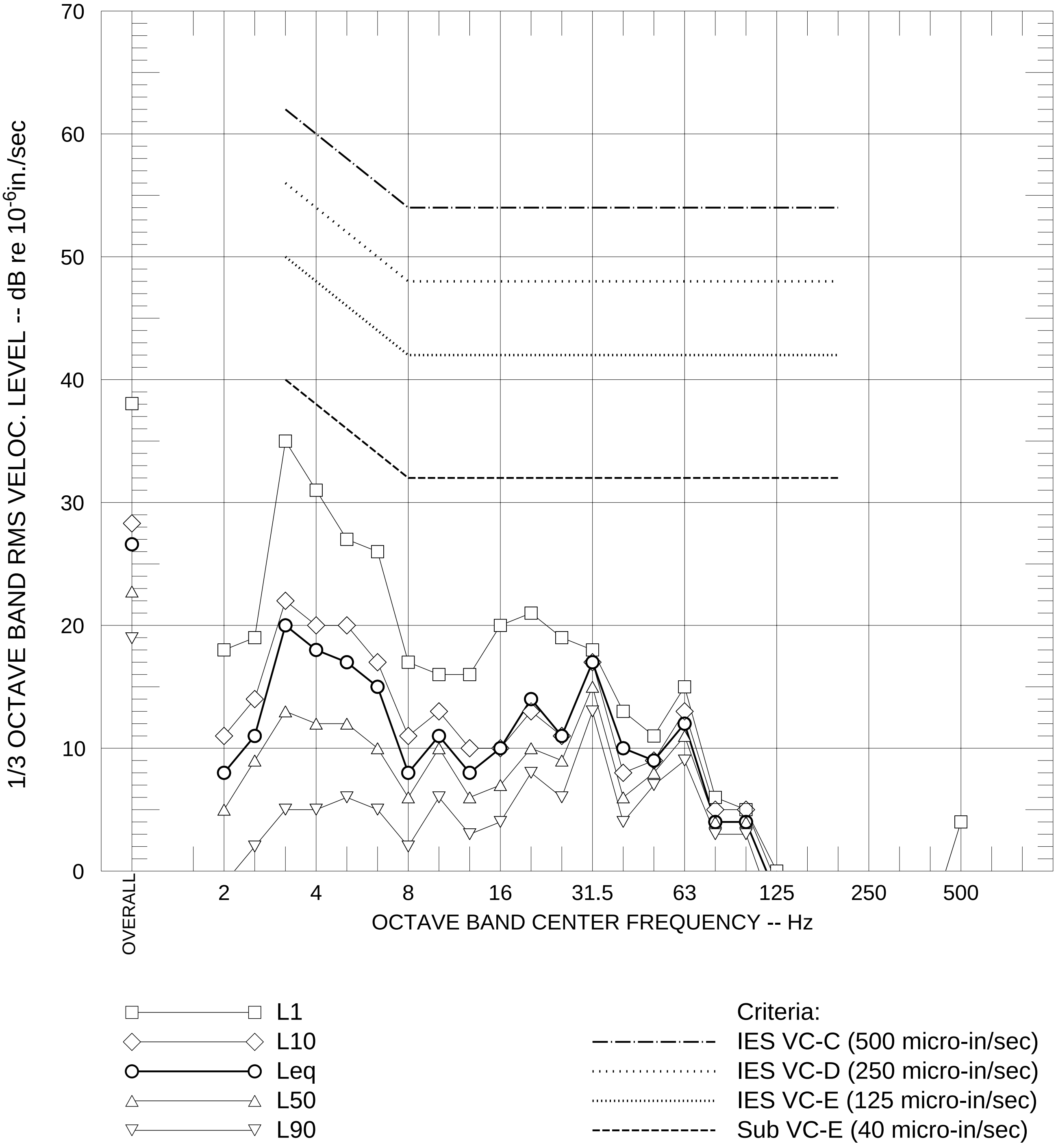

FIGURE 3C STATISTICAL VIBRATION LEVELS AT POSITION 3
CH.3 - HORIZONTALLY PERPENDICULAR TO BEAM HALL (TRANSVERSE)
LOWER LEVEL - INJECTOR HALL

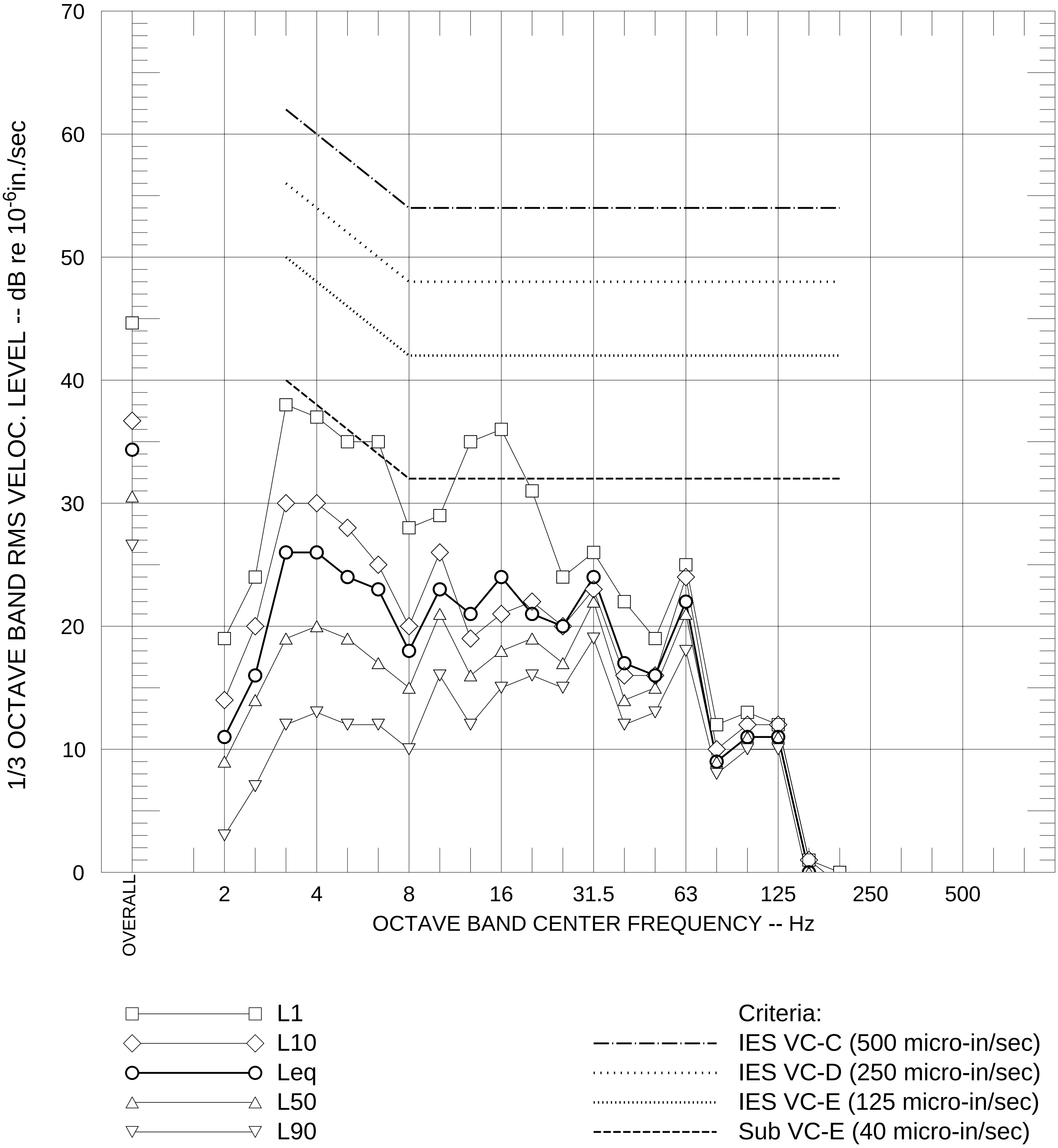

FIGURE 3D STATISTICAL VIBRATION LEVELS AT POSITION 3
CH.4 - VERTICALLY PERPENDICULAR TO BEAM HALL (at 1 m)
LOWER LEVEL - INJECTOR HALL

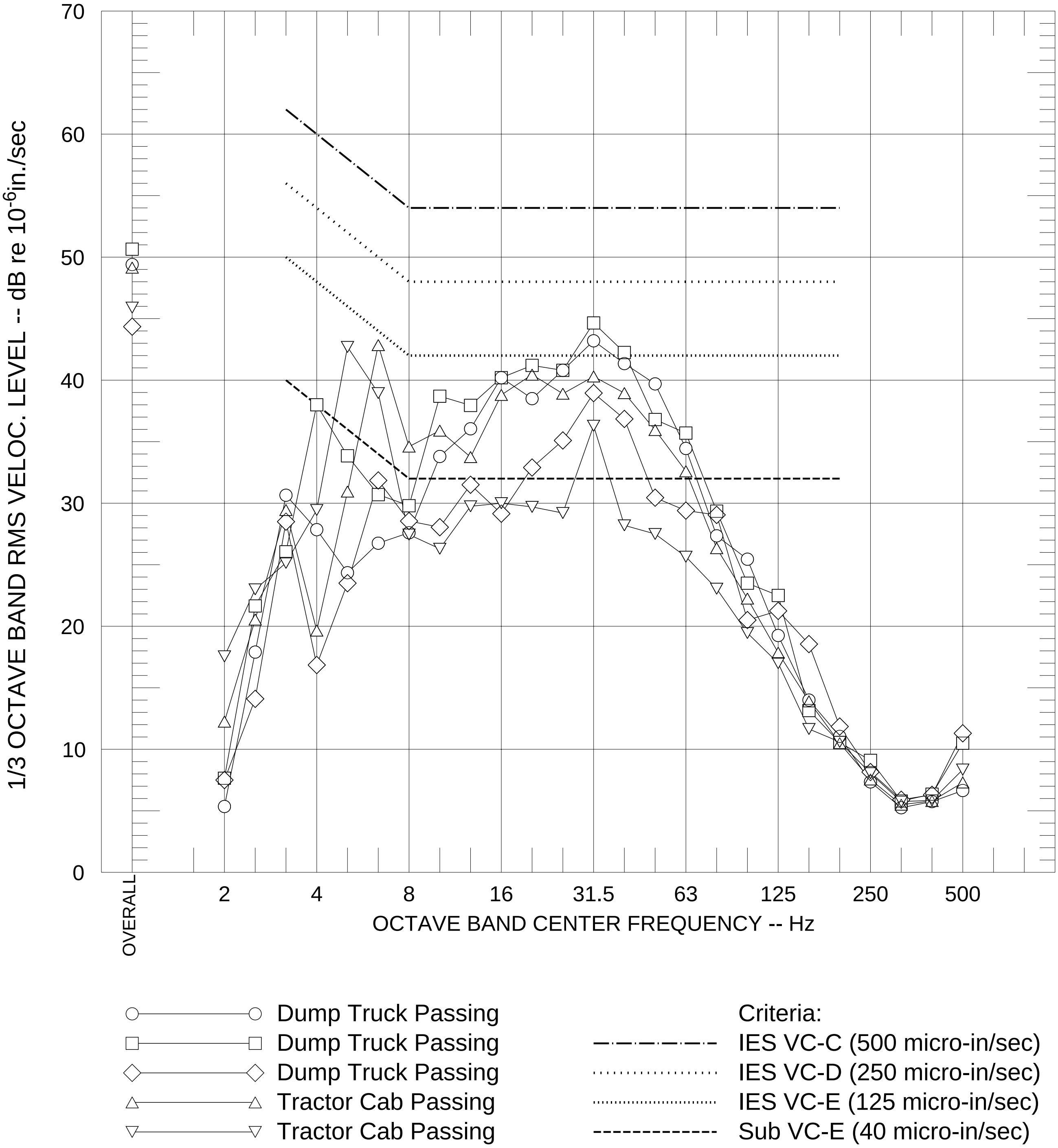

FIGURE 4A SINGLE-EVENT VIBRATION LEVELS AT POSITION 1
CH.1 - VERTICALLY PERPENDICULAR TO BEAM HALL
STREET LEVEL - EAST

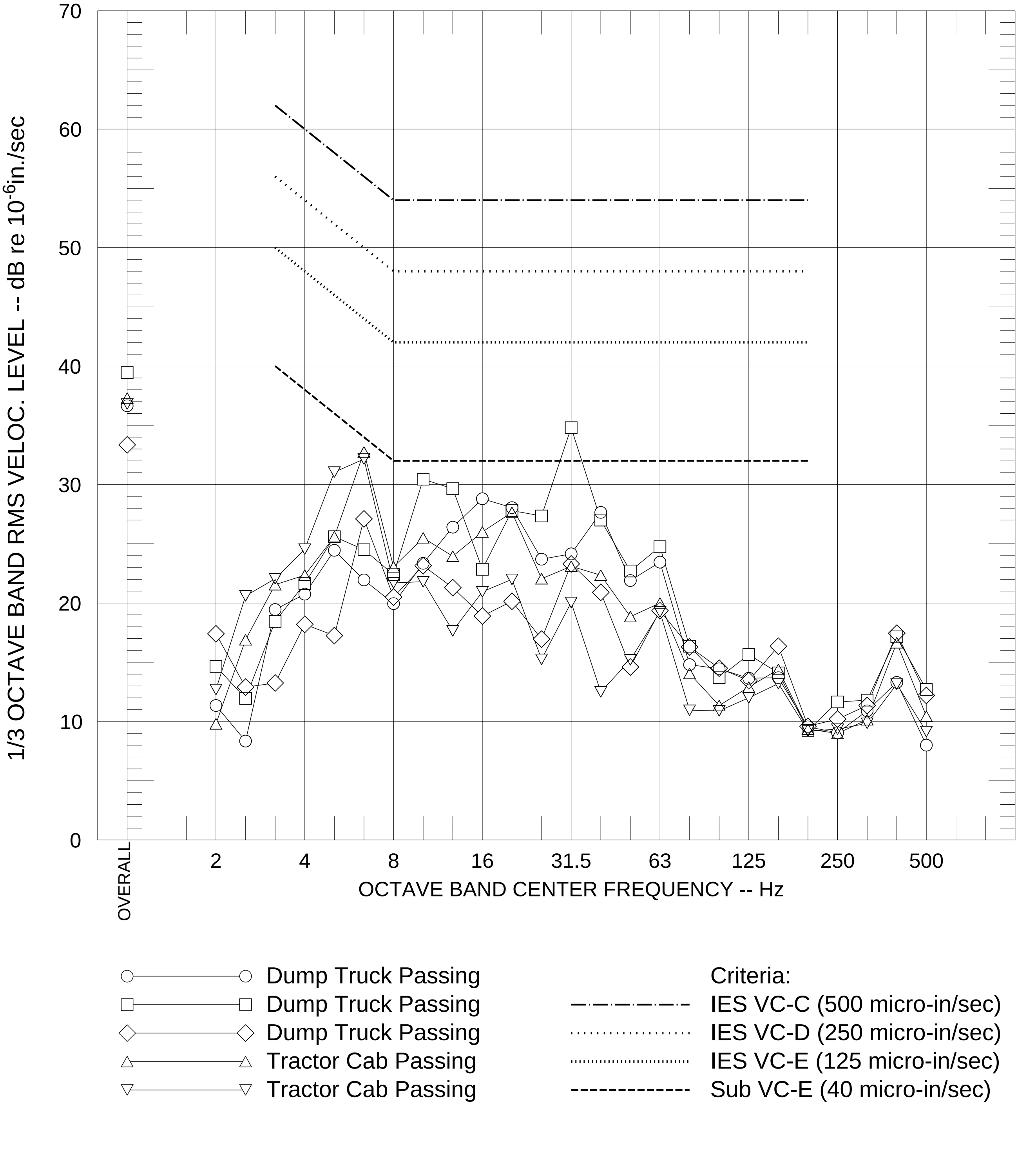

FIGURE 4B SINGLE-EVENT VIBRATION LEVELS AT POSITION 1
CH.2 - PARALLEL TO BEAM HALL
STREET LEVEL - EAST

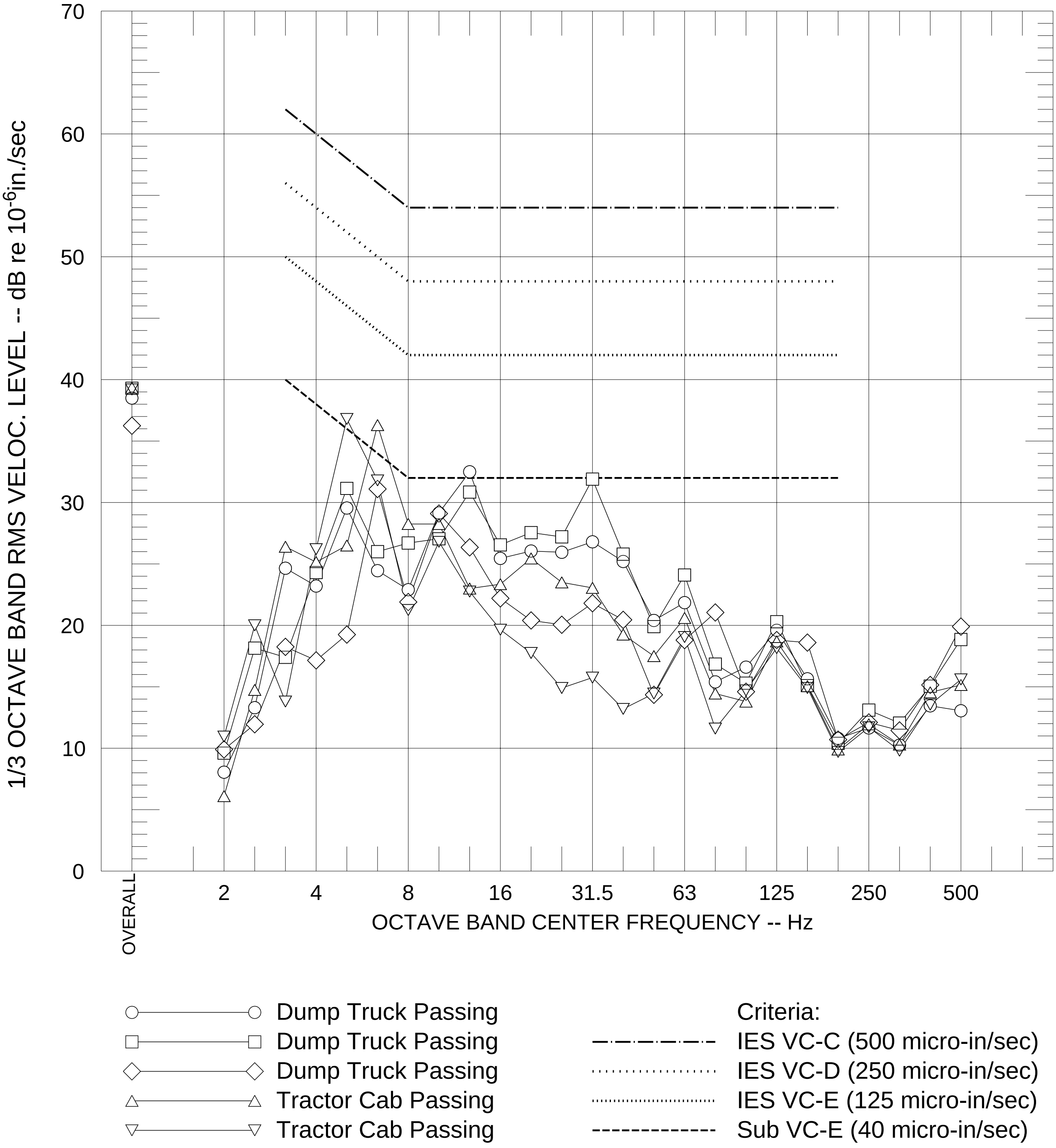

FIGURE 4C SINGLE-EVENT VIBRATION LEVELS AT POSITION 1
CH.3 - HORIZONTALLY PERPENDICULAR TO BEAM HALL (TRANSVERSE)
STREET LEVEL - EAST

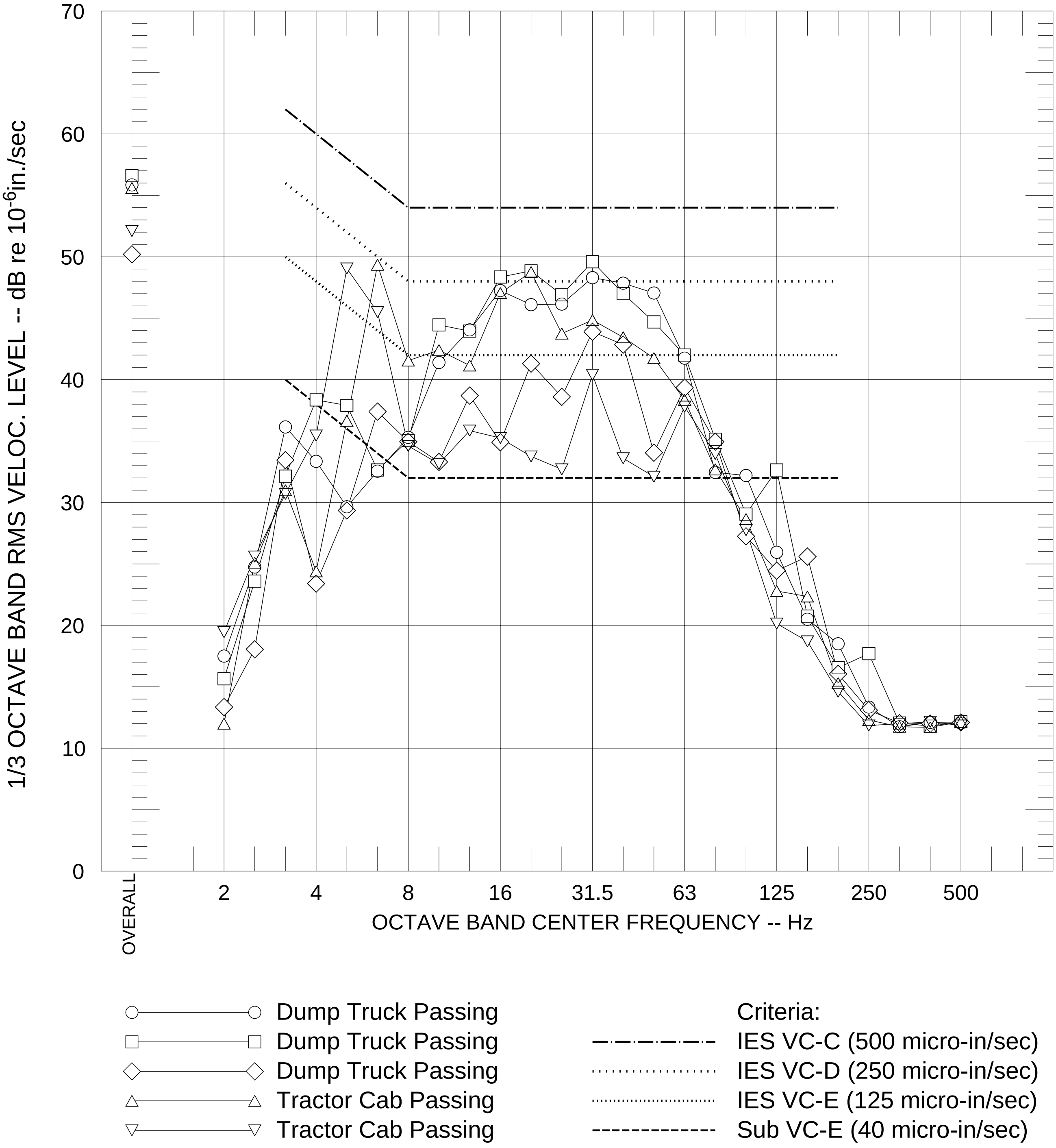

FIGURE 4D SINGLE-EVENT VIBRATION LEVELS AT POSITION 1
CH.4 - VERTICALLY PERPENDICULAR TO BEAM HALL (at 2 m)
STREET LEVEL - EAST

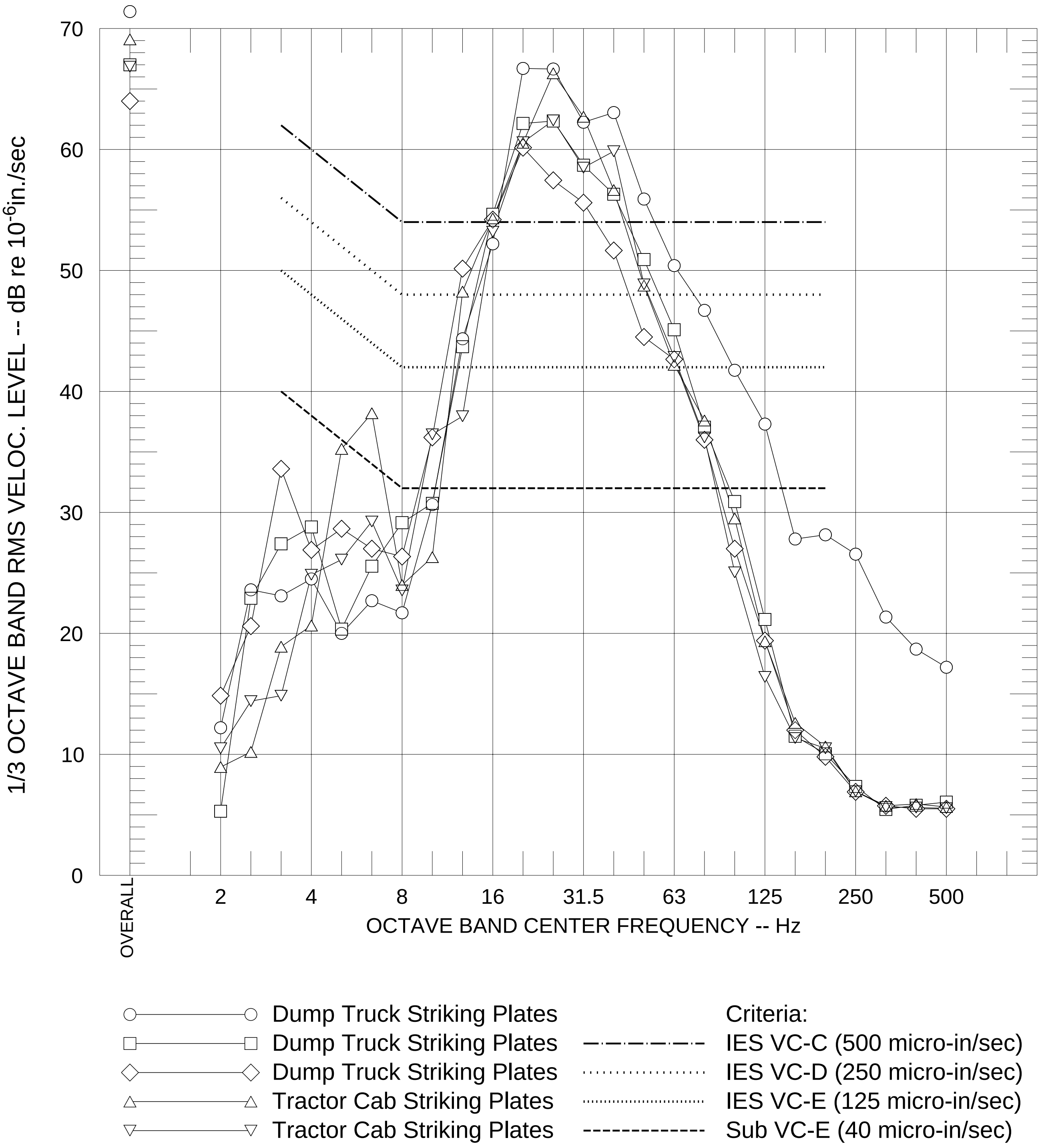

FIGURE 5A SINGLE-EVENT VIBRATION LEVELS AT POSITION 1
CH.1 - VERTICALLY PERPENDICULAR TO BEAM HALL
STREET LEVEL - EAST

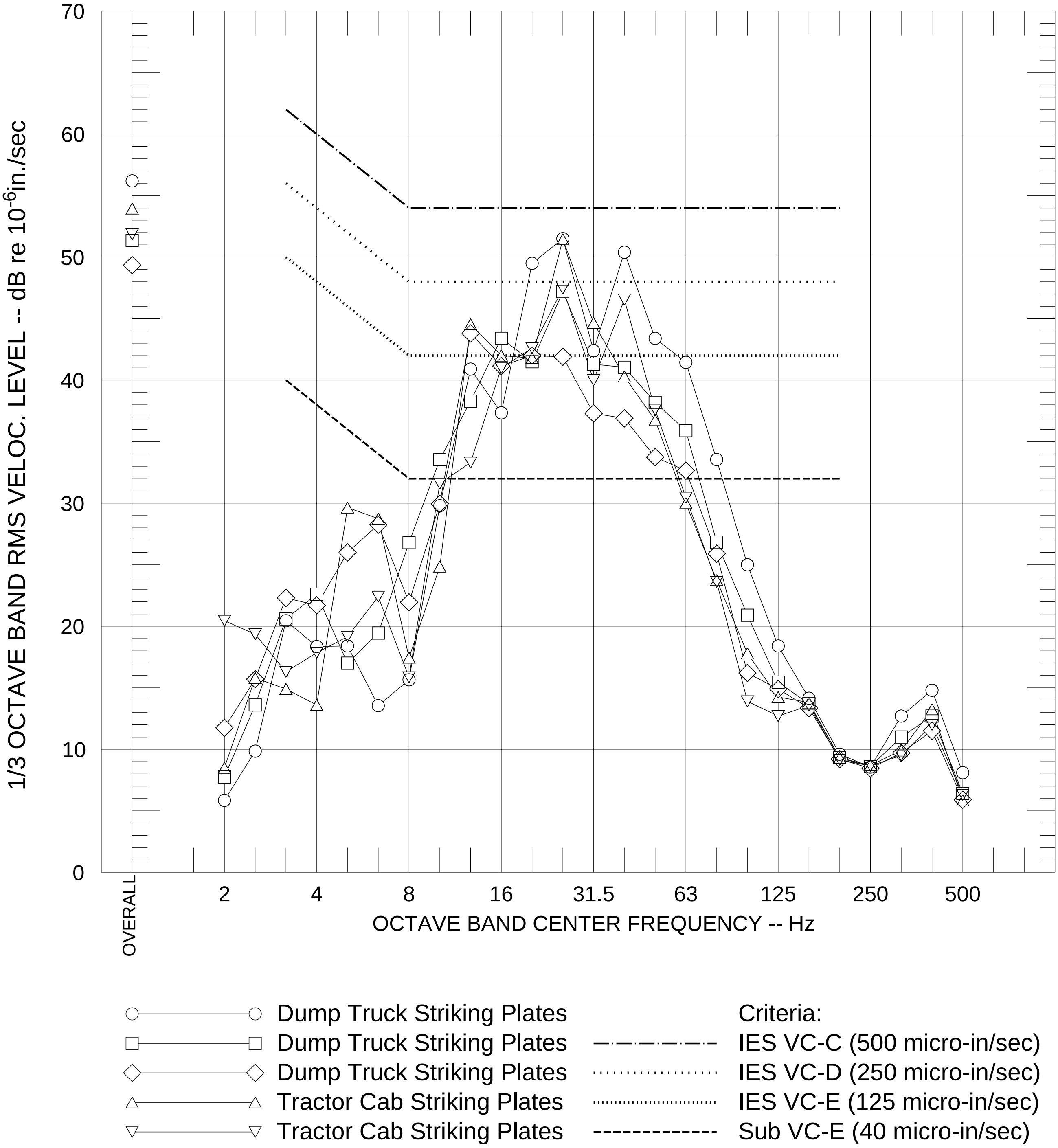

FIGURE 5B SINGLE-EVENT VIBRATION LEVELS AT POSITION 1
CH.2 - PARALLEL TO BEAM HALL
STREET LEVEL - EAST

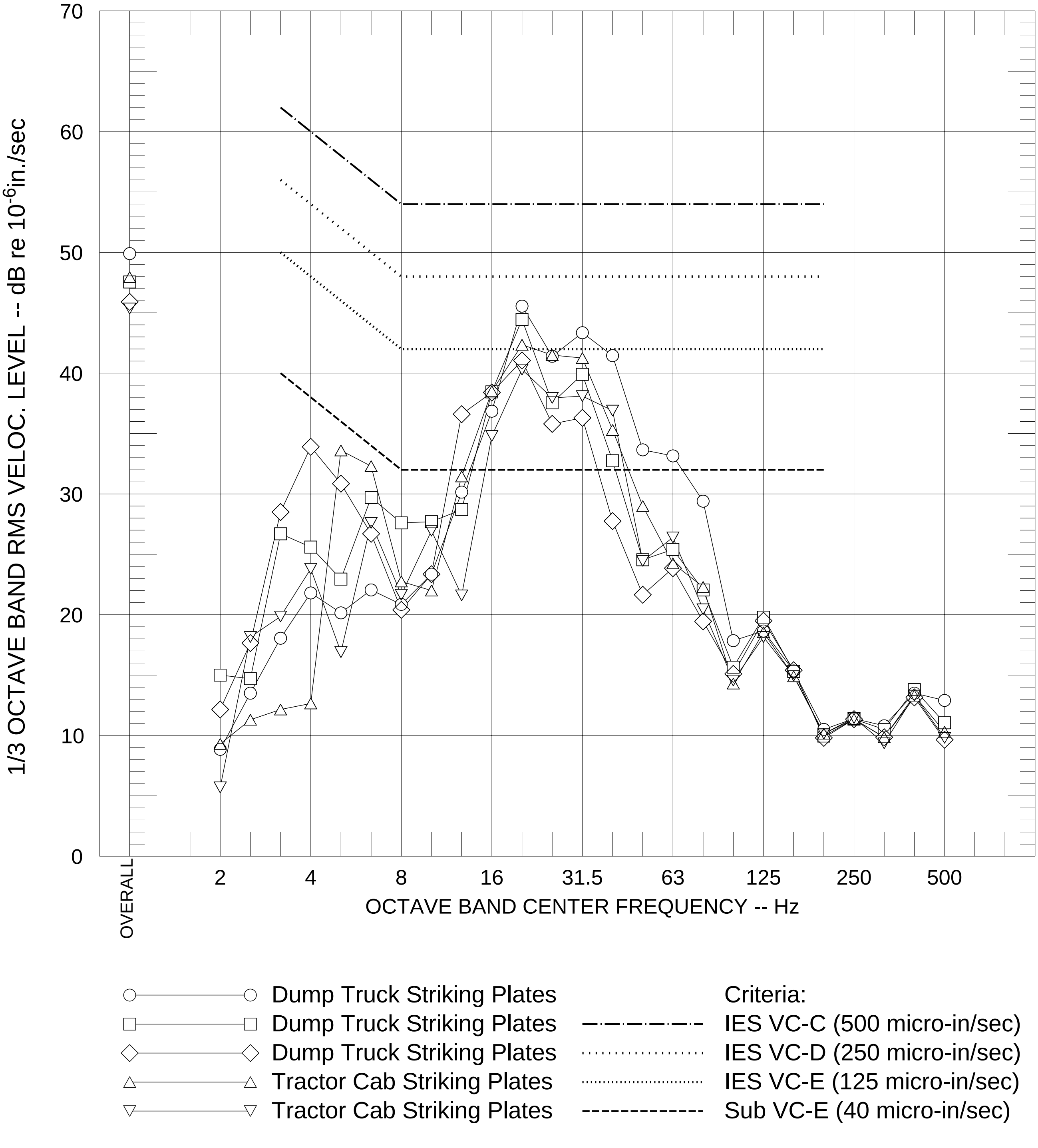

FIGURE 5C SINGLE-EVENT VIBRATION LEVELS AT POSITION 1
CH.3 - HORIZONTALLY PERPENDICULAR TO BEAM HALL (TRANSVERSE)
STREET LEVEL - EAST

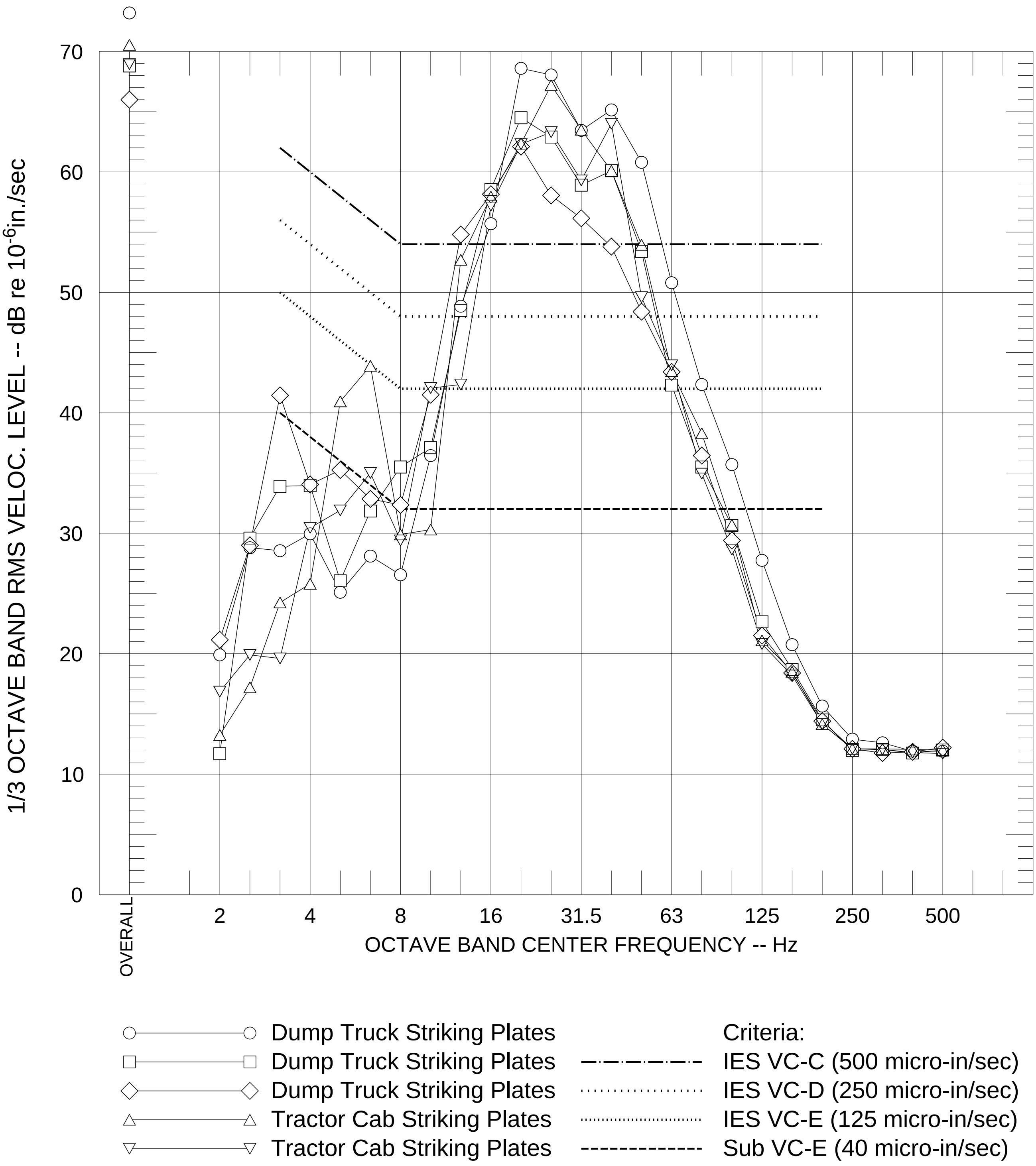

FIGURE 5D SINGLE-EVENT VIBRATION LEVELS AT POSITION 1
CH.4 - VERTICALLY PERPENDICULAR TO BEAM HALL (at 2 m)
STREET LEVEL - EAST

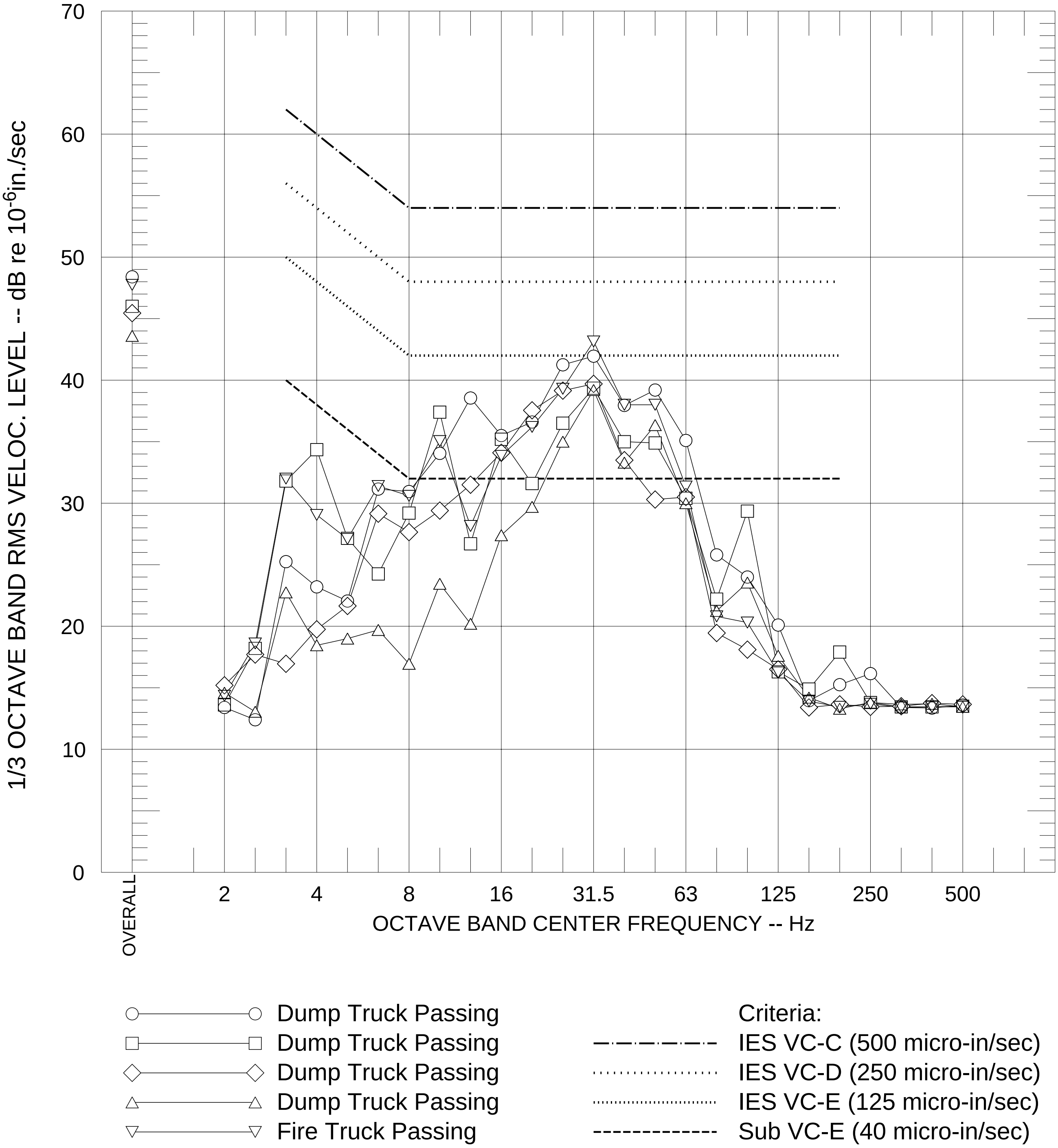

FIGURE 6A SINGLE-EVENT VIBRATION LEVELS AT POSITION 2
CH.1 - VERTICALLY PERPENDICULAR TO BEAM HALL
STREET LEVEL - WEST

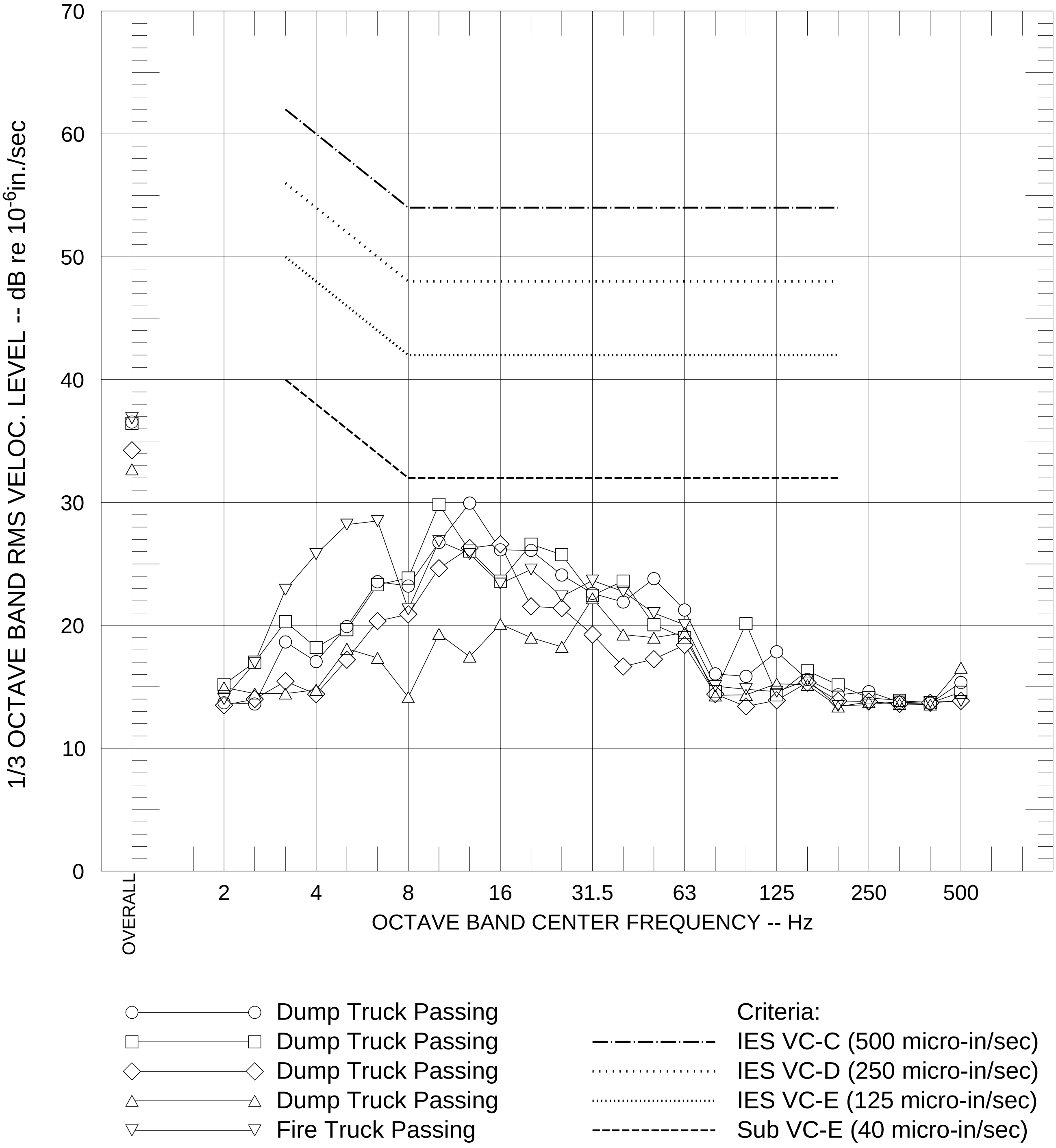

FIGURE 6B SINGLE-EVENT VIBRATION LEVELS AT POSITION 2
CH.2 - PARALLEL TO BEAM HALL
STREET LEVEL - WEST

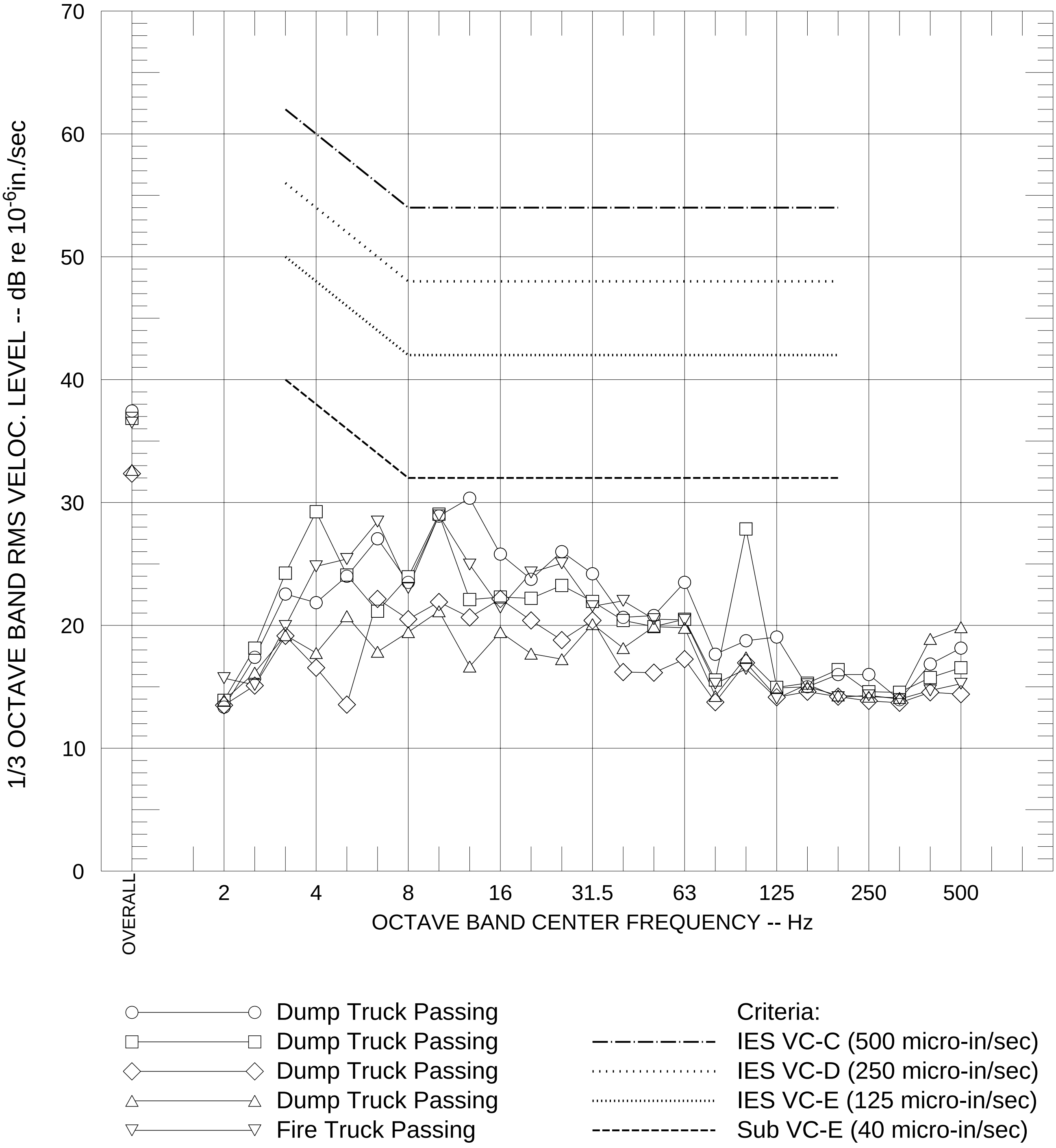

FIGURE 6C SINGLE-EVENT VIBRATION LEVELS AT POSITION 2
CH.3 - HORIZONTALLY PERPENDICULAR TO BEAM HALL (TRANSVERSE)
STREET LEVEL - WEST

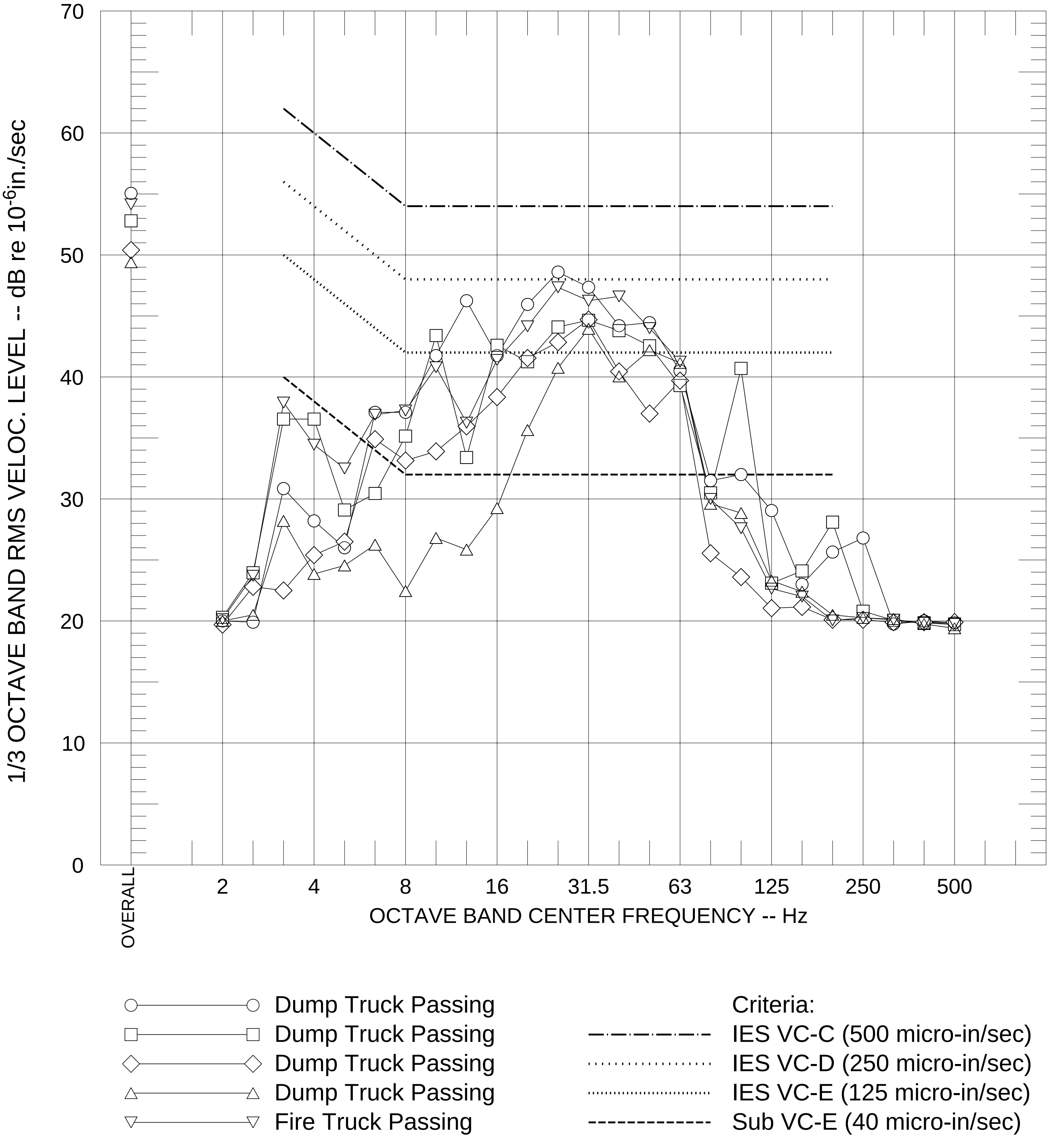

FIGURE 6D SINGLE-EVENT VIBRATION LEVELS AT POSITION 2
CH.4 - VERTICALLY PERPENDICULAR TO BEAM HALL (at 2 m)
STREET LEVEL - WEST

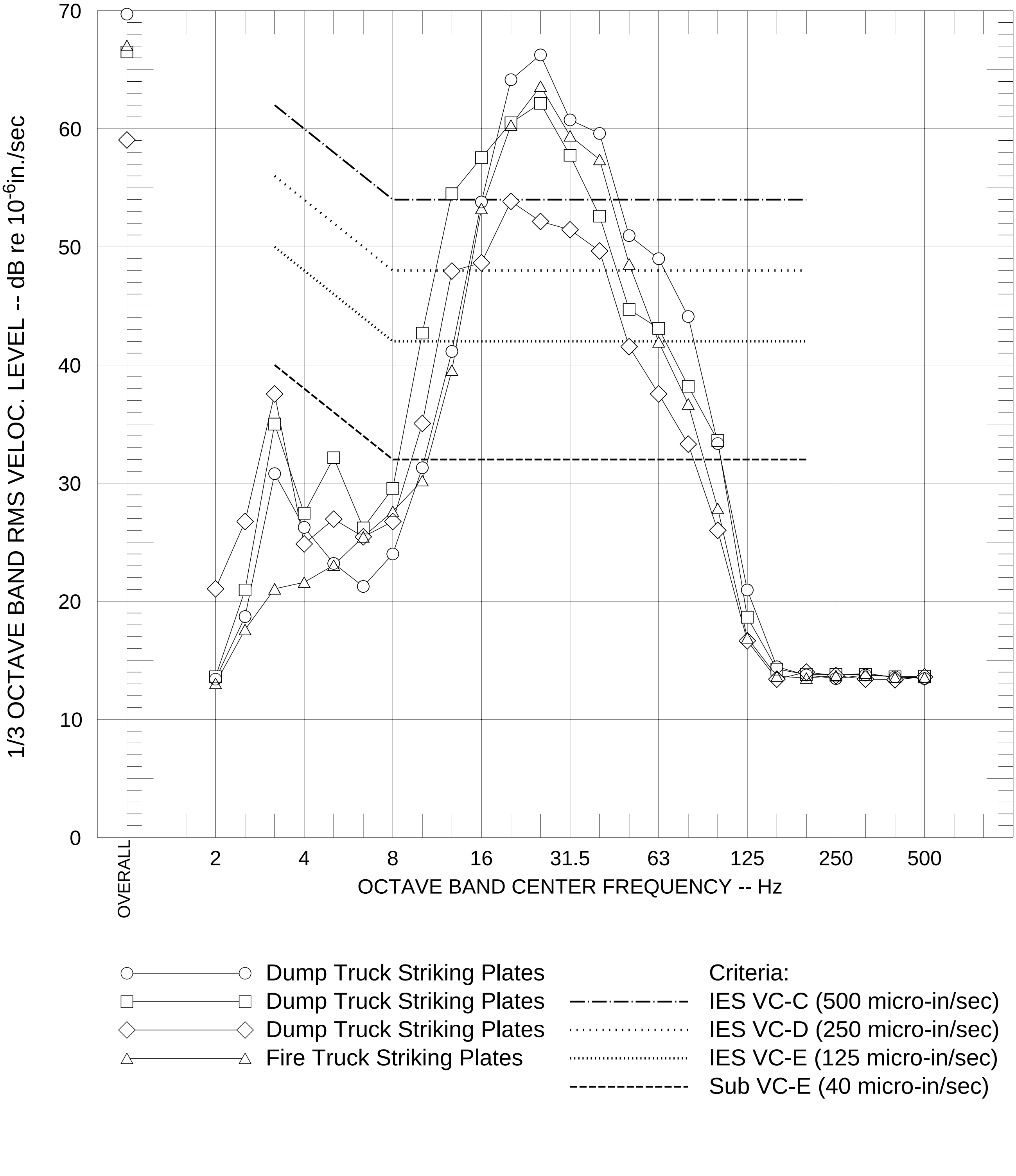

FIGURE 7A SINGLE-EVENT VIBRATION LEVELS AT POSITION 2
CH.1 - VERTICALLY PERPENDICULAR TO BEAM HALL
STREET LEVEL - WEST

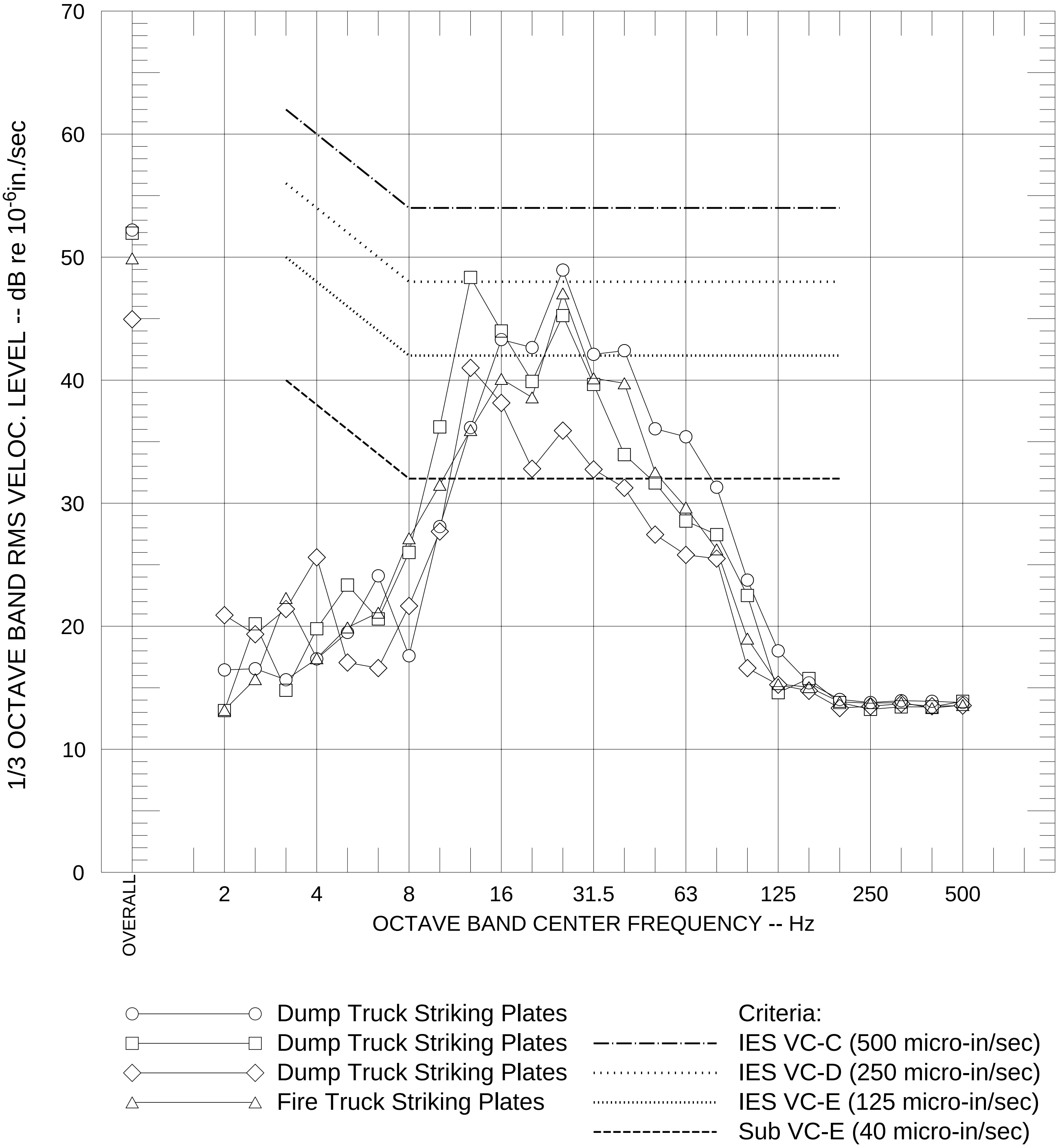

FIGURE 7B SINGLE-EVENT VIBRATION LEVELS AT POSITION 2
CH.2 - PARALLEL TO BEAM HALL
STREET LEVEL - WEST

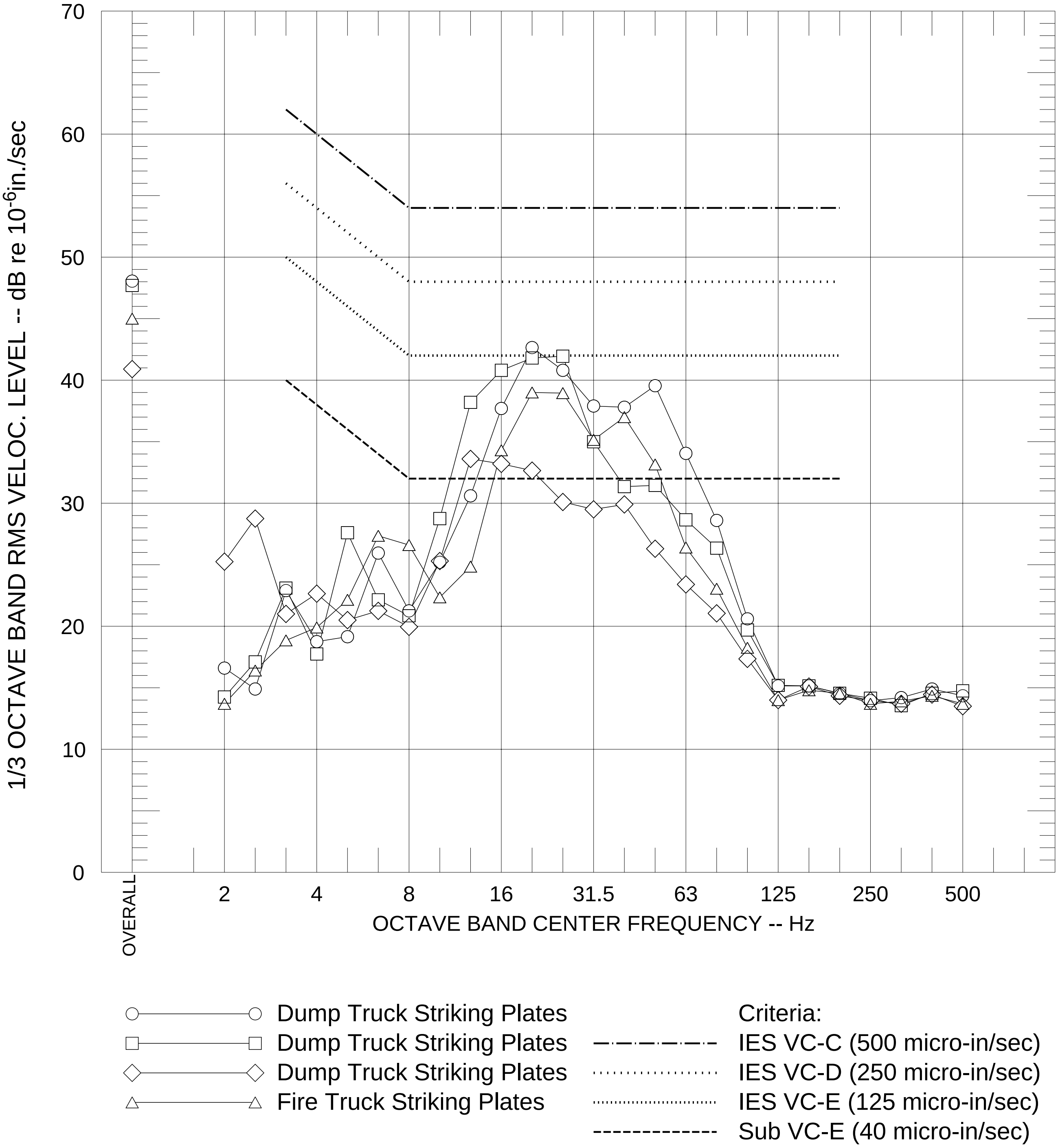

FIGURE 7C SINGLE-EVENT VIBRATION LEVELS AT POSITION 2
CH.3 - HORIZONTALLY PERPENDICULAR TO BEAM HALL (TRANSVERSE)
STREET LEVEL - WEST

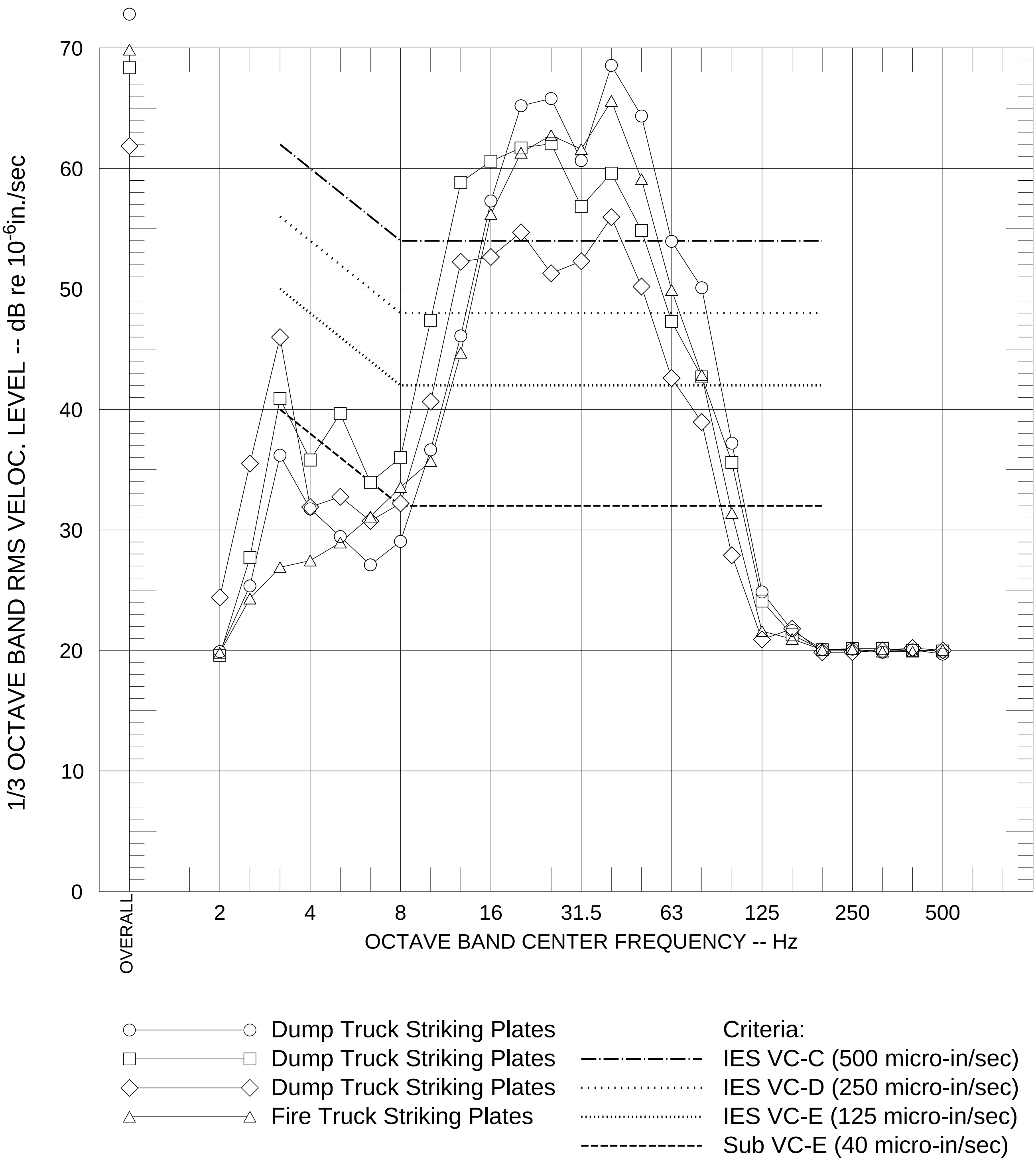

FIGURE 7D SINGLE-EVENT VIBRATION LEVELS AT POSITION 2
CH.4 - VERTICALLY PERPENDICULAR TO BEAM HALL (at 2 m)
STREET LEVEL - WEST

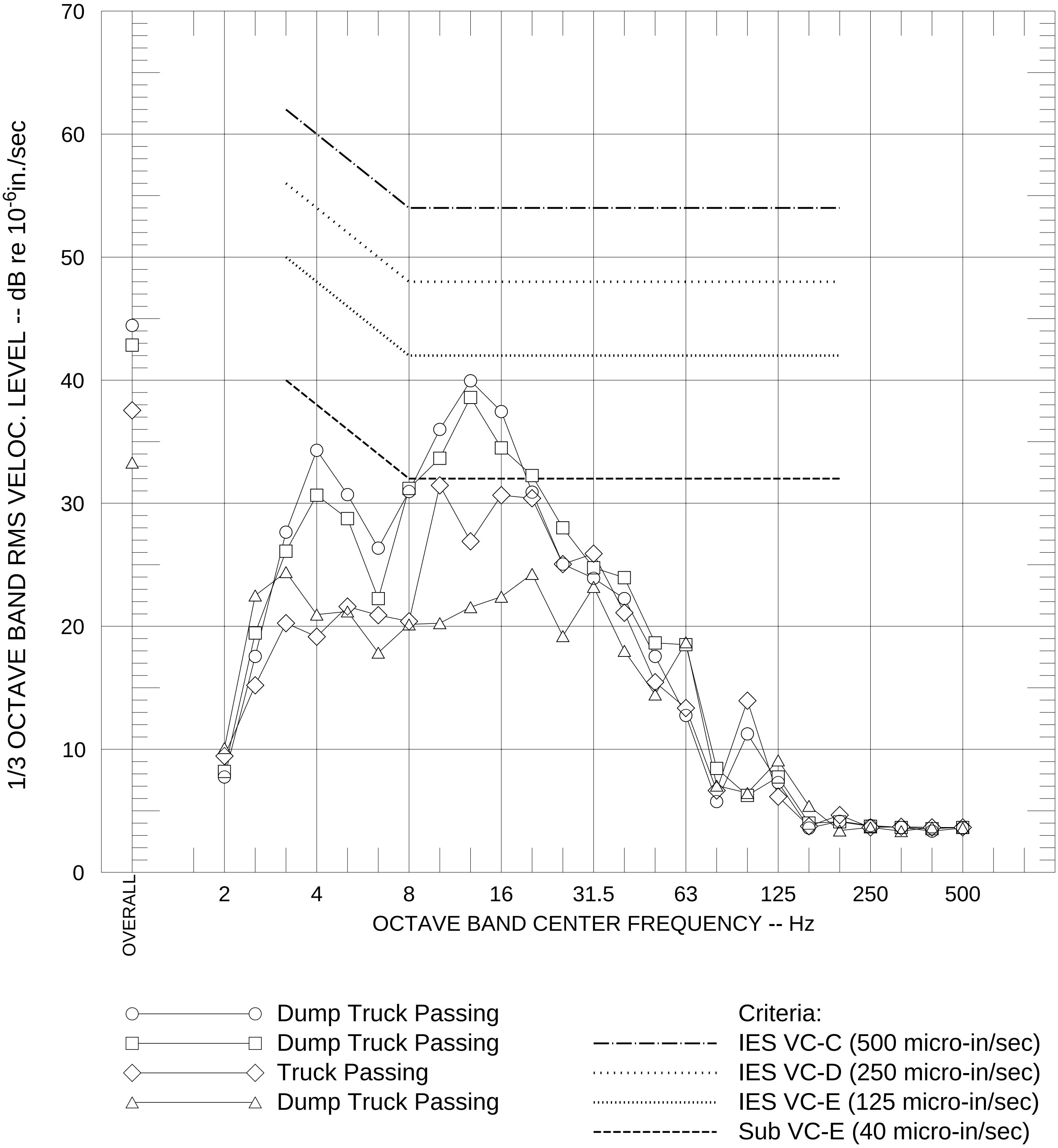

FIGURE 8A SINGLE-EVENT VIBRATION LEVELS AT POSITION 3
CH.1 - VERTICALLY PERPENDICULAR TO BEAM HALL
LOWER LEVEL - INJECTOR HALL

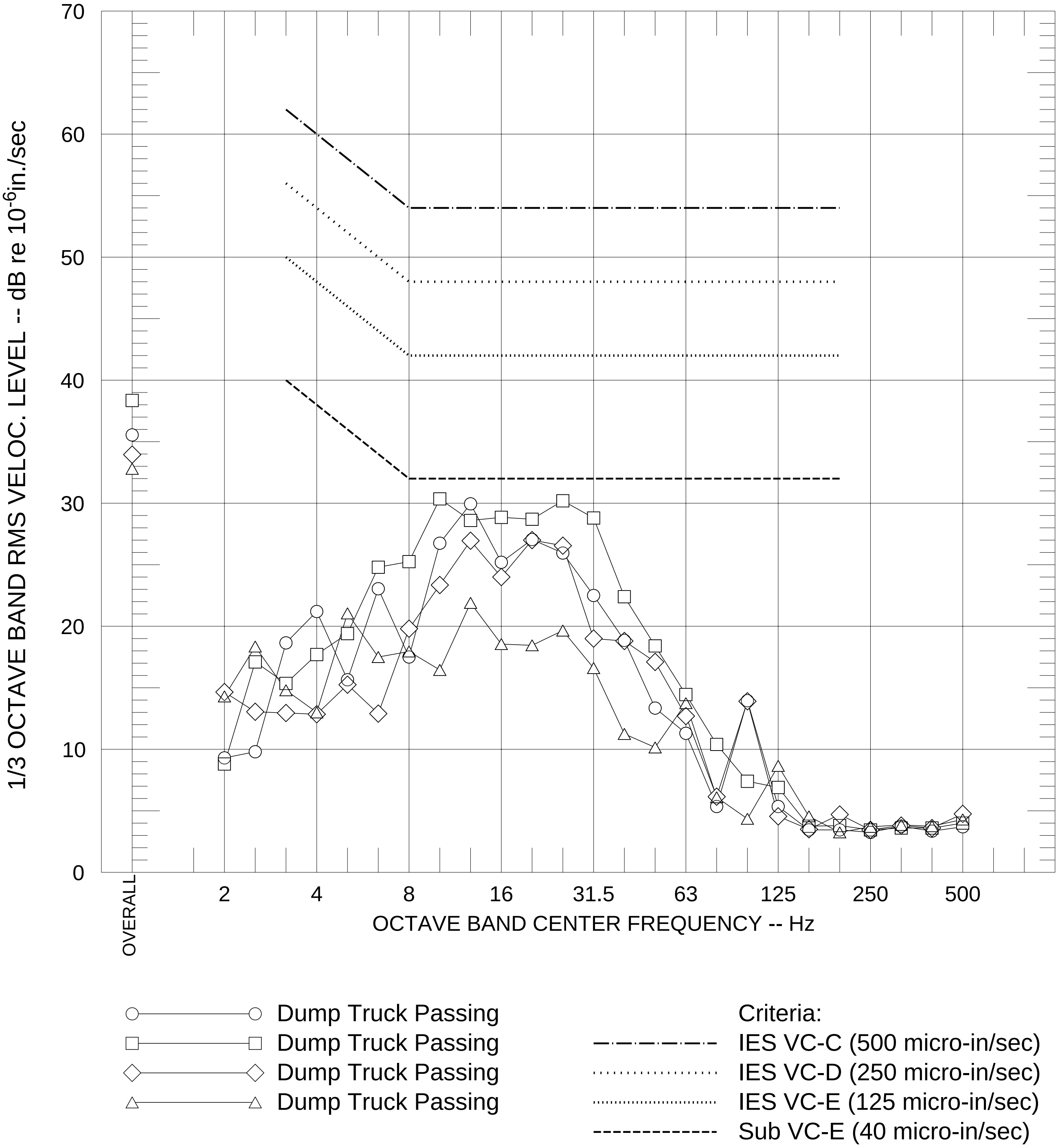

FIGURE 8B SINGLE-EVENT VIBRATION LEVELS AT POSITION 3
CH.2 - PARALLEL TO BEAM HALL
LOWER LEVEL - INJECTOR HALL

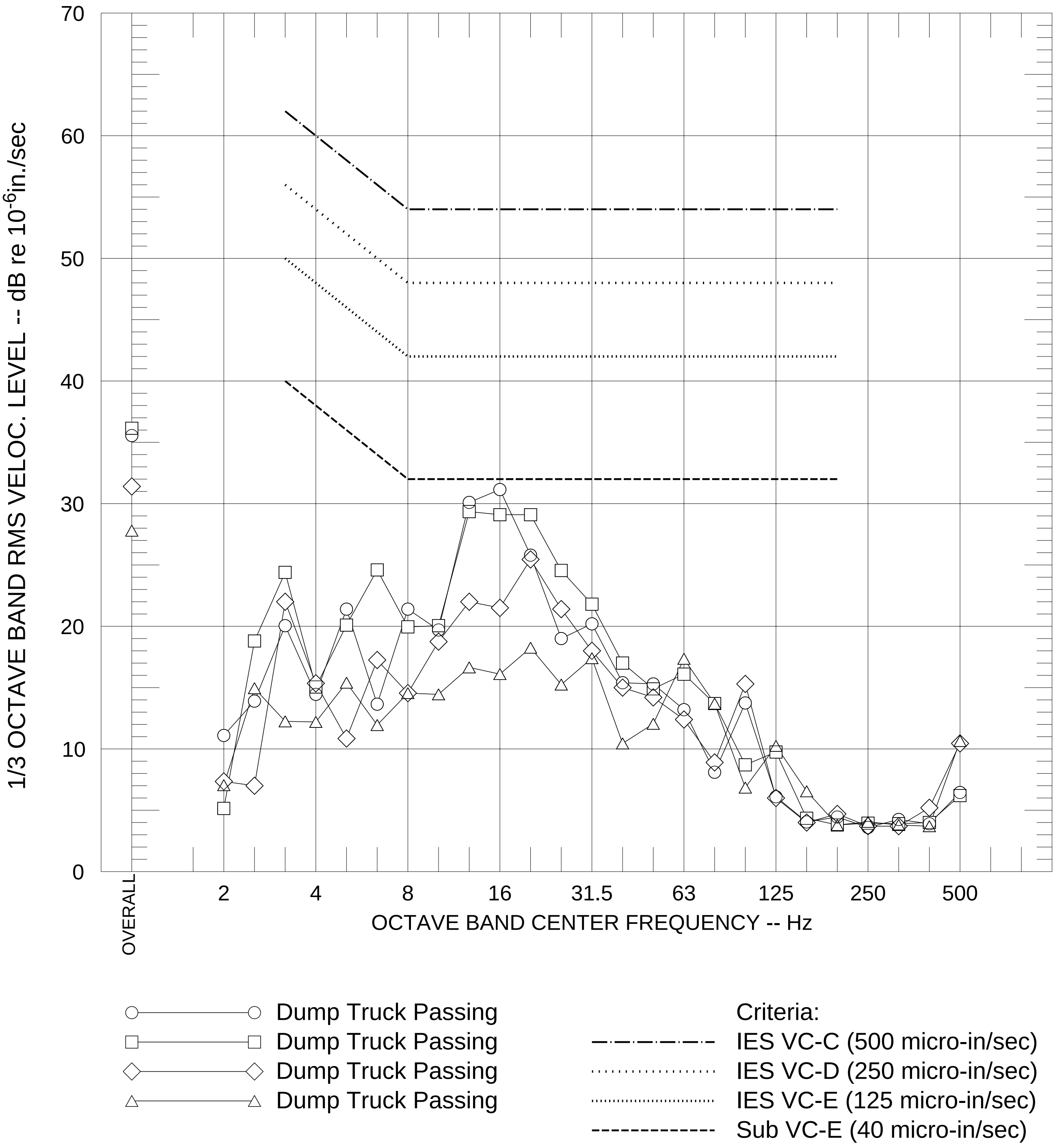

FIGURE 8C SINGLE-EVENT VIBRATION LEVELS AT POSITION 3
CH.3 - HORIZONTALLY PERPENDICULAR TO BEAM HALL (TRANSVERSE)
LOWER LEVEL - INJECTOR HALL

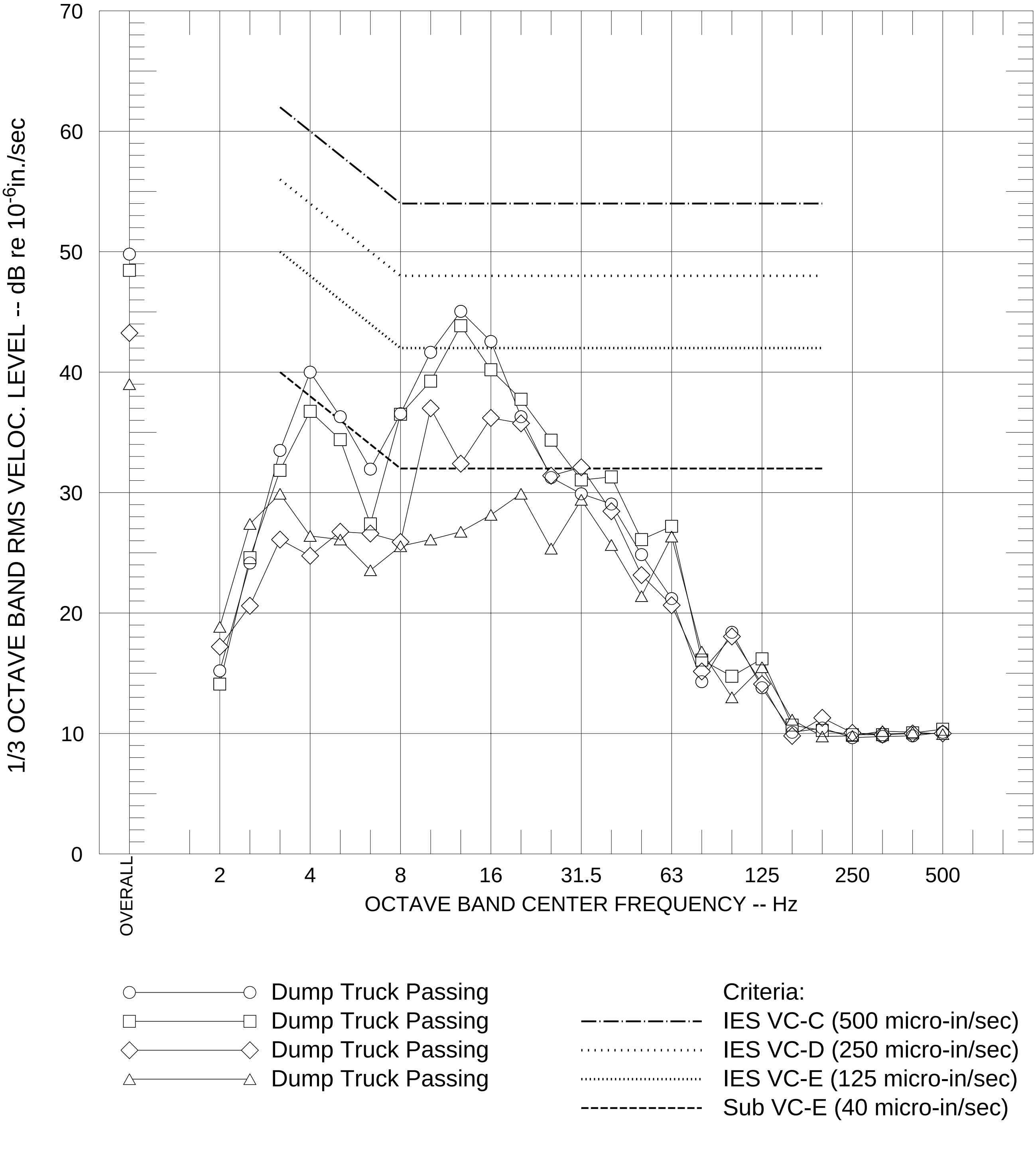

FIGURE 8D SINGLE-EVENT VIBRATION LEVELS AT POSITION 3
CH.4 - VERTICALLY PERPENDICULAR TO BEAM HALL (at 1 m)
LOWER LEVEL - INJECTOR HALL

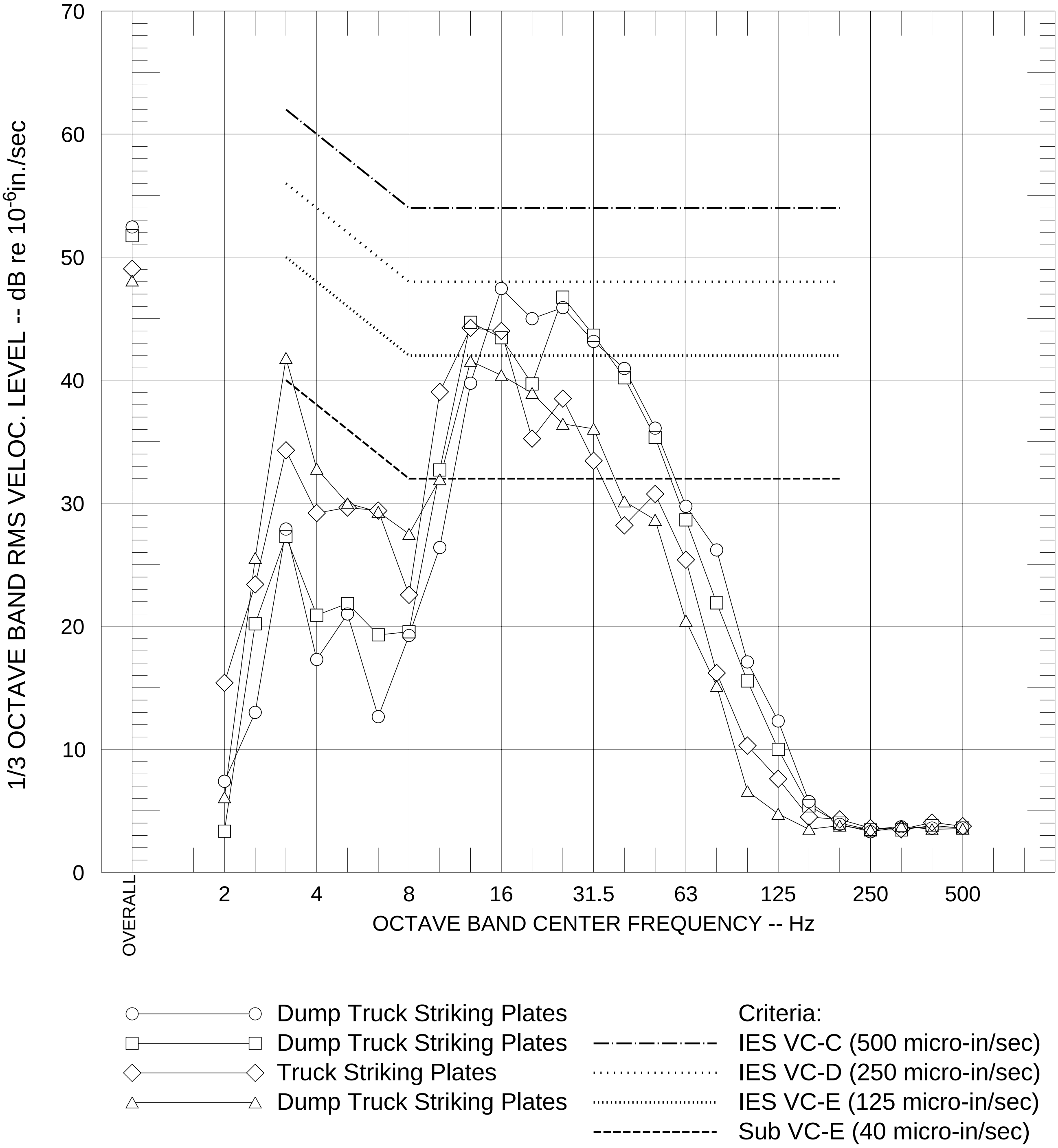

FIGURE 9A SINGLE-EVENT VIBRATION LEVELS AT POSITION 3
CH.1 - VERTICALLY PERPENDICULAR TO BEAM HALL
LOWER LEVEL - INJECTOR HALL

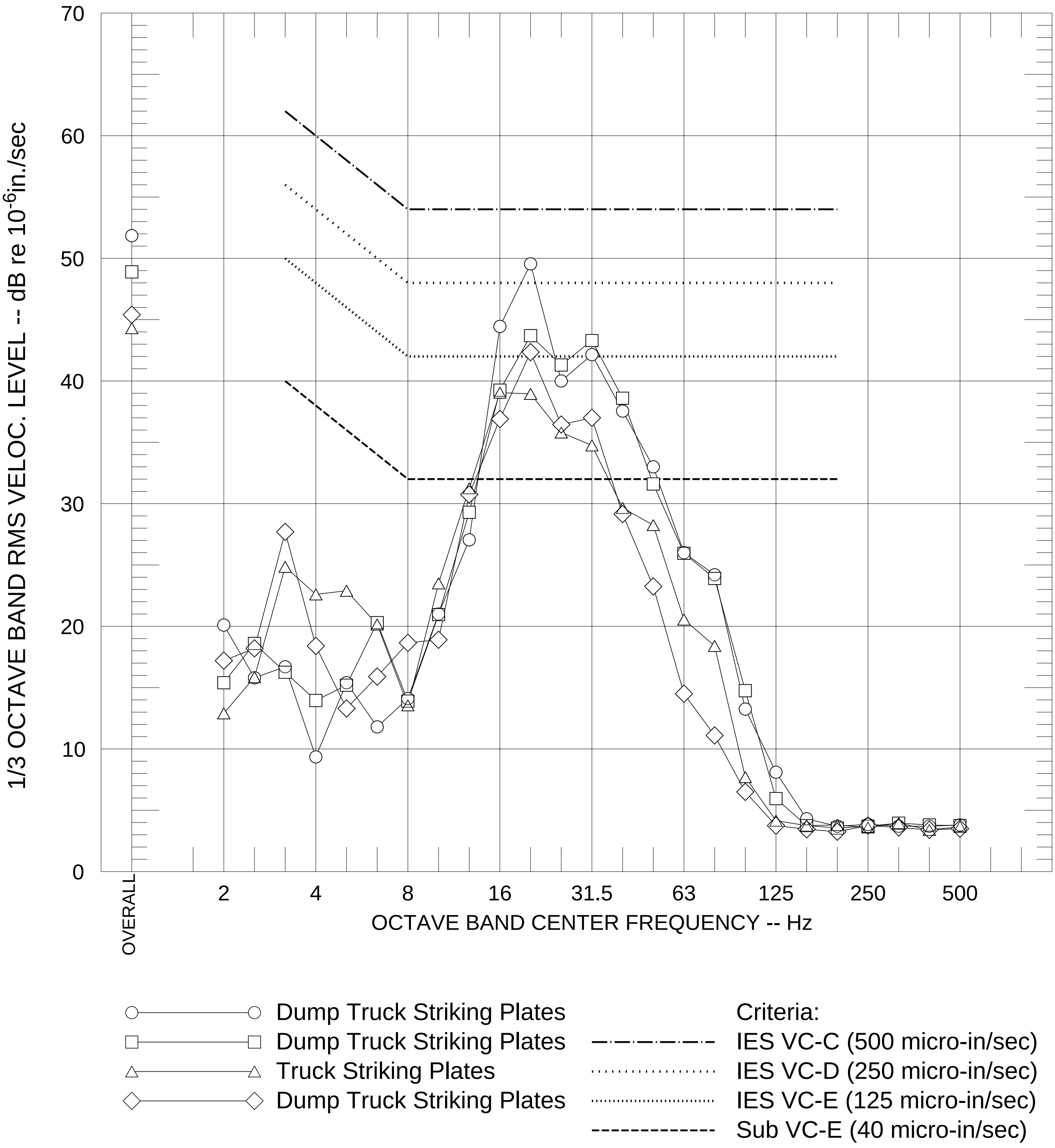

FIGURE 9B SINGLE-EVENT VIBRATION LEVELS AT POSITION 3
CH.2 - PARALLEL TO BEAM HALL
LOWER LEVEL - INJECTOR HALL

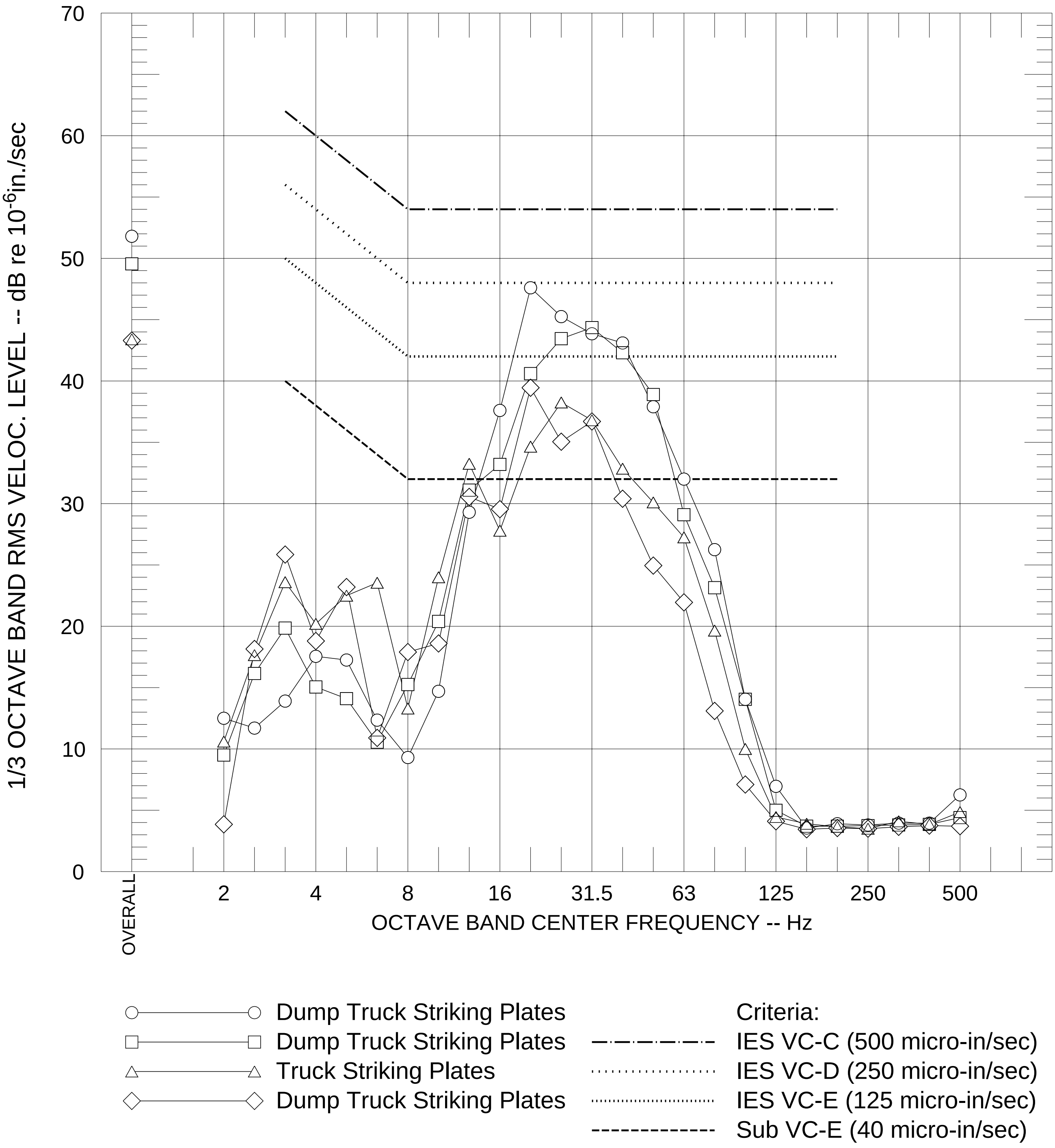

FIGURE 9C SINGLE-EVENT VIBRATION LEVELS AT POSITION 3
CH.3 - HORIZONTALLY PERPENDICULAR TO BEAM HALL (TRANSVERSE)
LOWER LEVEL - INJECTOR HALL

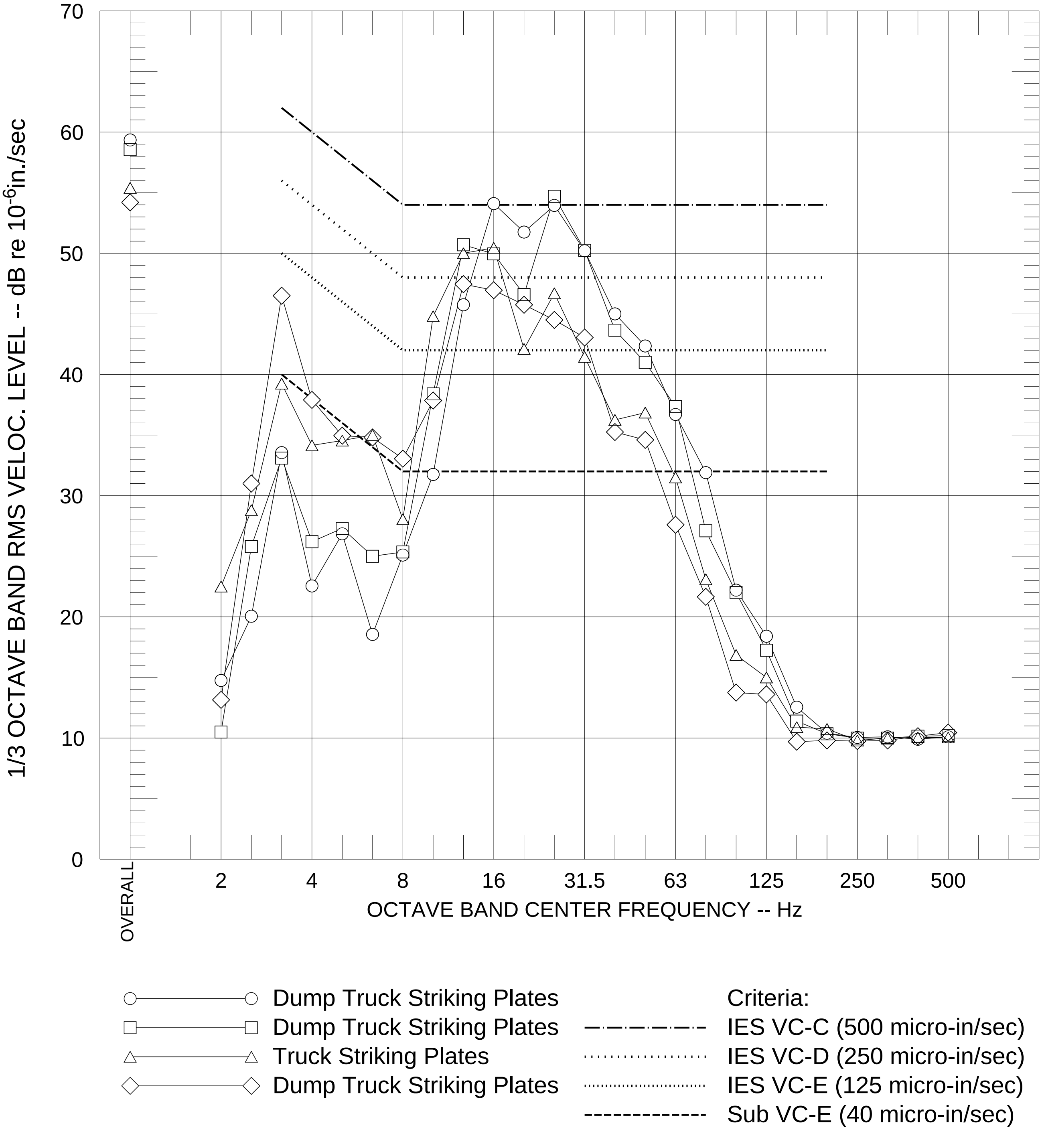

FIGURE 9D SINGLE-EVENT VIBRATION LEVELS AT POSITION 3
CH.4 - VERTICALLY PERPENDICULAR TO BEAM HALL (at 1 m)
LOWER LEVEL - INJECTOR HALL

APPENDIX A

FIGURE A-1: SECTOR 20 VIBRATION MEASUREMENT POSITIONS - STREET LEVEL POSITIONS 1 & 2

FIGURE A-2: SECTOR 20 VIBRATION MEASUREMENT POSITION - LOWER LEVEL (INJECTOR HALL) POSITION 3

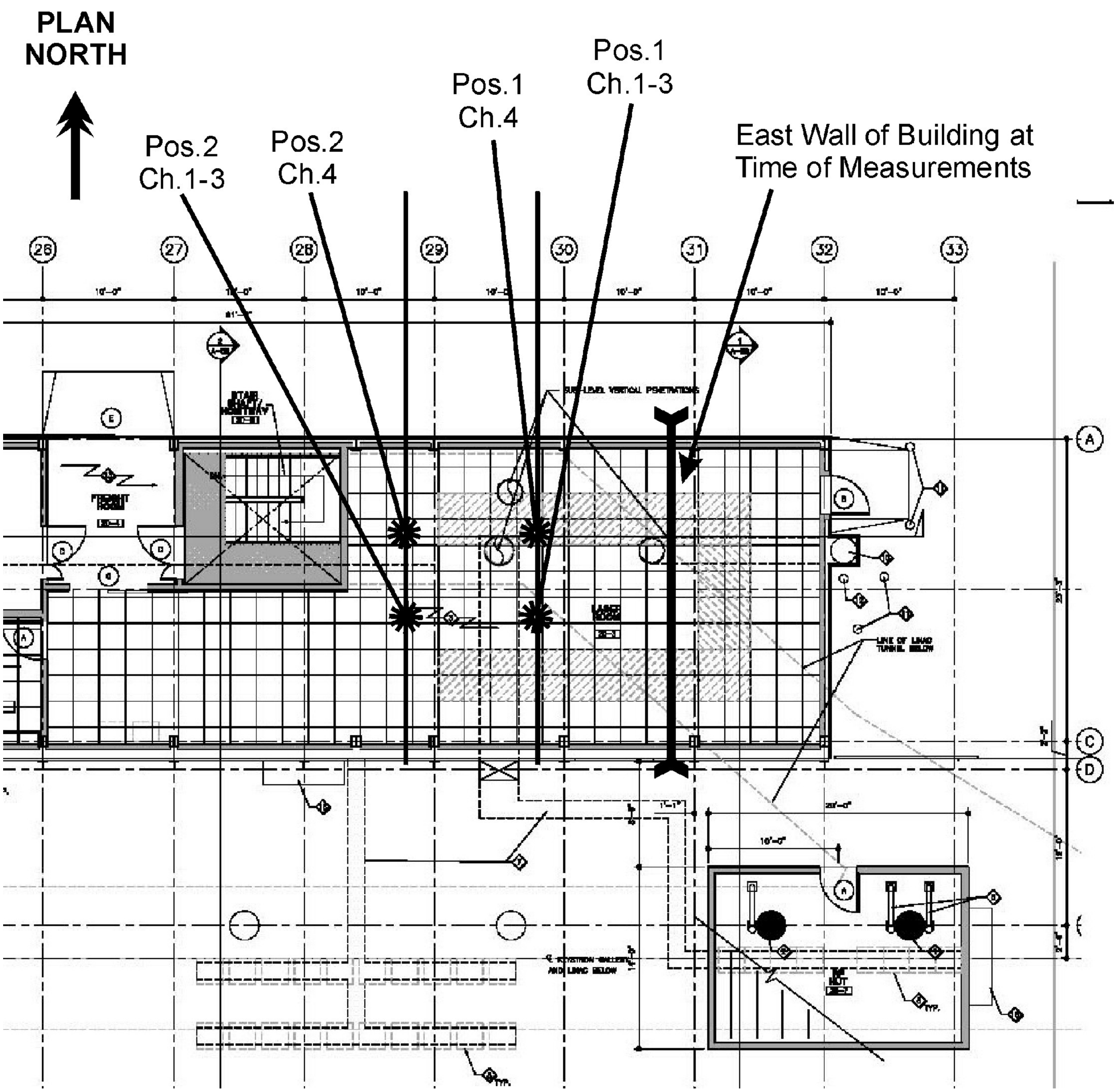

FIGURE A-1 SECTOR 20 VIBRATION MEASUREMENT POSITIONS - STREET LEVEL POSITIONS 1 & 2

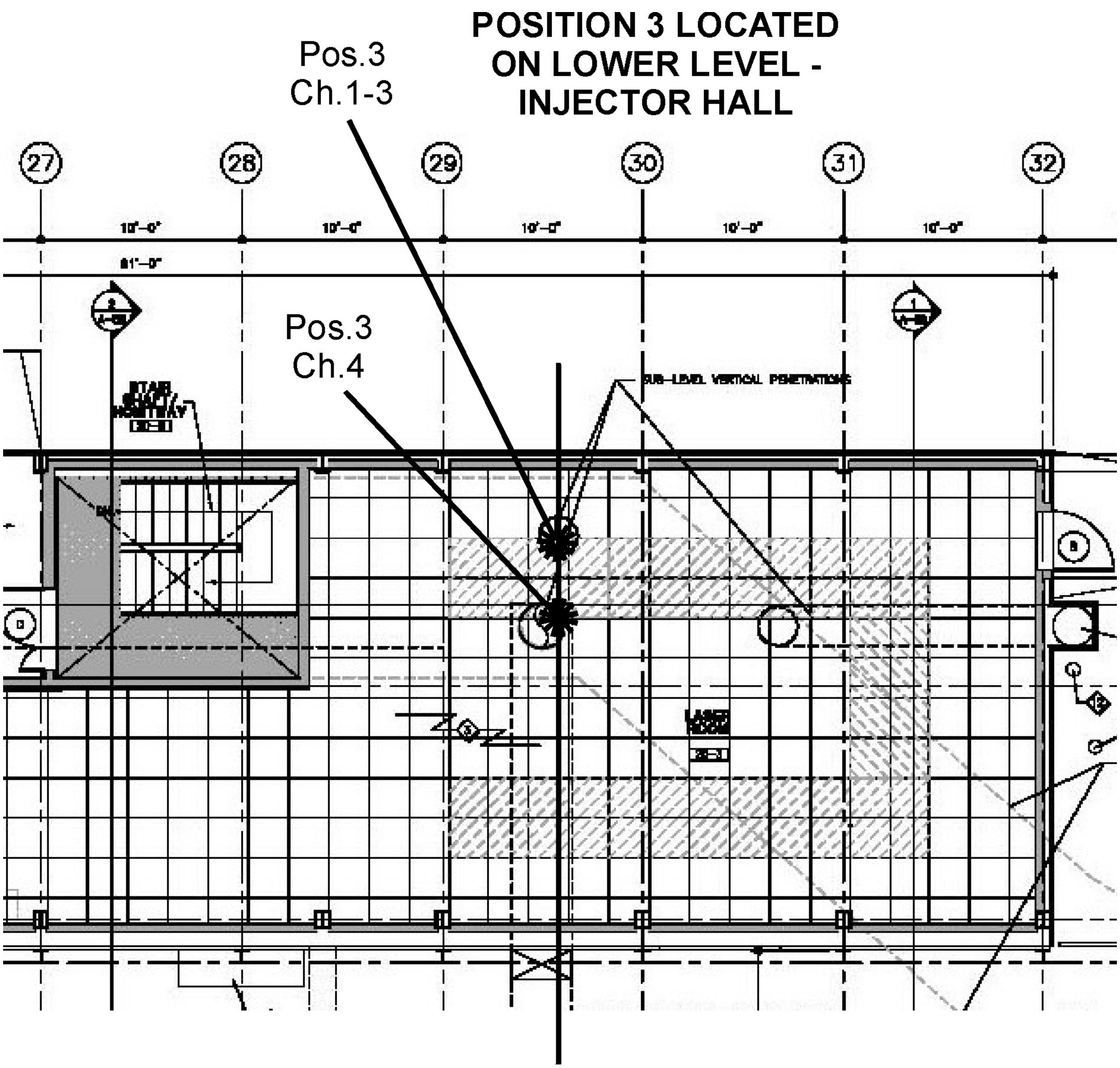

FIGURE A-2 SECTOR 20 VIBRATION MEASUREMENT POSITION - LOWER LEVEL (INJECTOR HALL) POSITION 3

APPENDIX B

FIELD EQUIPMENT USED FOR OBTAINING VIBRATION MEASUREMENTS

Channel	Accelerometer	Decade Amplifier
1 (vertical)	Wilcoxon Research Type 731, S/N 111	WIA Type 222, S/N 2, Ch. 1
2 (parallel to beam)	Wilcoxon Research Type 731, S/N 112	WIA Type 222, S/N 2, Ch. 2
3 (horizontally perpendicular to beam)	Wilcoxon Research Type 731, S/N 348	WIA Type 222, S/N 5, Ch. 1
4 (vertical, at 1 or 2 m from Ch.1)	Wilcoxon Research Type 731A, S/N 1810	WIA Type 222, S/N 5, Ch. 2

All of the vibration data were recorded on a Teac Model RD 135T 8-channel digital tape recorder, S/N 723884.

Vibration measuring systems are checked prior to field use and calibrated in the WIA laboratory with a shaker and simultaneous measurement between the seismic accelerometers and a reference accelerometer used solely for this purpose. The reference accelerometer used for this purpose is a Kistler Type 808K, S/N 849, which was most recently calibrated by Odin Metrology on October 10, 2002. This calibration is traceable to NIST Test No. 822/263351-00 and certified through 24 August 2004.

APPENDIX C

GLOSSARY AND SIGNIFICANCE OF ACOUSTICS AND VIBRATION TERMINOLOGY

A-Weighted Sound Level (dBA):

The sound pressure level in decibels as measured on a sound level meter using the internationally standardized A-weighting filter or as computed from sound spectral data to which A-weighting adjustments have been made. A-weighting de-emphasizes the low and very high frequency components of the sound in a manner similar to the response of the average human ear. A-weighted sound levels correlate well with subjective reactions of people to noise and are universally used for community noise evaluations.

Accelerometer:

A vibration sensitive transducer that responds to the vibration acceleration of a surface to which it is attached. The electronic signal generated by an accelerometer is directly proportional to the surface acceleration.

Acceleration Level:

Also referred to as the "vibration acceleration level". Vibration acceleration is the rate of change of the speed and direction of a vibration. An accelerometer generates an electronic signal that is proportional to the vibration acceleration of the surface to which it is attached. The acceleration level is 20 times the logarithm to the base 10 of the ratio of the RMS value of the acceleration to the reference acceleration. The generally accepted reference vibration acceleration is 10^{-6} g (10^{-5} m/sec).

Airborne Sound:

Sound that travels through the air, as opposed to structure-borne sound.

Ambient Noise:

The prevailing general noise existing at a location or in a space, which usually consists of a composite of sounds from many sources near and far.

Background Noise:

The general composite non-recognizable noise from all distant sources, not including nearby sources or the source of interest. Generally background noise consists of a large number of distant noise sources and can be characterized by L_{90} or L_{99}.

Community Noise Equivalent Level (CNEL):

The L_{eq} of the A-weighted noise level over a 24-hour period with a 5 dB penalty applied to noise levels between 7 p.m. and 10 p.m. and a 10 dB penalty applied to noise levels between 10 p.m. and 7 a.m.

Day-Night Sound Level (L_{dn}):

The L_{eq} of the A-weighted noise level over a 24-hour period with a 10 dB penalty applied to noise levels between 10 p.m. and 7 a.m.

Decibel (dB):

The decibel is a measure on a logarithmic scale of the magnitude of a particular quantity (such as sound pressure, sound power, sound intensity) with respect to a standardized quantity.

Energy Equivalent Level (L_{eq}):

The level of a steady noise which would have the same energy as the fluctuating noise level integrated over the time period of interest. L_{eq} is widely used as a single-number descriptor of environmental noise. L_{eq} is based on the logarithmic or energy summation and it places more emphasis on high noise level periods than does L_{50} or a straight arithmetic average of noise level over time. This energy average is not the same as the average sound pressure levels over the period of interest, but must be computed by a procedure involving summation or mathematical integration.

Frequency (Hz):

The number of oscillations per second of a periodic noise (or vibration) expressed in Hertz (abbreviated Hz). Frequency in Hertz is the same as cycles per second.

Groundborne Noise:

Noise propagated through soil and building structures. It is normally radiated by the ground in open air and by walls, floors and ceilings inside a building as a result of vibration which, after being produced by a source some distance away, travels through the soil in the form of elastic waves.

Octave Band - 1/3 Octave Band:

One octave is an interval between two sound frequencies that have a ratio of two. For example, the frequency range of 200 Hz to 400 Hz is one octave, as is the frequency range of 2000 Hz to 4000 Hz. An octave band is a frequency range that is one octave wide. A standard series of octaves is used in acoustics, and they are specified by their center frequencies. In acoustics, to increase resolution, the frequency content of a sound or vibration is often analyzed in terms of 1/3 octave bands, where each octave is divided into three 1/3 octave bands.

Sound Pressure Level (SPL):

The sound pressure level of sound in decibels is 20 times the logarithm to the base of 10 of the ratio of the RMS value of the sound pressure to the RMS value of a reference sound pressure. The standard reference sound pressure is 20 micro-pascals as indicated in ANSI S1.8-1969, "Preferred Reference Quantities for Acoustical Levels".

Statistical Distribution Descriptors (L_1, L_{10}, L_{50}, L_{90}, etc):

Also called *Exceedance Levels,* they represent the level of the noise (A-weighted for environmental studies) which is exceeded a percentage of the duration of the measurement period, as denoted by the subscript. So, for instance, L_{10} is the level of the noise exceeded for 10% of the measurement period (usually 1 hour in long-term environmental studies)

L_{99} and L_{90} are descriptors of the typical minimum or "residual" background noise (or vibration) levels observed during a measurement period, normally made up of the summation of a large number of sound sources distant from the measurement position and not usually recognizable as individual noise sources. Generally, the prevalent source of this residual noise is distant street traffic. L_{90} and L_{99} are not strongly influenced by occasional local motor vehicle passbys. However, they can be influenced by stationary sources such as air conditioning equipment.

L_{50} represents a long-term statistical median noise level over the measurement period and does reveal the long-term influence of local traffic.

L_{10} describes typical levels or average for the maximum noise levels occurring, for example, during nearby passbys of trains, trucks, buses and automobiles, when there is relatively steady traffic. Thus, while L_{10} does not necessarily describe the typical maximum noise levels observed at a point, it is strongly influenced by the momentary maximum noise level occurring during vehicle passbys at most locations.

L_1, the noise level exceeded for 1% of the time is representative of the occasional, isolated maximum or peak level which occurs in an area. L_1 is usually strongly influenced by the maximum short-duration noise level events which occur during the measurement time period and are often determined by aircraft or large vehicle passbys.

Velocity Level:

Also referred to as the “vibration velocity level”. Vibration velocity is the rate of change of displacement of a vibration. The velocity level is 20 times the logarithm to the base 10 of the ratio of the RMS value of the velocity to the reference velocity. In this report, the reported vibration velocity levels are all referenced to 10^{-6} in/sec. Above approximately 10 Hz, human response to vibration is more closely correlated to the velocity level than to the acceleration level.