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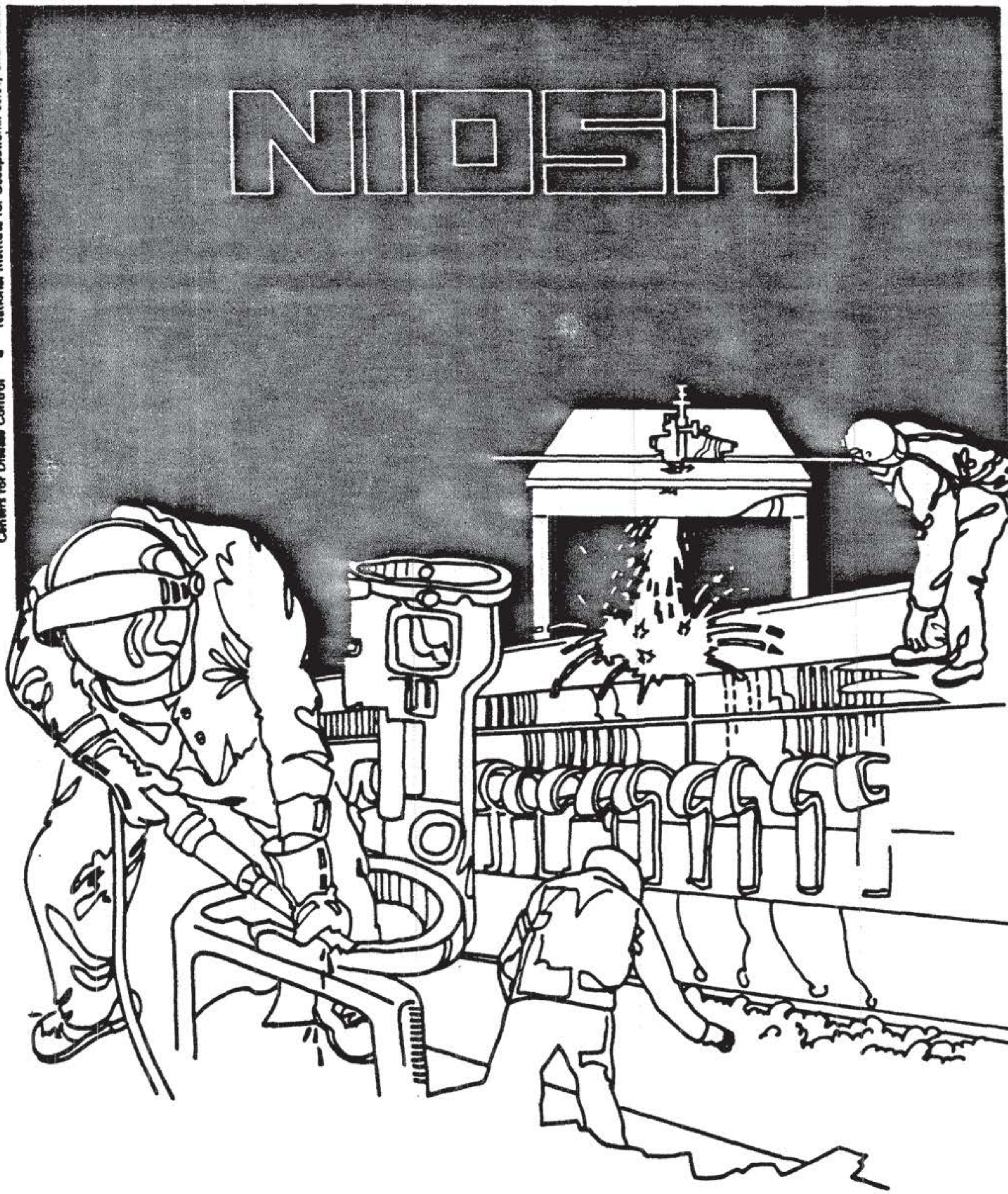

Health Hazard Evaluation Report

HETA 83-349-1901
WEYERHAEUSER CORPORATION
LONGVIEW, WASHINGTON

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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I. SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) received a request in June 1983 from Local 3-536 of the International Woodworkers of America, AFL-CIO to measure whole-body vibration exposures among heavy equipment operators who worked in the wood sorting yard of the Weyerhaeuser Lumber Company in Longview, Washington.

A visit was made on October 18-19, 1984, to conduct an initial assessment of the working conditions and equipment used at the Weyerhaeuser Company. Because of the time needed to develop reliable vibration assessment equipment and because of a temporary marked decrease in the log handling activity in the wood sorting yard due to economic conditions, the follow-up environmental visit was not conducted until October 7-9, 1986. During that visit, vibration measurement data were collected on five log stackers and two trucks using a seat mounted tri-axial accelerometer disc.

Fourteen of 20 log stacker drivers reported having experienced work-related low back pain, and lesser numbers reported work-associated musculoskeletal symptoms in the neck, shoulder or arm area. Ten of the 14 stacker operators reporting back pain had sought medical attention for that pain on one or more occasions. Two of these workers reported having received a diagnosis of herniated disk as the cause of their low back pain. Twelve of 13 truck drivers reported having experienced work-associated low back pain. Nine had sought medical treatment for their low back pain on one or more occasions, and two of the truck drivers had also received a diagnosis of herniated intervertebral disk.

Analysis of 8 to 22 minute representative segments of the vibration data revealed that, in one or more axes, vibration for all the machines exceeded the 8-hour "fatigue-decreased proficiency" limits set by the International Standard Organization's (ISO) Standard 2631-1978 for whole body vibration. Several machines exceeded the 2.5-hour "fatigue" curves. These exposures could result in a reduced ability to perform tasks efficiently after only 2.5 hours. Should vibration exposures at the 2.5-hour "fatigue" levels continue for 8 hours, the recommended ISO whole body vibration "exposure limit" (the level set to preserve health or safety) would also be exceeded.

Due to the possibility that chronic vibration exposure at the levels measured at the sorting yard could cause chronic health effects (e.g. on the musculoskeletal system), and considering the frequency of low back and other musculoskeletal symptoms reported by the wood sorting yard employees, combined with reports of frequent similar symptoms in other worker populations chronically exposed to whole-body vibration, it would be advisable to implement measures to decrease the whole-body vibration exposure of workers in the sorting yard.

All the machines evaluated exceeded the ISO 8-hour "fatigue-decreased proficiency" limits in one or more axes. In addition, the vibration exposures on three of the machines (determined for 8 to 22 minute representative intervals) would have exceeded the ISO "exposure limit" if they had been incurred for 8 hours. Thus, a potential health hazard existed at the time of the survey. Because of the significant levels of vibration measured on the log handling equipment at the Weyerhaeuser facility, recommendations are made in Section VIII of this report to reduce the vibration exposure of the wood sorting yard employees.

KEYWORDS: SIC 2421 (Lumber Industry), whole-body vibration, fatigue-decreased proficiency, logging, log stacker, logging truck.

II. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) received a request in June 1983 from Local 3-536 of the International Woodworkers of America to measure whole-body vibration exposures received by log stacker operators.

A visit was made on October 18-19, 1984, to conduct an initial assessment of the conditions at the Weyerhaeuser Lumber Company in Longview, Washington. Because of the time needed to develop reliable vibration assessment equipment and because of a temporary marked decrease in the log handling activity in the wood sorting yard due to economic conditions, the follow-up environmental visit was not conducted until October 7-9, 1986. At that time, acceleration data were collected using a tri-axial accelerometer disc mounted on the seats of seven different log stackers and trucks in use at at the Weyerhaeuser Lumber Company.

III. BACKGROUND

The wood sorting yard at the Weyerhaeuser Lumber Company is a multi-acre area that is unpaved except for the boat dock area, which is smooth asphalt, and a few macadam roads that connect various worksites. The ground is uneven, hard-packed and characterized by deep ruts in some places.

Logs are delivered to the wood sorting yard by truck or railcar. The various log stackers are used to off-load, sort logs by size and type, and stack the logs before and after processing. The log stackers are huge machines, which lift and transport heavy loads weighing as much as 60 tons. The combination of weight, rough surface, and driving speed results in substantial amounts of whole-body vibration being transmitted to the vehicle operator.

IV. METHODS

A. Medical

On October 18-19, 1984, an initial site visit to the Weyerhaeuser wood sorting yard was conducted by a NIOSH physician. During that visit, work practices were observed and the equipment in use was examined. The ten log stacker drivers on the day shift were interviewed privately, and self-administered questionnaires were completed by 10 other log stacker operators and 13 log truck drivers.

B. Environmental

All measurements were made in accordance with the direction definitions specified by the International Standard Organization (ISO) Standard 2631-1978 for whole body vibration.[1] According to the standard, the Z-axis represents vertical acceleration through the head, the X-axis represents acceleration in the direction from dorsal to ventral (chest-to-back), and the Y-axis is represented by side-to-side motions in the seated operator (Graphs 1 & 2).

A Bruel and Kjaer Model 7005 tape recorder was used to record tri-axial acceleration measurements. The recorder was connected to a rubber seat disc which had a tri-axial accelerometer embedded in it. The model 7005 recorder has four-channel capabilities, allowing for the simultaneous recording of all three directional axes, as well as a timing channel, which was placed on the tape with a Datum Time Code Generator. Using a tape speed of 1.5 in/sec, a frequency range of 0 to 1250 Hz was obtainable, which spans the range of human whole-body vibration measurements (1 Hz to 80 Hz). The tape recorder, time code generator, and seat disc were placed in the cab of the log stacker or logging truck and securely fastened out of the way of the operator with bunge cords and duct tape.

Five different log stackers were continuously monitored during the measurement period using a portable videocamera. The camera tripod was set up as close as possible to the work site where it would not interfere with the normal work routine. At the beginning of a measurement period, the internal stopclock in the camera was synchronized with the time code generator so that a visual description of the measured acceleration data could be obtained.

Before and after any data collection, all accelerometers were dynamically calibrated according to manufacturer's instructions using a Bruel and Kjaer Model 4291 accelerometer calibrator.[2] The tri-axial accelerometer was calibrated in all three orthogonal directions (X, Y, and Z). The acceleration charge signals from the tri-axial accelerometer were converted to voltages and amplified by charge amplifiers. This conversion allows compatibility with the input requirements of the FM tape recorder.

V. EVALUATION CRITERIA

Although there are over six million people within the United States who have significant occupational exposures to whole body vibration, the chronic health effects of such long-term exposure are not well understood. Short-term human and animal studies have shown that whole body vibration may be regarded as a non-specific generalized stressor and may have health effects, depending on the vibration strength and frequency.[3]

Many human performance studies in the area of whole body vibration have been conducted. The lowest subjective discomfort level to vibration occurs with frequencies around the five Hertz (cycles/second) whole body vibration resonance level. Manual tracking capability is also the most seriously affected at a frequency of five Hertz. Laboratory studies have shown that prolonged whole body vibration exposure will decrease the proficiency with which an operator performs his assigned tasks.[4]

In addition to the decreased performance effects of whole body vibration, there is concern that prolonged or recurrent whole body vibration exposure may have chronic adverse health effects. For example, certain disorders of the spine and digestive system have long been attributed to the effects of driving vehicles with rough motion.[3] NIOSH has conducted health record studies to determine the morbidity experienced by bus drivers, truck drivers, and heavy equipment operators. The bus driver study revealed that these bus drivers experienced a significant excess of gastro-intestinal, muscular, and back disorders. The study concluded that the combined effects of body posture, postural fatigue, dietary habits and whole body vibration may have contributed to the occurrence of these disorders.[5] The conclusions of the truck driver study indicated that the effects of forced body posture, cargo handling, improper eating habits, and whole body vibration may all have been contributing factors to significant excesses of back pain, and muscle strains, among truck drivers.[6] The study of heavy equipment operators found that exposed workers had an elevated risk of musculoskeletal problems and limb fractures.[7] While these studies indicated that workers who are exposed to whole body vibration while driving vehicles may suffer excesses of certain diseases, it has not been established how significant the exposure to whole body vibration may be in the occurrence of these excesses. As the studies stated, other factors, such as the heavy lifting and muscular effort required when loading the vehicles, dietary habits, falls, or accidents may have contributed to the excesses of certain of the health problems noted above.

There are three limits recognized in the International Standard 2631 for the evaluation of human exposure to whole-body vibration.[1] These limits are criteria for preserving comfort, preserving working efficiency, and for ensuring safety and health. These are denoted in the international standard as "reduced comfort boundary," "fatigue-decreased proficiency boundary," and the "exposure limit." The 1-hour through 16-hour "fatigue-decreased proficiency" boundary curves for the X, Y and Z axes are shown in Graphs 1 and 2.

The general shape of these two curves is dictated somewhat by a phenomenon known as resonance. Resonance occurs with those vibration frequencies that set the human body into motion most easily. In fact, at these resonance frequencies the human body will actually amplify the acceleration exposure levels by a factor of 1.5 to 3 times the original acceleration value. For example, at resonance, if a worker is seated on a tractor seat which is delivering 1 meter per second per second of vibration, then one might measure acceleration values of up to 3 meters per second per second at the worker's head. This resonance phenomenon appears in the ISO curves as the frequencies with the lowest allowed values of RMS accelerations. These are frequencies between 1 and 2 Hz for the transverse axes (X and Y), and frequencies between 4 and 8 Hz in the longitudinal axis (Z). The allowable amount of acceleration is greater at frequencies other than the resonance frequencies. Resonance frequencies for specific human organ systems are shown in Figure 1.

The Standard states that "where the primary concern is to maintain the working efficiency of the vehicle driver or a machine operator working in vibration, the 'fatigue-decreased proficiency boundary' would be used as a guiding limit in laying down vibration specifications or in carrying out vibration control measures, while, in the design of passenger accommodations, the 'reduced comfort boundary should be considered'." The international standard encompasses frequencies only within the range of 1 to 80 Hz.

In setting the fatigue-decreased proficiency levels, laboratory data obtained on young males (primarily members of the military) were used.[4] The fatigue-decreased proficiency boundary specifies a limit beyond which exposure to vibration can be regarded as carrying a significant risk of impaired working efficiency in many kinds of tasks, particularly those in which time-dependent effects ("fatigue") are known to worsen performance as, for example, in vehicle driving. Due to the general lack of data relating adverse health effects to specified levels of vibration exposure, the "exposure limit" (the level set to preserve health or safety) was set two times higher than the fatigue-decreased proficiency boundary. This health exposure limit is at approximately half the level considered to be the threshold of pain (or limit of voluntary tolerance) for healthy human subjects restrained to a vibrating seat. The reduced comfort boundary is 3.15 times lower than the fatigue-decreased proficiency boundary.

VI. RESULTS

A. Medical

The results of the questionnaires distributed to the log stacker drivers and log truck drivers are shown in Table 1. The average age of the truckdrivers (all were males) was 44 years (range 34 - 64), and they had worked in the Weyerhaeuser wood sorting yard for an average of 13.5 years (range 7 - 16). Fourteen of the 20 log stacker drivers reported having experienced work-related low back pain, and lesser numbers reported work-associated musculoskeletal symptoms in the neck, shoulder or arm area. Seven also reported frequently experiencing work-associated headache. Several of the workers related the onset of headache to the noise and vibration experienced while driving the log handling equipment. Three reported that the constant bouncing or jostling they experienced while operating the machines aggravated the discomfort in their backs, necks, shoulders, or arms. Two related the onset of their back pain to falls from ladders while entering or leaving the log stacking vehicle. Three of the drivers mentioned that the Le Tourneau machine suspensions provided a much harsher ride than the Kenworth machines. It is of note that 10 of the 14 stacker operators reporting low back pain had sought medical attention for that pain on one or more occasions. Two of these workers reported having received a diagnosis of herniated disk as the cause of their low back pain.

The 13 truck drivers (12 male, one female) had an average age of 38 years (range 28 - 49), and they had worked in the Weyerhaeuser wood sorting yard for an average of 5.3 years (range 3 months - 11.3 years). Twelve of the 13 reported having experienced work-associated low back pain (Table 1). Nine had sought medical treatment for their low back pain on one or more occasions, and two of the truck drivers had also received a diagnosis of herniated intervertebral disk as the cause of their low back pain. Two workers associated the onset of their low back symptoms to truck accidents. Three reported that setting the wrappers and binders that held the logs on the trucks definitely aggravated their low back symptoms. Three felt that rough roads and inadequate seats contributed to their low back and other musculoskeletal problems. One worker associated a traffic accident to the onset of work-associated headache problems, and another attributed his headaches to the smell of diesel fumes.

B. Environmental

Acceleration data were collected on five different log stackers and two trucks using the seat mounted tri-axial accelerometer disc. The vehicles measured were:

1. Kenworth Highway Log Truck, Vehicle #629
2. Mack Off Highway Log Truck, DML8955X, Vehicle #681
3. 25 Ton Hough Log Stacker, Model 560B, Vehicle #197
4. 17 Ton Pettibone Log Stacker, Model 204C, Vehicle #292
5. 60 Ton Dart Log Stacker, Model 120, Vehicle #294
6. 60 Ton Le Tourneau Log Stacker, Model 2794, Vehicle #198
7. 40 Ton Le Tourneau Log Stacker, Model 2594, Vehicle #199

These data were collected and stored while the vehicles operated under normal conditions for periods ranging from 30 to 50 minutes. This time interval provided samples of loading, transporting, unloading, idling or any combination of operating conditions. Equipment operators were asked to carry out their normal work routines so that "typical" acceleration measurements could be taken. Video and audio recordings were simultaneously made of the equipment to assist in the analysis of the acceleration information.

Using the videotape records of vehicle operation, an 8 to 22 minute segment that was representative of several typical work cycles was chosen for each vehicle. These segments of recorded acceleration data were then analyzed using a one-third octave band analyzer (Bruel & Kjaer Model 2131 Real-Time Analyzer). The acceleration levels in 25 one-third octave frequency bands, ranging from 0.4 to 100 Hz, were listed in tabular form. The tabular frequency information, in the X, Y, and Z-directions, was plotted along with the ISO Standard 2631 curves for "Fatigue-Decreased Proficiency Boundaries."

The frequency analyzer permitted one-third octave band analysis of the data. Spectral information was plotted as average acceleration values in meters per second per second (m/s^2 rms) versus frequency (Hz). The permitted fatigue decreased proficiency (FDP) acceleration curves for one hour through 16 hours are shown on each of the graphs. If the spectral plot crosses a FDP curve, then the person has exceeded the allowed exposure for the duration indicated on the FDP curve. For example, between 2 and 3 Hz the Le Tourneau #199 exceeded the permitted 8 hour "fatigue" exposure in the X direction, was acceptable in the Y direction, and exceeded the 8 hour "fatigue" curve in the Z direction.

The spectral plots on each vehicle, for all three directions, are included in the Appendix. Table 2 lists the highest Fatigue-Decreased Proficiency (FDP) curve for each axis exceeded by a vehicle at the specified frequency bands (1-2Hz, 2-4Hz, 4-8Hz, 8-20Hz and greater than 20Hz) for all three axes.

In most cases, the vehicle had the seat issued by the original equipment manufacturer (OEM). Although the management stated that the company would install the type of seat desired by the vehicle's regular operator, only a few of the original equipment seats had been replaced by seats designed to provide increased vibration dampening.

In evaluating the data, we noted when the spectral plots exceeded the 8-hour FDP or "fatigue" curve. However, if 12 to 16 hour work shifts are used, then the 16-hour "fatigue" curve would be important. If the spectral plot exceeds the 2.5-hour "fatigue" curve, the average acceleration would exceed the ISO "exposure limit" for eight hours of work because of the relationship between the two sets of curves noted earlier in the report.

The synchronized recording of video made it possible to construct a description of the work activity undertaken by the vehicles while the acceleration data were being collected. These descriptions are given in the remainder of this section, and spectral plots of the vibration data are presented in the Appendix.

1. <u>Kenworth Highway Truck #629</u>

This truck was operated over highways at speeds up to 55 miles per hour. The acceleration measurements include the periods when the truck was stopped as well as during the shifting of gears as the truck attained highway speeds. Separate data were collected when the tri-axial seat disk was in the operator's custom ordered seat while the truck was both empty and loaded. Data were also obtained when the seat disk was in the passenger's OEM seat and the truck was empty. Because this vehicle was operated outside of the Weyerhaeuser facilities, no video taping of the operation was made. Instead of videotaping, a NIOSH investigator rode in the passenger seat and described the vehicles journey on an audio track of the tape used to record the vibration measurements.

Acceleration values for the driver's seat while the truck was loaded exceeded the 2.5-hour "fatigue" curve at frequencies below whole-body resonance in the Z axis. Therefore, in this situation, the driver was being exposed to vibration levels exceeding the 8-hour "exposure limit" set to protect against possible health effects. In the X and Y axes, the 8-hour "fatigue" curve was exceeded in the resonance frequencies.

When truck #629 was empty, the driver's seat registered acceleration values tha exceeded the 8-hour "fatigue" curve for frequencies below resonance in the Z direction. No 8-hour curves were exceeded for the transverse axes.

For the situation where this truck was empty and vibration measurements were being made for the OEM passenger's seat, the acceleration levels in the Z direction were approaching the 1-hour "fatigue" curve at the resonance frequencies of 4 - 8 Hz. The 8-hour "fatigue" boundaries were also exceeded for frequencies both above and below resonance. In the Y axis, the 8-hour "fatigue" curve was exceeded for frequencies above resonance.

2. Mack Off-Road Truck #681

This vehicle was used within the Weyerhaeuser facilities to transport logs from location to location. Because of this, it was usually operated at fairly slow speeds, over a variety of terrains, while making several short trips. It was subject to vibration from the uneven ground over which it traveled, as well as an occasional shock from hitting a pothole. The acceleration data collected during the survey did not include periods when the vehicle was stopped and idling while waiting for a load of logs to be put on or removed from the truck. If these periods had been factored into the analyses, then the acceleration values would have possibly been lower. Also, because of the nature of the operation, no video recordings of this vehicle were made during the collection of vibration data and a NIOSH investigator rode in the vehicle to record vehicle activities during the measurement period.

The vehicle exceeded the 8-hour "fatigue" boundary in the Z axis only at frequencies below the resonance frequencies. For the Y direction, the 4-hour "fatigue" curve was exceeded for resonance frequencies.

3. Hough Log Stacker #197

The Hough log stacker was used in the dock area to load logs on an ocean going ship. The dock area was paved with asphalt, which made for a smooth surface to operate the vehicle. The process consisted of the Hough stacker getting logs from a storage pile in the dock area and transporting them to one of 4 holding bins. The Hough operator would drop the logs into the holding bin and then move to the end position of the bin with the stacker and push the logs until they were lined up in the bin. A Kenworth log stacker operated by a longshoreman would then transport the logs to a second holding area. There, they were collected by a ship's crane and loaded into the holding bays of the ship. The Hough operator repeated this process on a very cyclic basis, keeping the 4 holding bins filled for the longshoreman.

The Hough operation was recorded for a total time of 50 minutes, 37 seconds. During the recording period, a total of 22 cycles of filling the loading bins were completed. During the observation period, the Hough stacker was operated with its front forks empty a total of 25 minutes, 47 seconds, or 51% of the time. A 21 minute, 20 second period of vibration data were analyzed from the total observation time. During the analysis section, a total of 9 loading cycles were completed. The front forks were empty 46% of the vibration analysis time.

In the Z axis, the results showed that the Hough exceeded the 8-hour "fatigue" curve both below and above the resonance area. In the two transverse directions, the 8-hour boundary was passed in the resonance frequencies of 1 - 2 Hz. The low frequency accelerations seen in the results were most likely the result of the lifting of the rear wheels off the ground during the pick up and dropping of logs. This was observed several times on the video recording.

4. Pettibone Log Stacker #292

Much like the Hough stacker, the Pettibone log stacker operated in a very well defined, cyclic pattern. Its job was to transport logs which had been laid out in a single row on the ground at a sorting area of the Weyerhaeuser wood sorting yard. After the logs had been sized and sorted according to the kind of wood and the intended use of the log, the Pettibone stacker would pick up the logs, generally one or two at a time, and place them in a holding bin for later pick up by another log stacker. The terrain where this operation took place was unpaved ground which had been watered to reduce dust exposures. The Pettibone operator would occasionally pull a log across the area to smooth the surface.

The Pettibone's operation was recorded for a total of 45 minutes, 55 seconds. During this observation time, a total of 40 cycles of moving logs from the ground to a holding bin were completed. The amount of time that the front forks were unloaded was 17 minutes, 39 seconds, or 38% of the recording period. A 21 minute, 20 second period was analyzed for the vibration acceleration levels resulting from 22 work cycles. The front forks were empty during the analysis period for one-third of the time.

The average acceleration value in the Z direction was found to be in excess of the 2.5-hour "fatigue" boundary in the frequency range below whole-body resonance. For the X and Y axes, the 8-hour "fatigue" curves were exceeded for the resonance frequencies.

5. Kenworth Dart Log Stacker #294

The Kenworth Dart stacker was observed in the area surrounding the log debarking machine. The video recordings were made with the camera located in the observation tower at the top of the debarking machine. The log stacker was engaged in the process of unloading trucks that were parked on the roadway running next to this general area. The Dart stacker would also move logs to the sizing and sorting bins at this location and also move logs to a storage pile adjacent to this general area. Because the debarking machine was not in operation during the second shift when this recording took place, the Dart stacker was not moving logs to this machine during the observation period.

A total of 48 minutes, 40 seconds elapsed while this log stacker was being observed performing the above mentioned work activities. Of this total time, the front forks of the stacker were not loaded for 30 minutes, 35 seconds. or 62% of the period. A 10 minute, 40 seconds analysis period was chosen where the stacker was in the process of unloading 4 logging trucks and placing the load of logs either in the sorting, sizing bins or in the log storage pile. During the analysis period, the front forks were empty for 4 minutes, 56 seconds, or 46% of the time.

The log stacker was found to have acceleration values in excess of the 4-hour "fatigue" curve in the frequency range below resonance for the Z axis. In the X direction, the acceleration levels exceeded the 8-hour boundary at the resonance frequencies. No boundaries were exceeded for Y axis accelerations.

6. Le Tourneau Log Stacker #198

The Le Tourneau log stacker is a 60-ton machine. An attempt was made to observe the operation of this machine from the observation tower at the debarking machine. However, because of miscommunication between the operator and the NIOSH survey personnel, the vehicle traveled out of camera range towards the Weyerhaeuser paper mill during the time when acceleration levels were being recorded on the tape recorder. During the 10 minute, 40 second analysis period, it was observed that the Le Tourneau stacker picked up a load of logs from one of the sorting, sizing bins and traveled in reverse toward the paper mill and out of camera range. Before the analysis period was finished, the vehicle had returned to the log debarking area with its front forks empty and the machine moving in the reverse direction.

The results of the vibration analysis revealed a large average acceleration peak at approximately 2 Hz in the longitudinal (z) axis. The peak exceeded the 2.5-hour "fatigue" curve at this point. Because the vehicle was not observed during this recording period, it is not possible to determine what might be the cause of these relatively high acceleration values.

7. Le Tourneau Log Stacker #199

The Le Tourneau 40-ton log stacker was operated in the same location as the Pettibone stacker. During the observation period, the stacker was unloading and loading logging trucks, putting logs into a storage pile, and spreading logs into a single file along the ground for sizing and sorting. Each of these operations was observed during the recording period, but there was no periodicity to their occurrence.

Overall, this vehicle was recorded for a total of 33 minutes, 45 seconds. Of this time, the front forks of the log stacker were empty 42% of the time, or 14 minutes, 14 seconds. An 8 minute, 32 second segment of this time was analyzed for vibration levels. During the analysis period, the forks of the stacker were empty for 2 minutes, 27 seconds (29%).

The analysis of the X axis accelerations revealed a crossing of the 8 hour "fatigue" curve at frequencies above whole-body resonance. A peak that exceeded the 4-hour FDP boundary for the Z direction was observed at frequencies below the resonance range. No 8-hour "fatigue" boundaries were exceeded for acceleration values measured in the Y axis.

VII. DISCUSSION AND CONCLUSIONS

Vibration exposure of heavy equipment operators such as were measured in this health hazard evaluation result from three major sources:

1. Road-borne vibration transmitted to the operator is caused by road surface irregularities, which are transmitted through the suspension to the floor of the machine and then through the seat to the worker. An irregular surface can be smoothed to reduce the vibration, and the seat, if it is adjustable, can be set to minimize vibration transmitted from the floor.

2. Vibration can be caused by the work being accomplished with the equipment. A machine which lifts logs will create vibration as part of the lifting process. Here vibration is caused by the collision between the fork and the log pile, by running on the return portion of the work cycle with the fork empty, and by emptying the fork. This vibration is transmitted to the floor of the vehicle and then through the seat to the worker. It is most easily controlled by changing work practices, namely, slowing the running speed on the return to the supply log pile and slowing the fork descent back to the ground.

3. Vibration can be caused by the vehicle's power source. Peaks in the spectral curve in the 40 Hz region often can be attributed to vehicle engine vibration. The level of vibration from most engines is not of concern unless the accelerations are transmitted to the hands (e.g., vibration of the steering wheel).

Analysis of the data revealed that, in one or more axes, all the machines produced vibration levels that exceeded the 8-hour "fatigue-decreased proficiency" limits set by the International Standard 2631. Vibration levels in the Hough #197, Pettibone #292, Mack Truck #681, and Highway Truck #629 exceeded the 8-hour "fatigue" curve in all three axes. The Mack Truck #681 was the only vehicle to exhibit acceleration levels that exceeded the 4-hour "fatigue" curve in the Y axis. None of the machines had acceleration levels above the 4-hour "fatigue" curve in the X axis.

Of special concern is the fact that the vibration levels measured on the Pettibone #292, the Le Tourneau #198, and the Kenworth Highway Truck #629 all exceeded the 2.5-hour "fatigue" curve in the Z axis. These vibration levels could result in a reduced ability to perform tasks accurately after only 2.5-hours. Should vibration exposures at the 2.5-hour "fatigue" levels continue for 8 hours, the recommended "exposure limit" would be exceeded. However, for the 7 vehicles observed, all drivers operated the vehicles less than 8 hours per 8-hour work shift due to scheduled breaks, waiting for log trucks to arrive, etc. Thus, none of the employees was likely to have received vibration exposures that exceeded the ISO 8 hour "exposure limit." The exposure limit could have been be exceeded, however, if the operators of the three vehicles had worked a 12 or 16 hour shift.

Analysis of the vibration data for the passenger seat of the empty Highway Truck #629 revealed that the 8-hour "fatigue" curve was exceeded in the Y direction between 2-4 Hz and, the 2.5-hour curve was exceeded in the Z axis between 4-8 Hz. The driver's seat acceleration levels were above the 8-hour "fatigue" limit only at 1-4 Hz when the truck was empty. Spectral plots for all three axes for both the driver and passenger seats for Truck #629 reveal that there is more energy concentrated above 4 Hz for the passenger's seat than for the driver's seat. This difference suggests that the custom seat helps to protect the driver from vibration exposure in the resonant frequency range for the longitudinal (Z) axis.

The high acceleration levels measured on the highway truck's passenger seat are of interest because they occur at the resonant frequency of the thoracic cavity and abdominal contents.[2] Vibration levels between 4 and 8 Hz can be expected to interfere with breathing if they are great enough. This effect was demonstrated by the observation that the NIOSH investigator sitting in the passenger's seat during this data collection had his voice modulated by the vibrations to the point that a very noticeable change in his voice was heard in the playback of the voice channel from the tape recorder.

As discussed in the Evaluation Criteria section, the potential adverse health effects of chronic whole-body vibration exposure are not well understood. However, although conclusive evidence is not available, numerous studies have suggested there may be an increased risk of low-back pain in workers exposed to whole body vibration like drivers of tractors, trucks, and busses.[8,9] Studies of vibration exposed populations also indicate that radiographic changes may occur in the spines of vibration exposed subjects.[6,8]

The levels given in the ISO standard for the fatigue decreased proficiency boundary were set at levels found to induce fatigue sufficient to decrease the efficiency of laboratory study participants. Due to the general lack of data relating the occurrence of adverse health effects to specified levels of chronic vibration exposure, the "exposure limit" (the level set to preserve health or safety) was arbitrarily set two times higher than the fatigue-decreased proficiency boundary. Thus, due to the incomplete information available regarding the possible chronic health effects of whole body vibration exposure, exposure to vibration at or even below the levels of the ISO exposure limit could be associated with adverse chronic health effects. It is of note that in 1986 Seidel et. al.,[10] after a comprehensive review of the world literature concerning whole body vibration exposure, concluded that "The data existing today do not permit the substantiation of a safe limit reliably preventing diseases of the locomotor (musculoskeletal)... system."

Due to the possibility that chronic vibration exposure at the levels measured in this study could cause chronic health effects (e.g. on the gastro-intestinal or musculoskeletal systems), and considering the frequency of low back and other musculoskeletal symptoms reported by the wood sorting yard employees, combined with reports of frequent similar symptoms in other worker populations chronically exposed to whole-body vibration, it would be advisable to implement measures to decrease the whole-body vibration exposure of workers in the sorting yard.

VIII. RECOMMENDATIONS

In light of the acceleration levels found, the following recommendations are offered to reduce the workers' vibration exposures.

1) The seat of each vehicle should be examined to determine whether it can be replaced or adjusted to offer more vibration isolation. Seat replacement should be considered especially on vehicles which exhibit high acceleration values at 4 to 8 Hz, i.e. whole-body resonance frequencies. This would include seat replacement for the Pettibone Log Stacker #292 and seat adjustment for optimum vibration attenuation on the Kenworth Highway Truck #629. The operators will have to be trained regarding the adjustments of these seats according to the manufacturer's recommendations in order to obtain the maximum amount of vibration isolation.

2) Modification of the work practices observed may limit the vibration exposures to the operators. For example, both the Hough Log Stacker #197 and the Le Tourneau Log Stacker #199 were observed to have their back wheels come completely off the ground when excessively heavy loads were lifted with the forks. This lifting of the rear wheels resulted in high levels of low frequency acceleration on the drivers' seats. Additionally, in a previous NIOSH study, decreasing the velocity of heavy equipment over uneven terain has been shown to reduce peak vibration levels on the driver's seat of the vehicle by a factor of 2.[11]

3) Vibration exposure can also be limited by reducing the time a worker operates the equipment. It may be possible in some situations to rotate workers between jobs with and without whole-body vibration exposure. Limiting workers to 8-hour shifts will lessen the potential for excessive vibration exposure during the work shift.

4) Frequent grading of the non-paved wood yard terrain should be intensified in order to maintain as smooth an operating surface as possible for the truck and log stacker operators.

IX. References

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X. AUTHORSHIP AND ACKNOWLEDGMENTS

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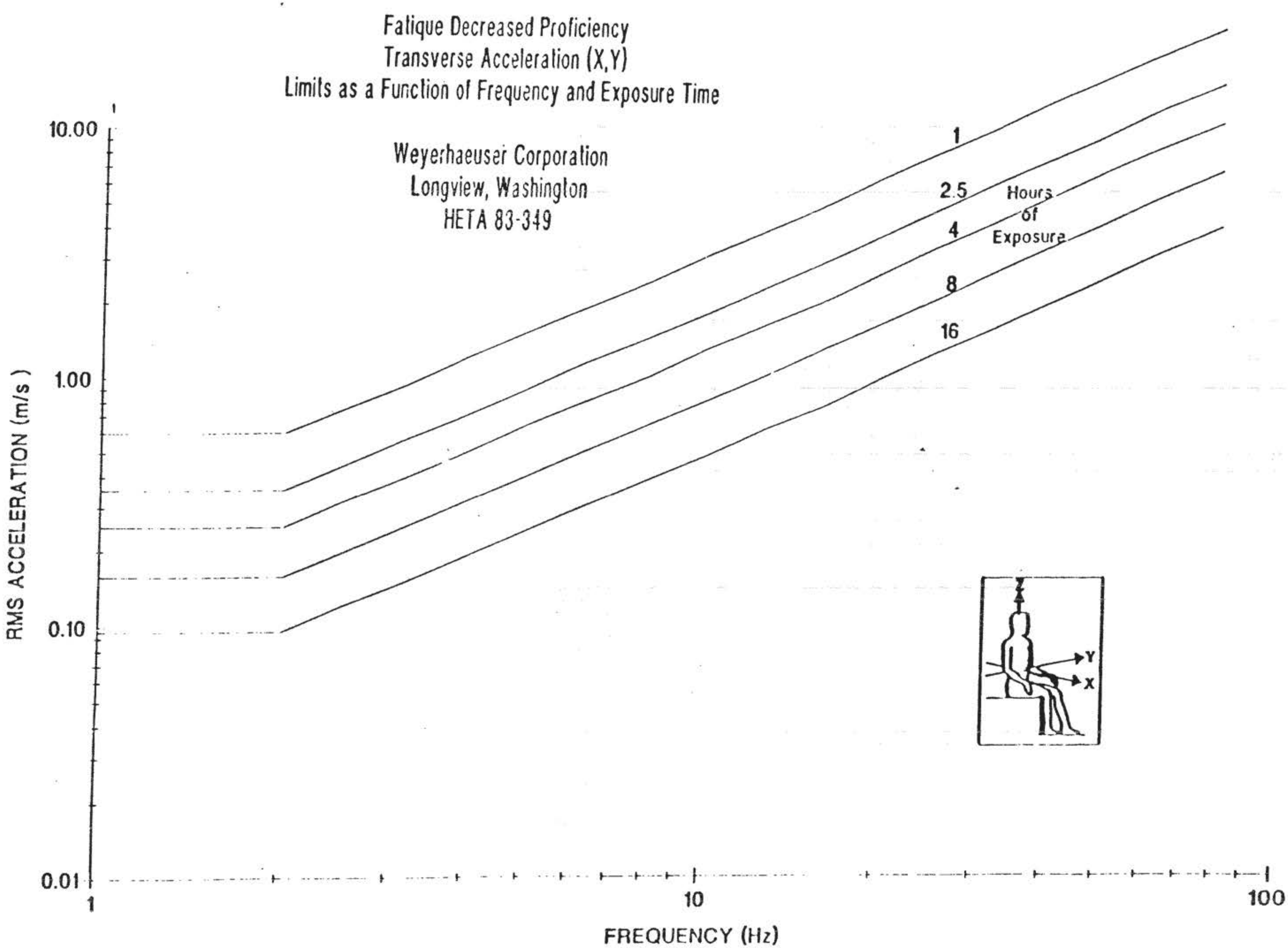
XI. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Services (NTIS), Port Royal Road, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH publications office at the Cincinnati address. Copies of this report have been sent to the following:

1. Local 3-536
   International Woodworkers of America, AFL-CIO

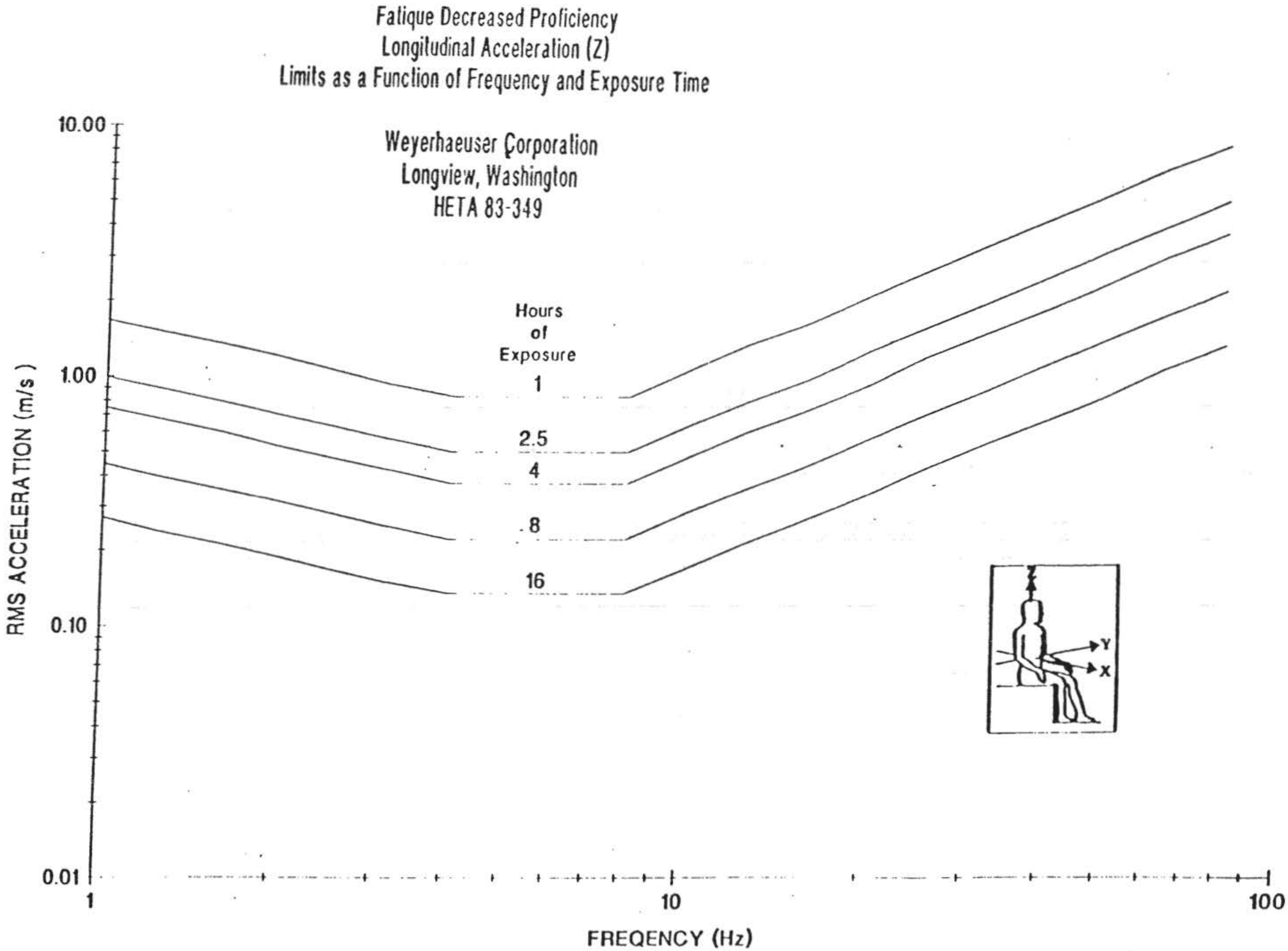
2. Weyerhaeuser Co.
   Longview, Washington

For the purposes of informing the affected employees, copies of the report should be posted in a prominent place accessible to the employees, for a period of 30 calendar days.



Fatique Decreased Proficiency
Transverse Acceleration (X,Y)
Limits as a Function of Frequency and Exposure Time
Weyerhaeuser Corporation
Longview, Washington
HETA 83-349
RMS ACCELERATION (m/s)
10.00
1.00
0.10
0.01
1
10
100
FREQUENCY (Hz)
1
2.5
4
8
16
Hours of Exposure
Z
Y
X

Graph 1

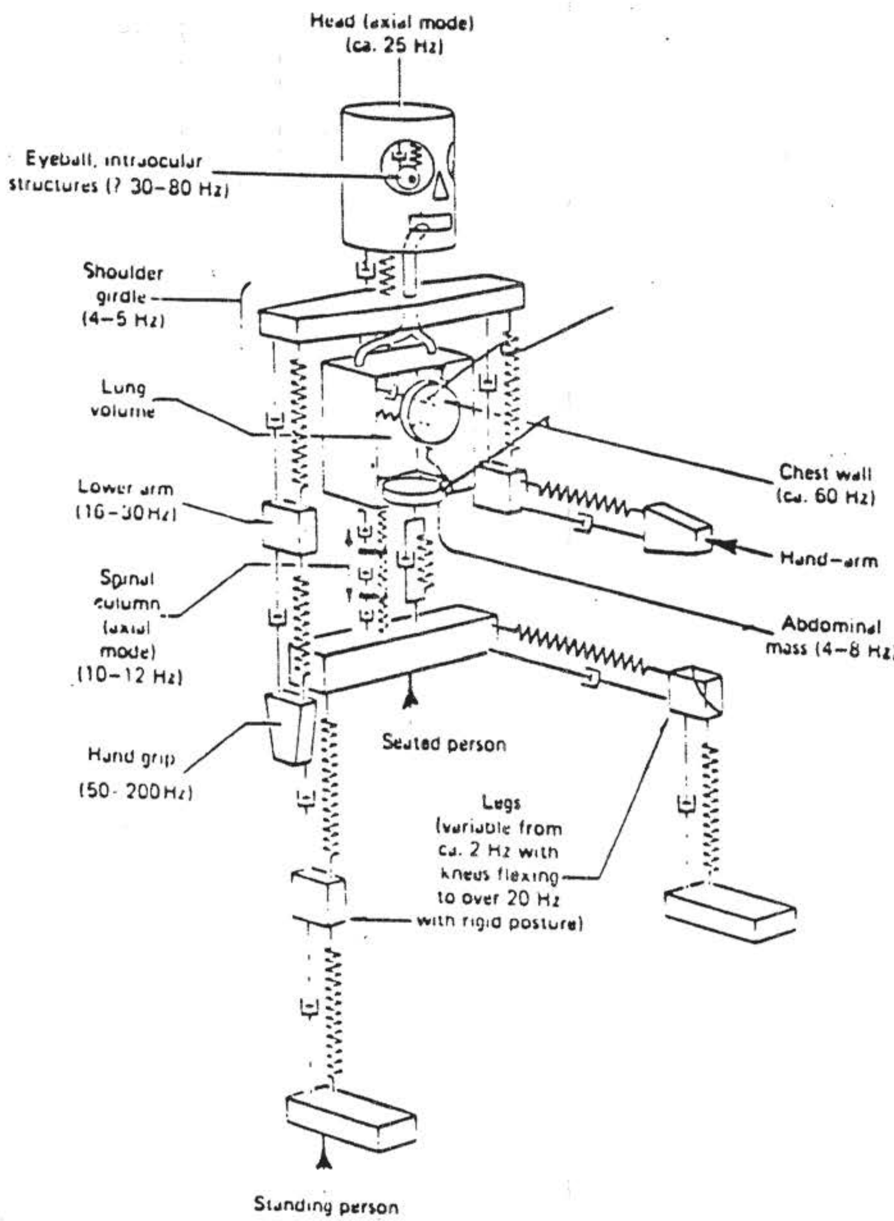


Fatique Decreased Proficiency
Longitudinal Acceleration (Z)
Limits as a Function of Frequency and Exposure Time
Weyerhaeuser Corporation
Longview, Washington
HETA 83-349
10.00
1.00
0.10
0.01
RMS ACCELERATION (m/s)
Hours
of
Exposure
1
2.5
4
8
16
Z
Y
X
1
10
100
FREQENCY (Hz)

Graph 2

Figure 1

Resonant Frequencies of the Human Body *



*From B&K Tech. Review No. 1, 1982

TABLE 1
Weyerhaeuser, Longview, Washington Sorting Yard
October 18, 1984
Number of Operators Reporting Work-Associated Symptoms

Symptom	13 Truck Drivers	20 Log Stacker Drivers
Dizziness	0 (0%)*	2 (10%)
Headache	2 (15%)	7 (35%)
Neck Pain	7 (54%)	7 (35%)
Shoulder Pain	6 (46%)	6 (30%)
Arm Pain	3 (23%)	5 (25%)
Low Back Pain	12 (92%)	14 (70%)

* - Number and (%) with symptom.

Table 2

Vehicle Acceleration Levels Exceeding "Fatigue-Decreased Proficiency" Boundaries in Specific Frequency Ranges.

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Frequency (Hertz)

Vehicle	1-2 Hz	2-4 Hz	4-8 Hz	8-20 Hz	20+ Hz
1. Kenworth Highway Truck Loaded (Driver)	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.
Z Axis	4	2.5	8	16	
Y Axis	8	8	16		
X Axis	8	8	16		
Kenworth Highway Truck Empty (Driver)					
Z Axis	8	8	16		
Y Axis	16	16			
X Axis					
Kenworth Highway Truck Empty (Passenger)					
Z Axis	16	8	2.5	4	
Y Axis		16	8		8
X Axis		16	16		
2. Mack off Road 681					
Z Axis	8	8	16	16	
Y Axis	4	4			
X Axis	16	8	16		
3. Hough 197					
Z Axis	8	8	16	8	
Y Axis	8	8			
X Axis	8	16			
4. Pettibone 292					
Z Axis	8	2.5	16	16	
Y Axis	8	8			
X Axis	8	8			
5. Dart 294					
Z Axis	8	4			
Y Axis			16		
X Axis	8	8			

Table 2 (Continued)

Vehicle Acceleration Levels Exceeding "Fatigue-Decreased Proficiency" Boundaries in Specific Frequency Ranges.

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Longview, Washington
HETA 83-349

	Frequency (Hertz)				
Vehicle	1-2 Hz	2-4 Hz	4-8 Hz	8-20 Hz	20+ Hz
6. Le Tourneau 198	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.
Z Axis	4	2.5			
Y Axis	8	16			
X Axis	16	16	16	16	
7. Le Tourneau 199					
Z Axis	16	4			
Y Axis	16	16			
X Axis	8	8			

Appendix

PART 1

Frequency Plots for each vehicle and direction

Average Acceleraton Levels (m/s^2) As a Function of Frequency (Hz)

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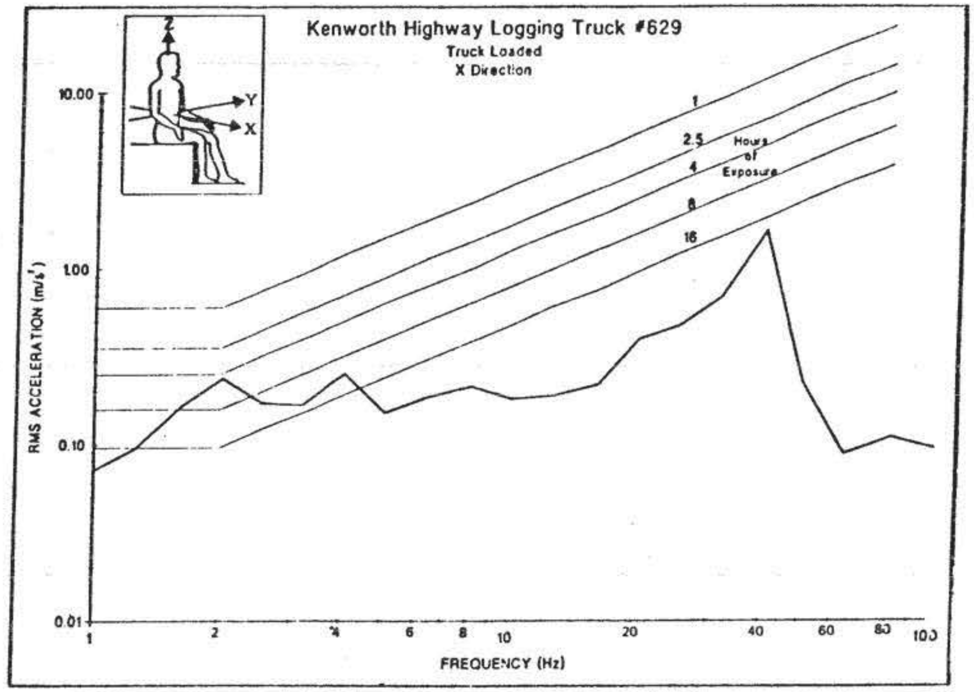

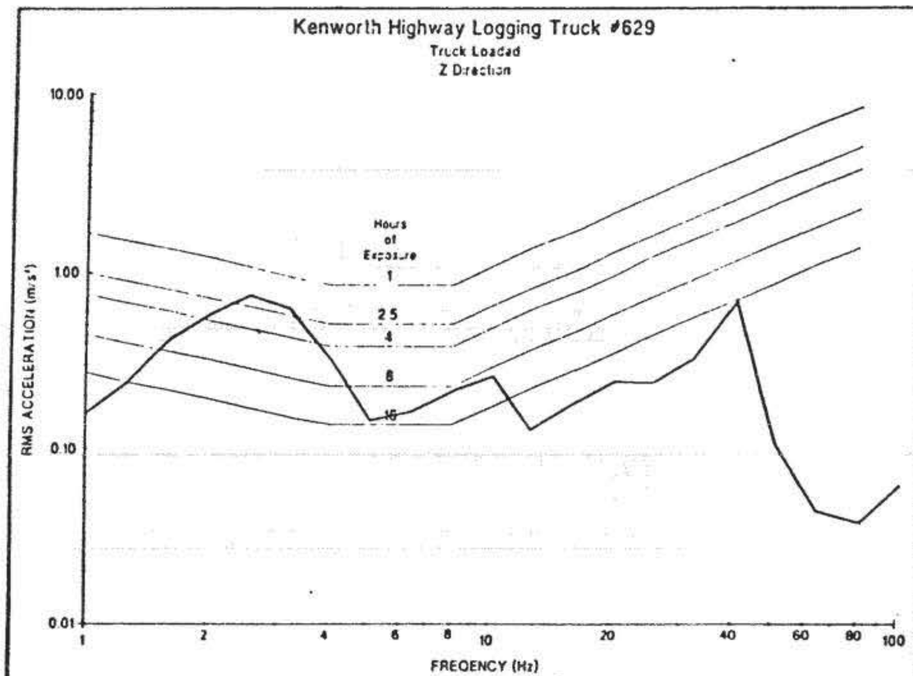

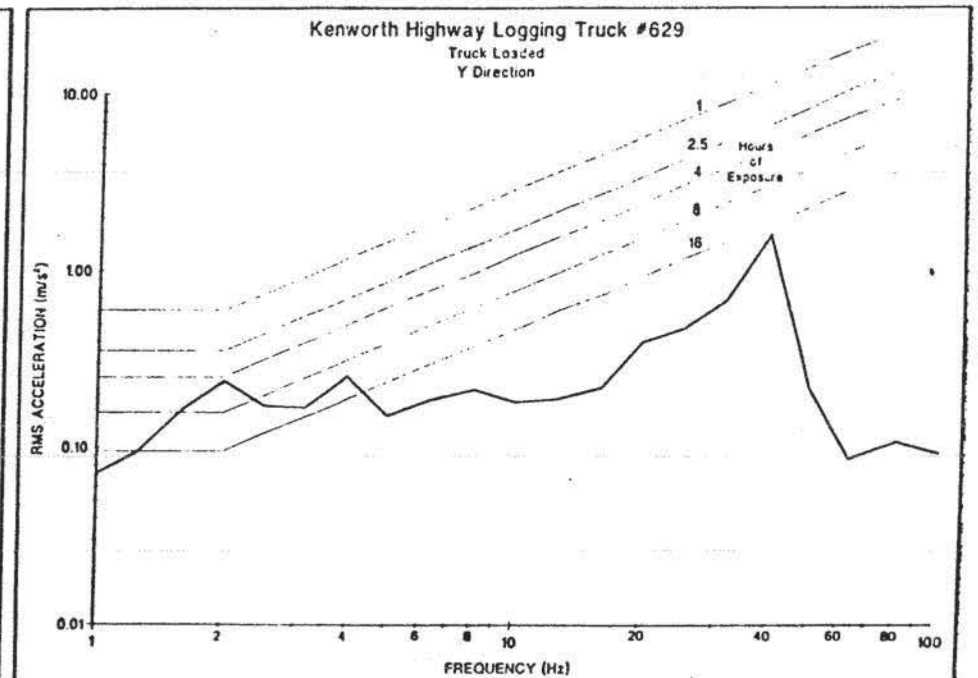

Average Acceleraton Levels (m/s^2) As a Function of Frequency (Hz)

Weyerhaeuser Corporation
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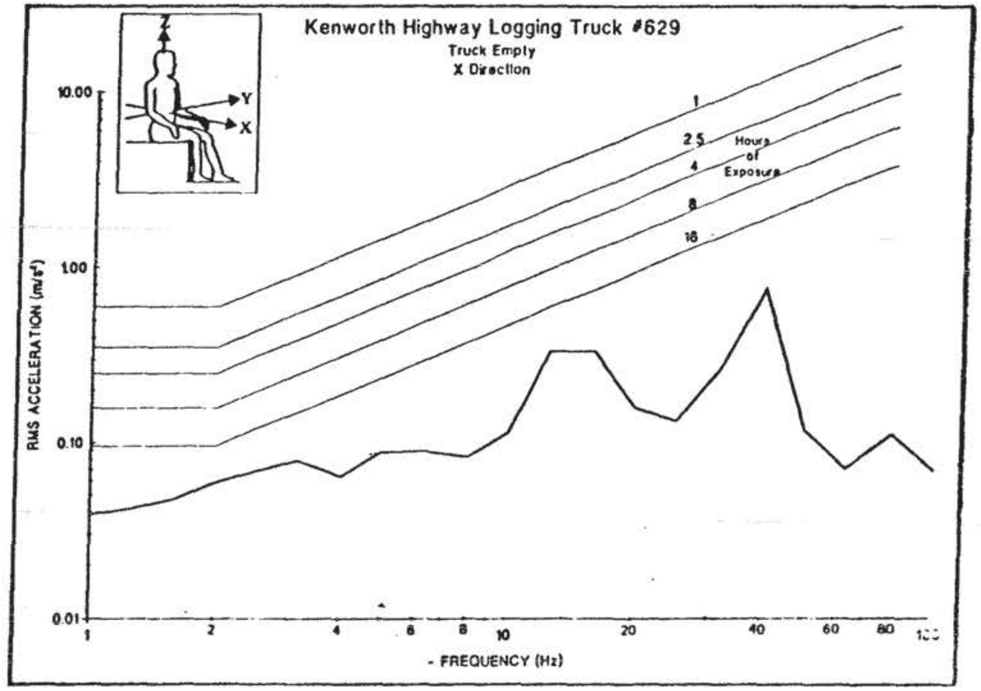

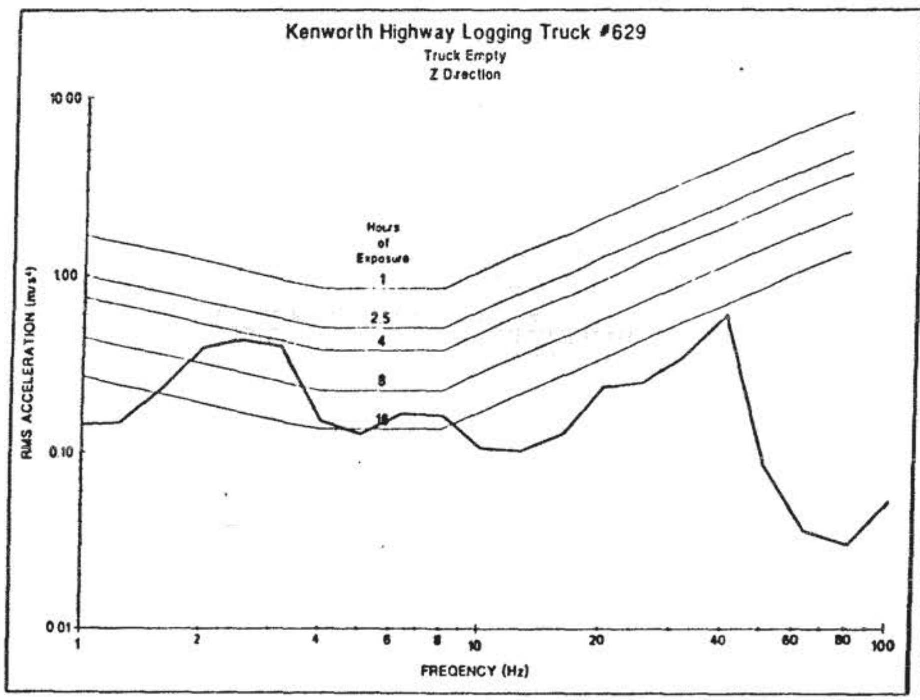

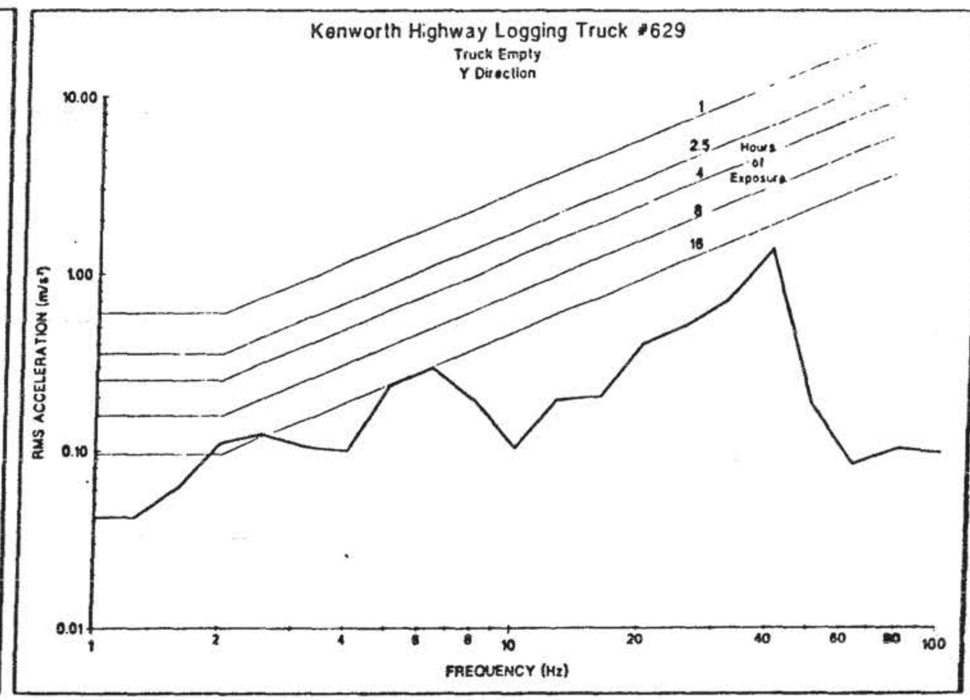

Average Acceleraton Levels (m/s^2) As a Function of Frequency (Hz)

Weyerhaeuser Corporation
Longview, Washington
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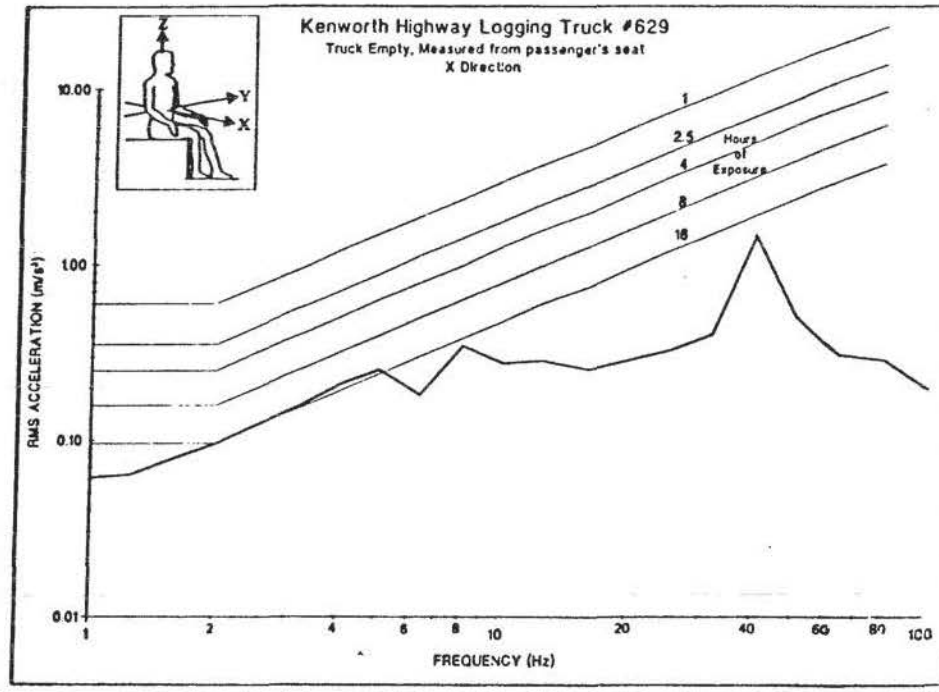
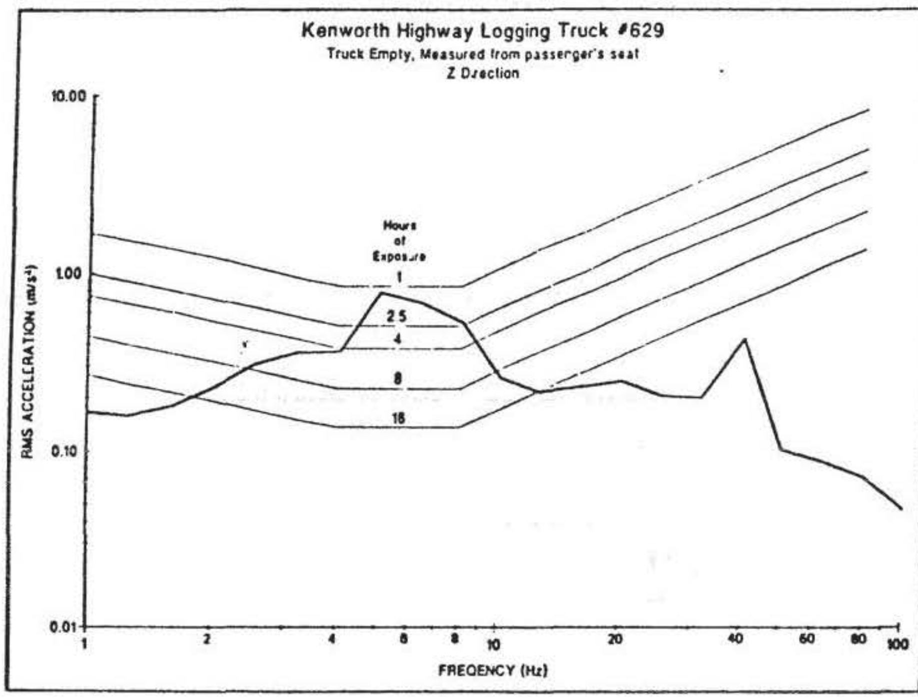
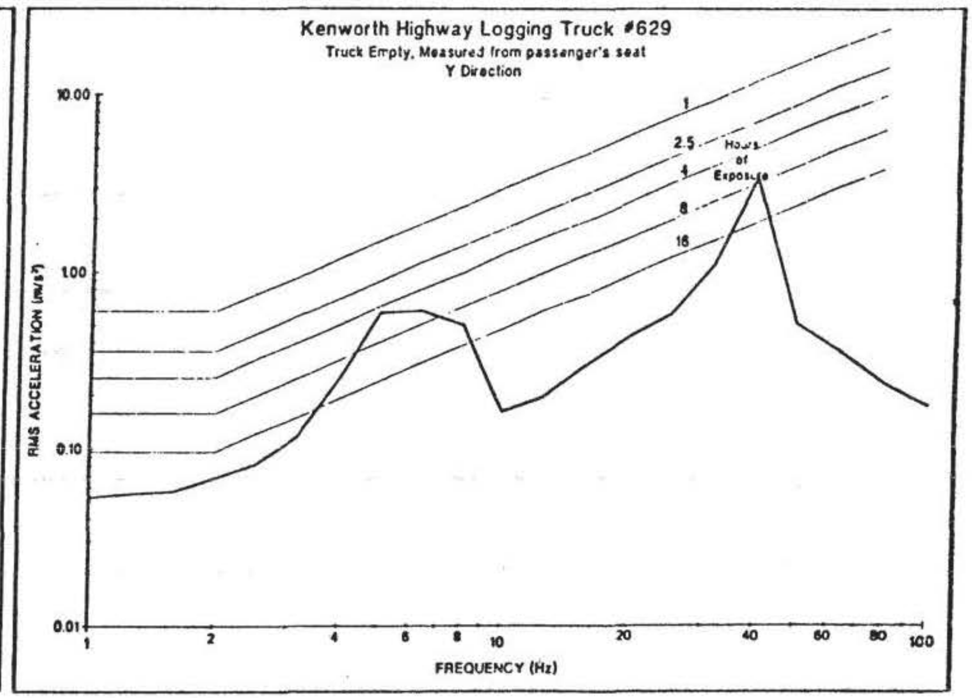
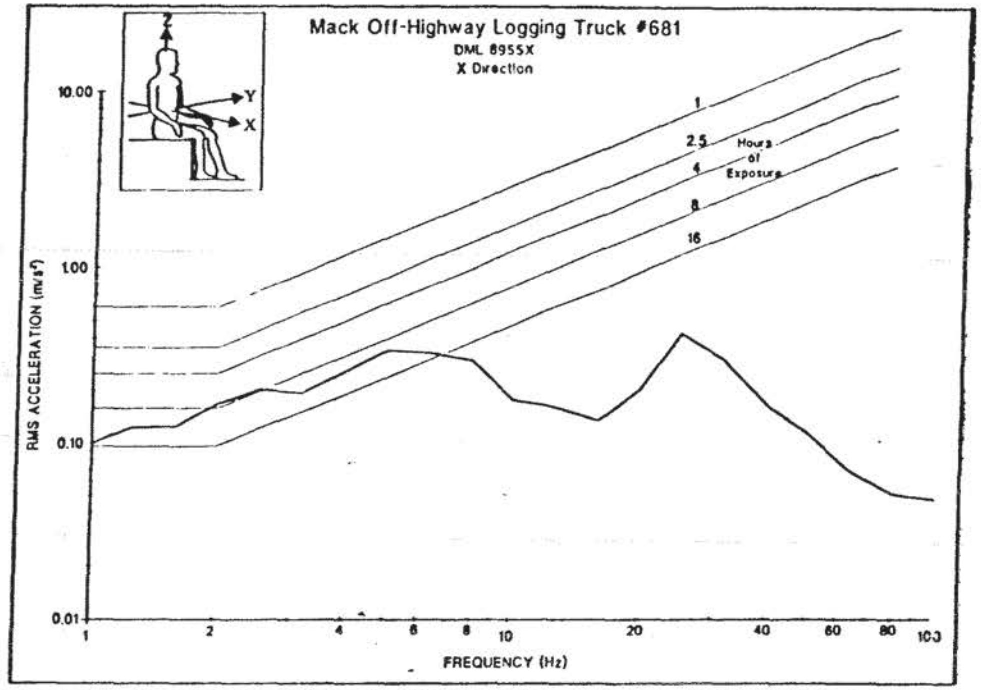


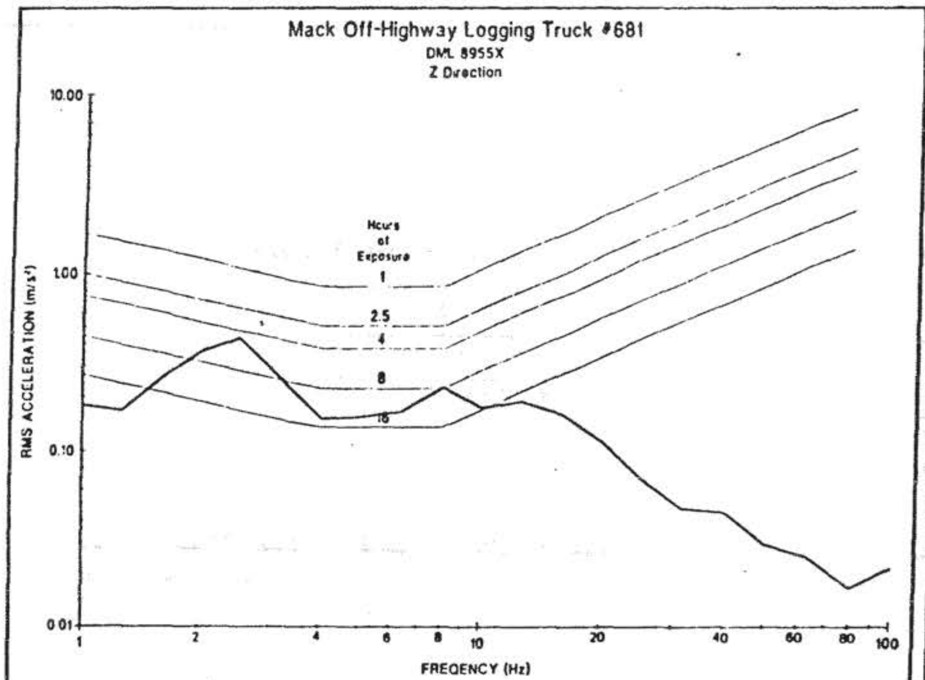


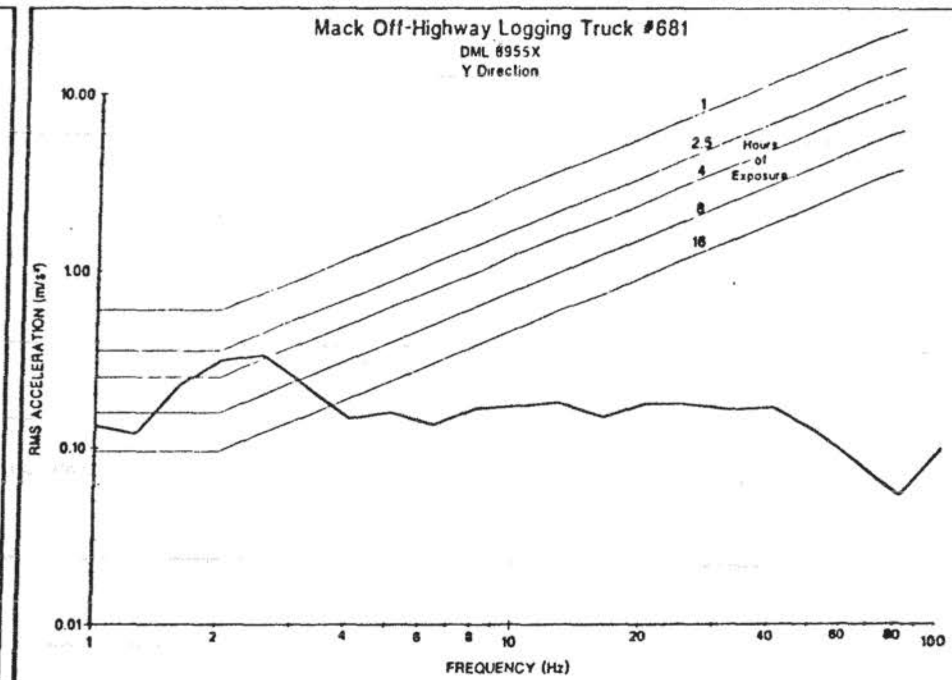


Average Acceleraton Levels (m/s^2) As a Function of Frequency (Hz)

Weyerhaeuser Corporation
Longview, Washington
HETA 83-349

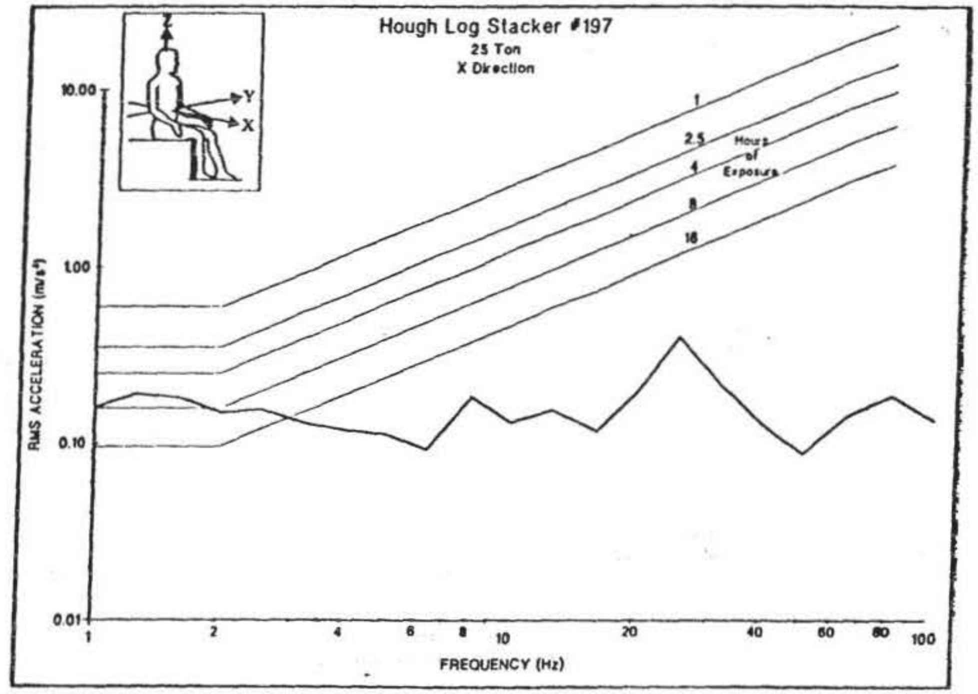


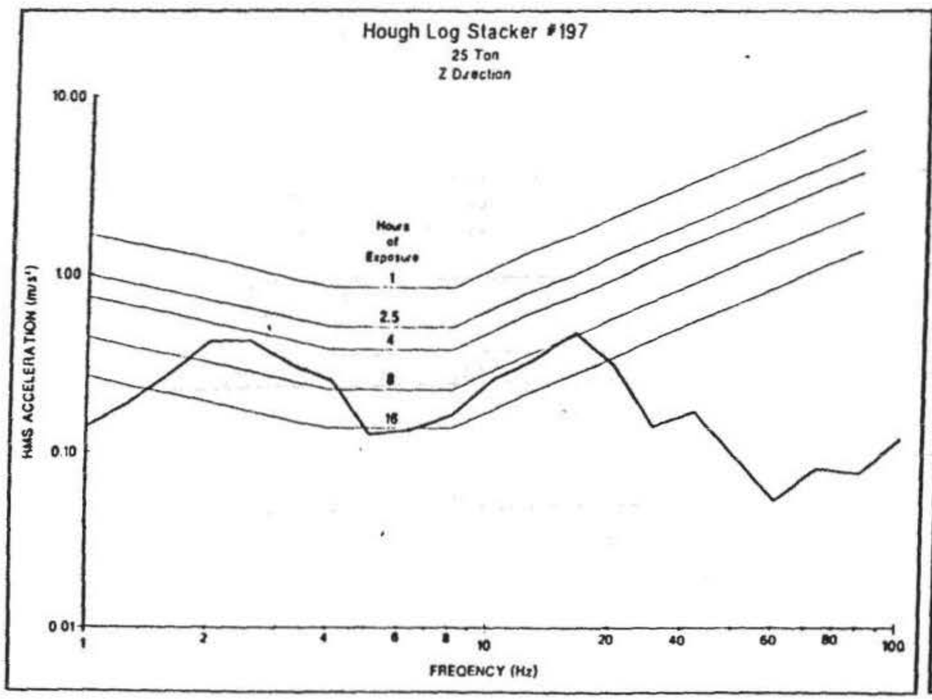


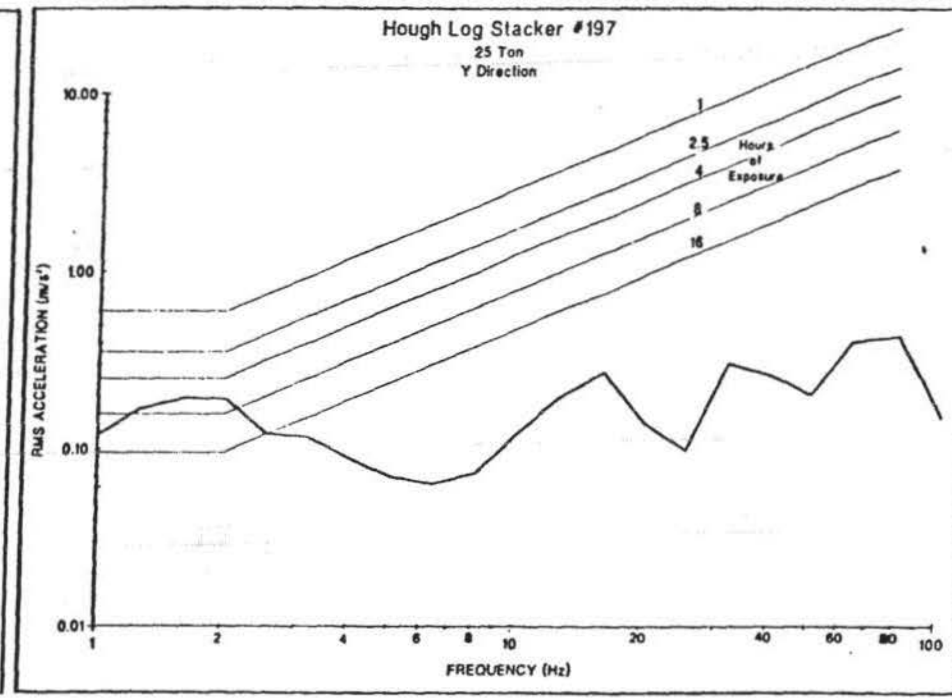


Average Acceleraton Levels (m/s^2)
As a Function of Frequency (Hz)

Weyerhaeuser Corporation
Longview, Washington
HETA 83-349







Average Acceleraton Levels (m/s^2) As a Function of Frequency (Hz)

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Longview, Washington
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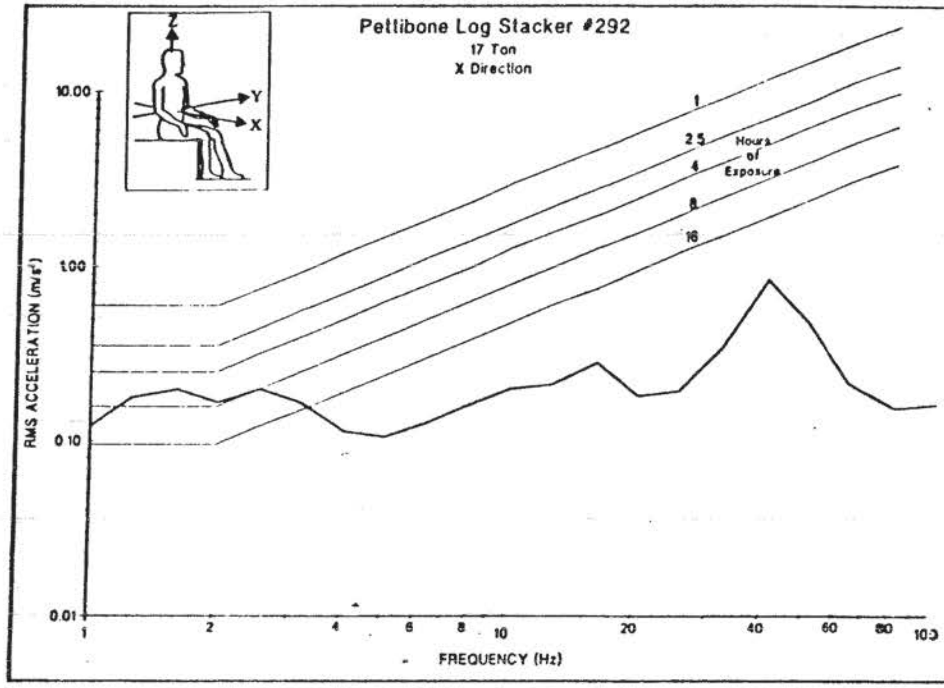

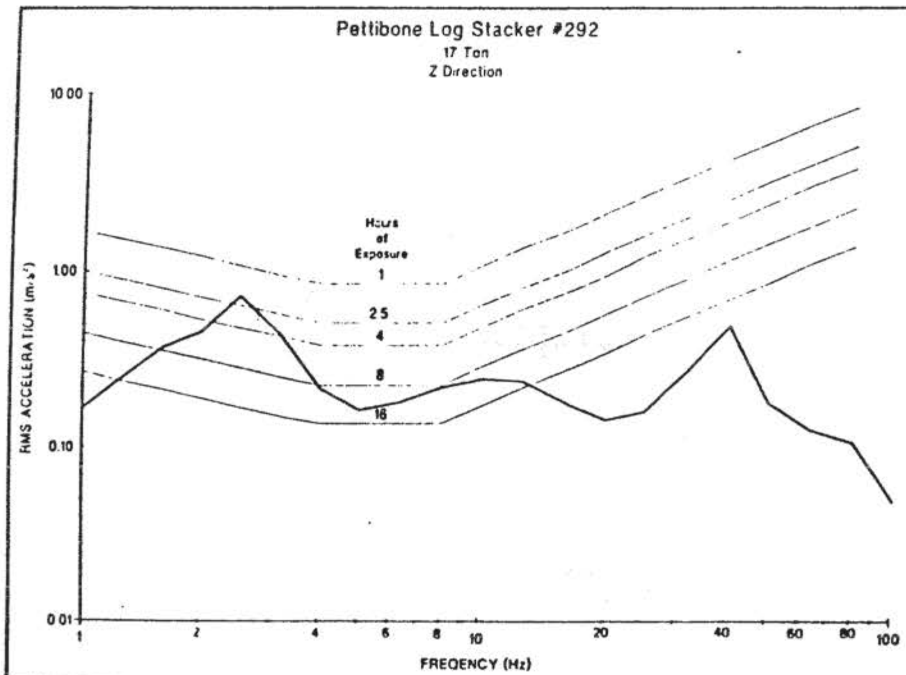

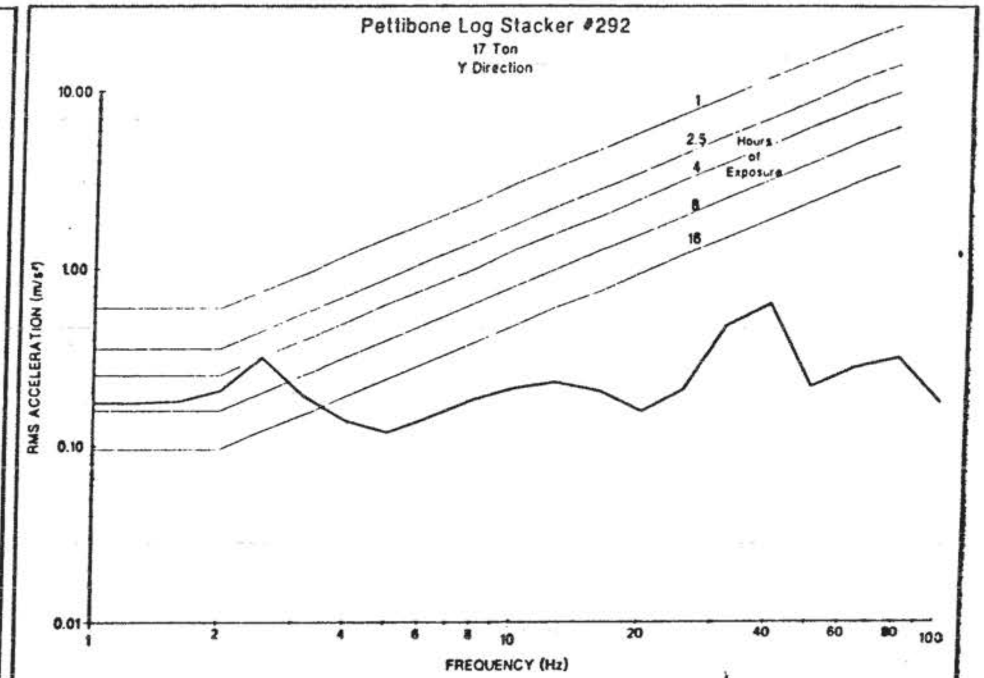

Average Acceleraton Levels (m/s^2)
As a Function of Frequency (Hz)

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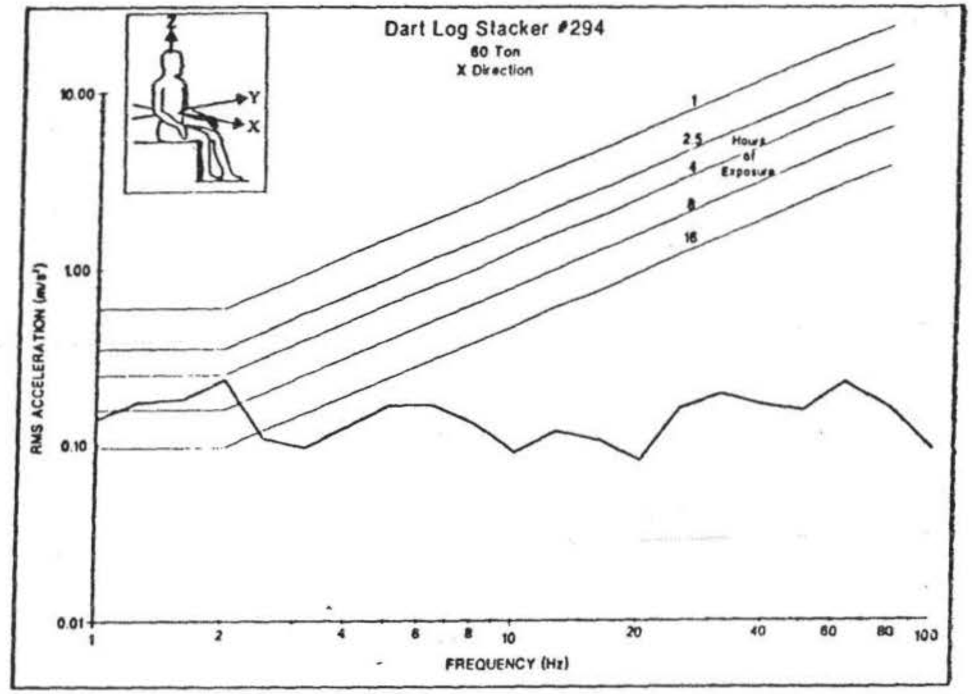

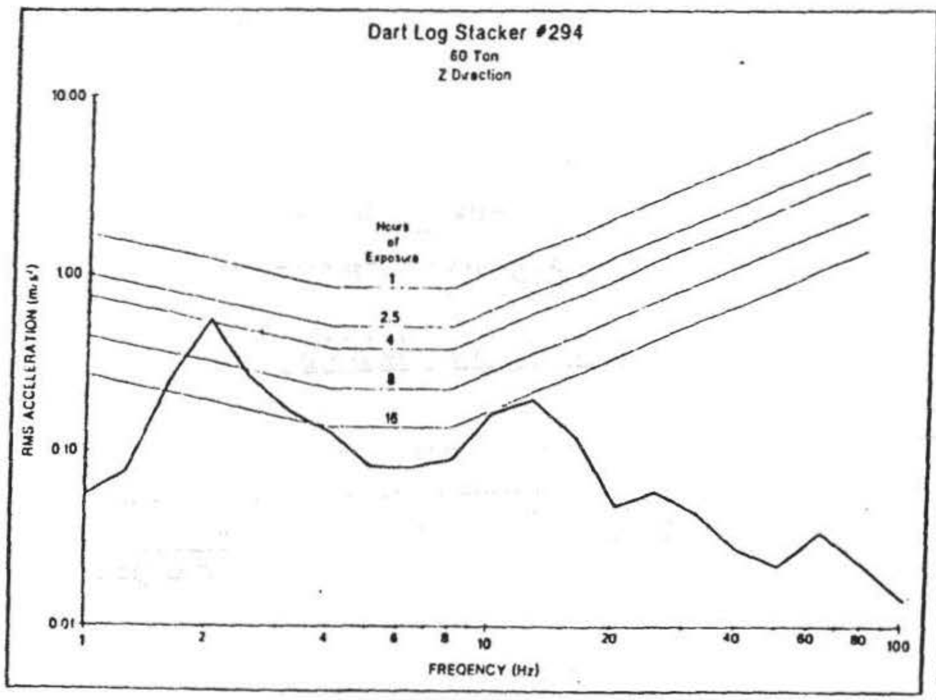

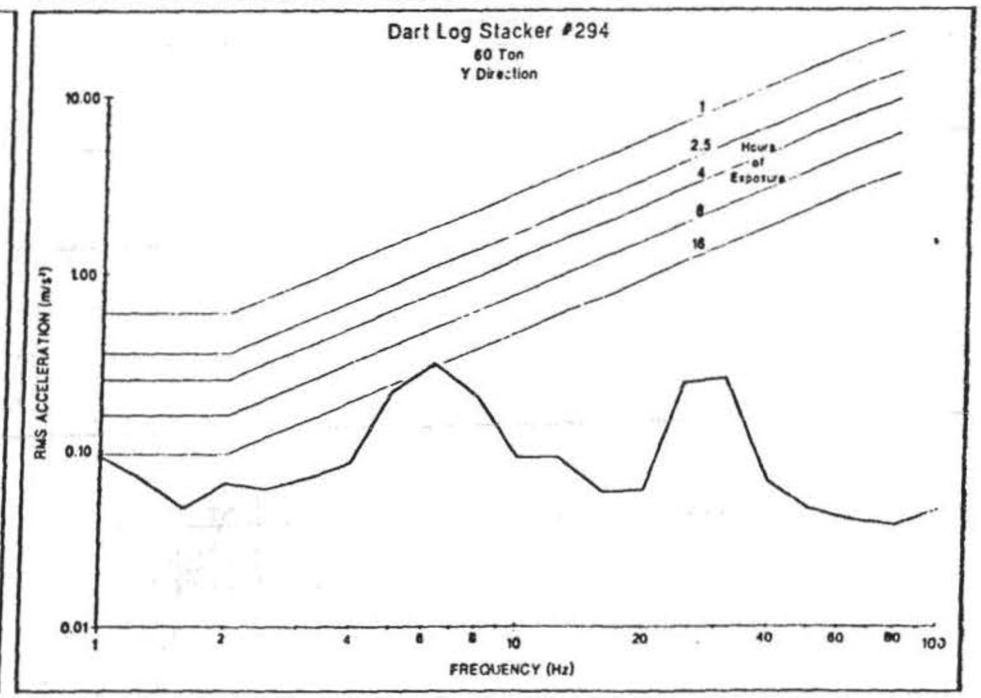

Average Acceleraton Levels (m/s^2)
As a Function of Frequency (Hz)

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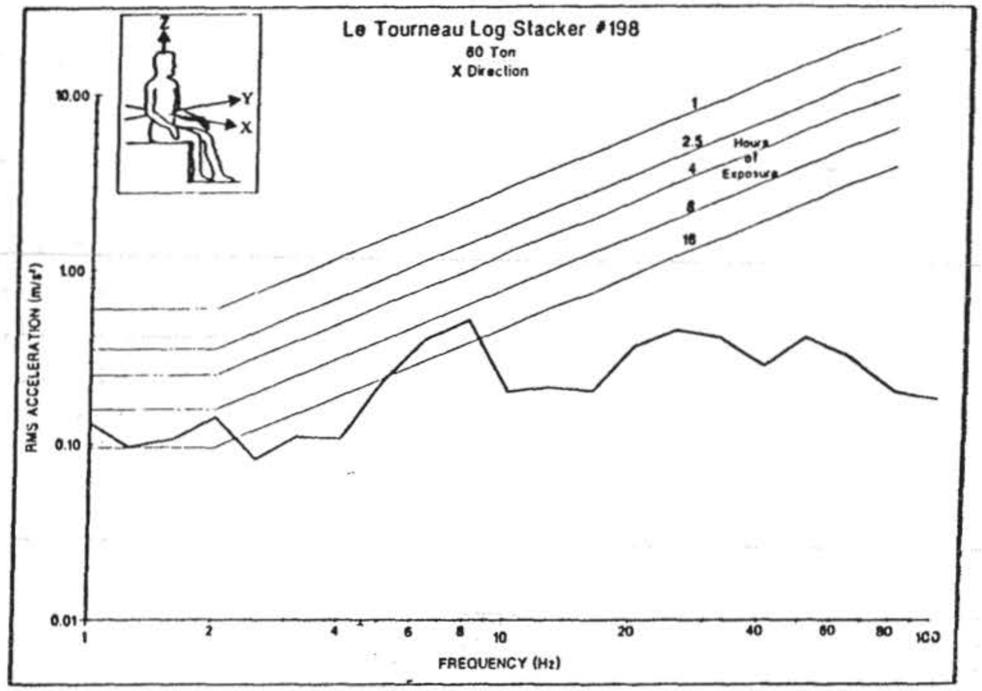

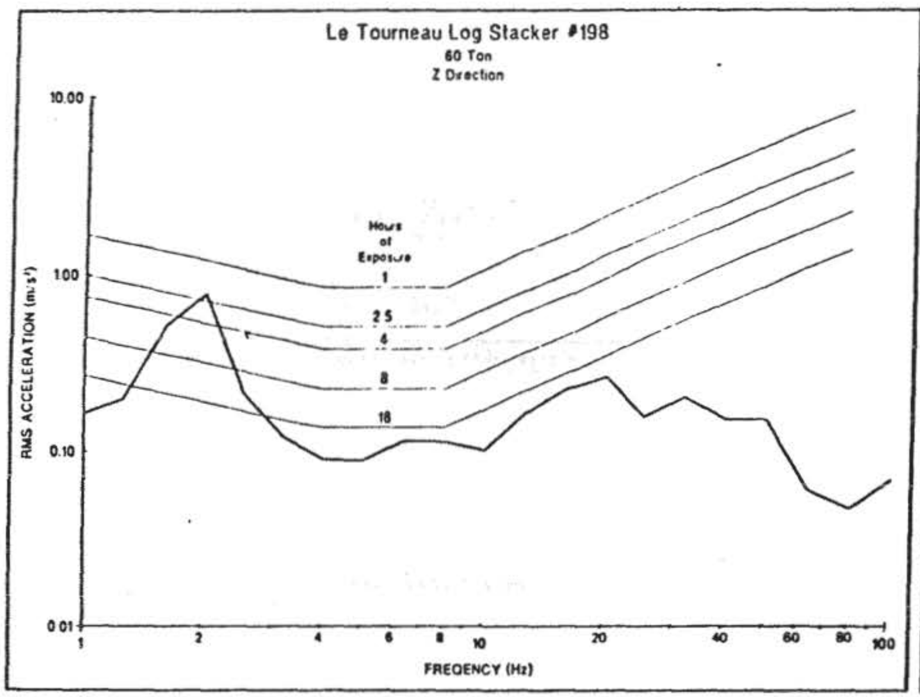

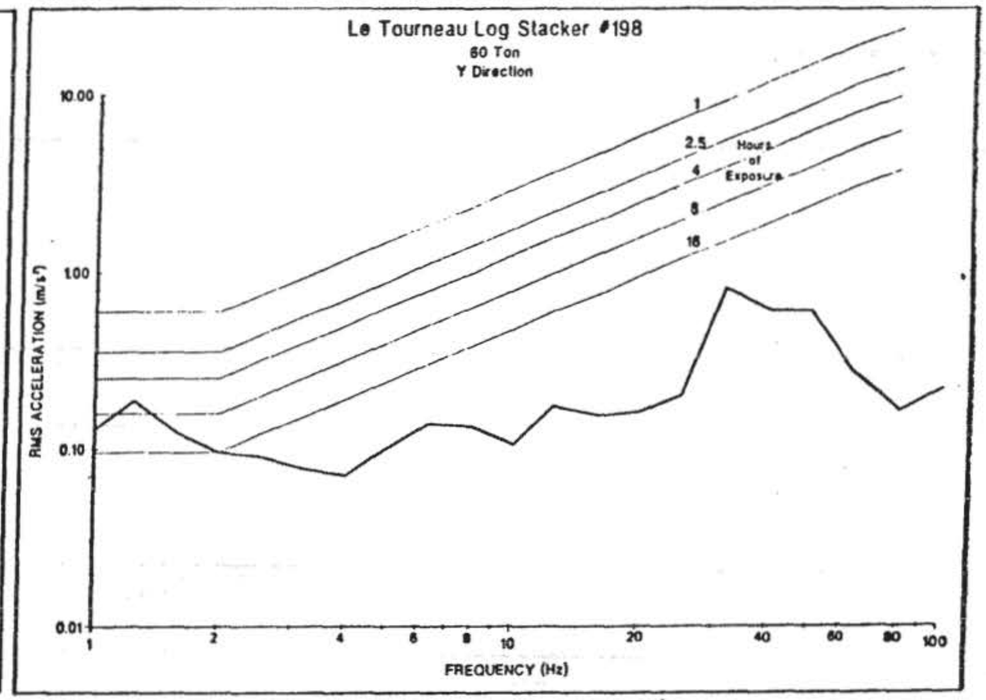

Average Acceleraton Levels (m/s^2)
As a Function of Frequency (Hz)

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