Paper No. 926033

AN ASAE MEETING PRESENTATION

VIBRATION OF FRESH FRUITS AND VEGETABLES DURING REFRIGERATED TRUCK TRANSPORT

by

R. T. Hinsch
Agricultural Marketing Specialist

U. S. Dept. of Agriculture
Agricultural Research Service
2021 S. Peach Ave.
Fresno, CA 93727

W. L. Craig
Agricultural Marketing Specialist

U. S. Dept. of Agriculture
Agricultural Marketing Service
Washington, D. C. 20250

D. C. Slaughter
Agricultural Engineer

J. F. Thompson
Agricultural Engineer

University of California
Davis, CA 95616

SUMMARY:

In transportation tests with fresh fruits and vegetables, refrigerated trailers equipped with steel-spring suspension systems had highest Power Spectral Density levels at about 3.5 Hz. Other frequencies with high PSD levels were 9, 18 and 25. However, in trailers equipped with an air-ride suspension system, the PSD levels were attenuated at 3.5 Hz and reduced at other frequencies. The highest PSD levels were found at the rear of the trailer, with resonance occurring in the loaded boxes at some frequencies. Horizontal acceleration was much less than the vertical acceleration. The results may show the less damaging suspension type of produce transport, how to improve either suspension type, or what packaging systems should be designed.

KEYWORDS:

air-ride, leaf-spring, resonance, pears, tomatoes, cherries, nectarines.

The author(s) is solely responsible for the content of this technical presentation. The technical presentation does not necessarily reflect the official position of ASAE, and its printing and distribution does not constitute an endorsement of views which may be expressed.

Technical presentations are not subject to the formal peer review process by ASAE editorial committees; therefore are not to be presented as refereed publications.

Quotation from this work should state that it is from a presentation made by (name of author) at the (listed) ASAE meeting. EXAMPLE: From Author's last name, Initials. "Title of Presentation". Presented at the Date and Title of meeting, Paper No. American Society of Agricultural Engineers, 2950 Niles Rd., St. Joseph, MI 49085-9659 USA.

For information about securing permission to reprint or reproduce a technical presentation, please address inquiries to ASAE.

American Society of Agricultural Engineers
2950 Niles Road, St. Joseph, Michigan 49085-9659 USA

VIBRATION OF FRESH FRUITS AND VEGETABLES DURING REFRIGERATED TRUCK TRANSPORT

R.T. Hinsch, D.C. Slaughter, W.L. Craig, and J.F. Thompson
Member ASAE, Member ASAE, Member ASAE

ABSTRACT

Fresh fruits and vegetables experience losses in the marketplace that are caused by mechanical injuries. Past studies have indicated that transit vibration contributes to this loss, and may be more important than impacts as a source of damage. In cross-country tests of cherries, nectarines, and pears in semi-trailers equipped with steel-spring suspension systems, highest Power Spectral Density (PSD) levels were found at about 3.5 Hz. In this study, PSD is used to mean acceleration spectral density. Other frequencies with high PSD levels were 9, 18, and 25 Hz. Similar results were found in tests with fresh tomatoes. However, in trailers equipped with an air-ride suspension and loaded with tomatoes, the PSD levels were attenuated at 3.5 Hz, and were reduced at other frequencies. The highest PSD levels were found at the rear of the trailer, with resonance in the loaded boxes occurring at some frequencies. Horizontal acceleration was much less than the vertical acceleration. Understanding acceleration levels and frequencies that occur during shipment of perishables in refrigerated trailers will help to determine methods that will dampen the vibration energy and reduce the present losses in produce quality. KEYWORDS: air-ride, leaf-spring, resonance, pears, tomatoes, cherries, nectarines.

INTRODUCTION

Fresh fruits and vegetables are subjected to injuries during handling, transportation, and distribution. Cherries, tomatoes, nectarines, and Bartlett pears have demonstrated these losses, ranging from 15 to 68 % of their total market losses (Ceponis and Butterfield, 1974, 1981, 1985; and Ceponis and Cappellini, 1985). "The basis for management of quality is the prediction

---

Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product listed by the USDA-Agricultural Reaearch Service.

The authors are R. Tom Hinsch, Agricultural Marketing Specialist, USDA, ARS, Fresno, CA, David C. Slaughter and James F. Thompson, Agricultural Engineers, Univ. of California, Davis, CA, and William L. Craig, Agricultural Marketing Specialist, USDA, AMS, Washington D. C.

of damage resulting from the susceptibility of the produce to the hazards of distribution" (Schoorl and Holt, 1982). O'Brien et al. (1963) also stated that "Two factors affect the bruising of fruits: the magnitude of the force and number of times this force is repeated at a given location". It has been suggested, however, that vibration may cause more bruising than impacts (Goff and Twede, 1979). Apple bruising was influenced by the quality of the road, shipment distance, and the type of container in which they were packed (Shulte-Pason et al., 1989). Reducing vibration and rubbing of peaches during transport from the orchard to the packinghouse reduced surface discoloration (Phillips, 1988). Laboratory tests have shown that table grapes positioned on the top layer of a stack sustained more damage than when they were in the bottom layer. The damage was a result of acceleration levels in the top layer being twice that of the lower ones (Fischer et al., 1989).

The objectives of our study were to: 1) determine the acceleration frequencies and relative amplitudes occurring in loads of fresh fruits and vegetables during commercial cross-country tests in refrigerated trailers with commonly-used steel-spring suspension systems; and 2) compare the vibration levels of refrigerated trailers equipped with steel-spring suspensions or air-ride suspensions.

EXPERIMENTAL METHODS

Fruit Tests:

Full refrigerated trailer loads of California cherries, nectarines, or Bartlett pears were loaded at commercial packinghouses in their respective production areas in California and transported on Interstate highways to east coast markets between Baltimore and New York City, about 4600 km (2900 miles). All fruit were packed in corrugated fiberboard boxes and unitized on disposable wood pallets. Plastic netting was used to secure the cherry boxes to the pallet, non-metallic strapping was used for the nectarine boxes, and palletizing glue (which has strength in shear but not in tension) was used for Bartlett pears. All fruit were cooled to, and shipped at about 1°C (34°F).

The palletized boxes were loaded by forklift into 14.6 m (48 ft) long by 2.6 m (8.5 ft) wide refrigerated highway trailers. One full trailer load each of cherries and nectarines, and two of Bartlett pears were shipped from California. All four trailers had steel-spring suspensions (Series 7600-7700-7800, Hutchens Industries Inc., Springfield, MO 65802). The tractors also had steel-spring suspensions. Gross weights were not obtained.

50 Hz were insignificant.

On arrival at the destination market, the instrumentation was retrieved, and the data were transferred to computer for analysis using EDR2S software (Instrumented Sensor Technology). The results are presented in terms of Power Spectral Density (PSD) plots, which at any given frequency show the variance of the root-mean square (rms) acceleration amplitude about a mean value of zero G (1 G equals the acceleration of gravity). The peak G values can be estimated using the method described by Brandenburg and Lee (1985).

RESULTS

Fruit Tests:

Refrigerated trailers with steel-spring suspensions had the highest vertical PSD level on the floor at the rear position, regardless of the commodity, in the fruit tests (figure 1 a-c). Peaks occurred at about 3.5 Hz, with other less severe peaks at about 9, 16-18, and 25 Hz. The vibration at 3.5 Hz corresponds to the harmonics of the trailer suspension, while the higher frequencies correspond to the trailer structure's natural frequencies (Ostrem and Godshall, 1979). The PSD curve for the center-floor position was essentially zero above 5 Hz, but not for the rear floor position.

The rear floor PSD results near 3.5 Hz for cherries, nectarines, and pears were about 0.05, 0.13, and 0.16, respectively. Therefore, 99.7 % of the 3.5 Hz peak accelerations observed at this location should be within ± 0.96, ± 1.53, and ± 1.68 G, respectively (Brandenburg and Lee, 1985).

For some frequencies between 5 and 30 Hz, the top box often vibrated considerably more than the middle and bottom boxes. For example, from about 8 to 10 Hz, the top box of pears loaded on the rear pallet exhibited about three times the PSD level of the bottom box, figure 2. The PSD values at 8.6 Hz were about 0.0030, 0.0016, and 0.0008 for the top, middle, and bottom box, respectively. Therefore, 99.7 % of the peak accelerations observed should be within ± 0.24, ± 0.18, and ± 0.12 G, respectively. The stack of boxes resonated near this frequency, so acceleration and displacement were amplified from the bottom to the top of the stack. If the pears also resonated within the box at this frequency, considerable bruise damage could result. These boxes had resonant characteristics at several frequencies, which may depend upon the type of fruit, package and packing method, and palletizing method.

Tomato Tests:

The vertical PSD levels at the rear of steel-spring trailers used in the tomato tests were similar to those found in the fruit tests, figure 3. The PSD levels for trailers with air-ride suspension were lower, and did not have the high value at 3.5 Hz. The air-ride suspension had prominant acceleration peaks near 2, 6, and 9 Hz, but these were relatively low. However, on the floor in the center of the trailers the PSD levels were nearly the same, regardless of suspension type (data not shown). This resulted in lower acceleration levels in the trailers with the air ride suspension.

The horizontal acceleration recorded on the top box of the rear pallet was much less than the vertical acceleration in trailers with either the steel-spring or air-ride suspension, figure 4 a-b. The horizontal PSD levels for these two trailers with two suspension types were nearly the same, but vertical PSD levels were very different.

DISCUSSION

Interstate highway shipments of refrigerated trailers equipped with steel-spring suspensions and loaded with fresh cherries, nectarines and Bartlett pears show the highest vertical acceleration levels at about 3.5 Hz. There were characteristic lower acceleration levels at about 9, 18, and 25 Hz. Similar results were obtained with full loads of fresh tomatoes in similar equipment. However, when tomatoes were loaded in refrigerated trailers with air-ride suspensions, the high vertical acceleration levels at 3.5 Hz did not occur at the rear of the trailer, but low to moderate accelerations at 6, 9, and 15-18 Hz did.

The vertical acceleration levels in the middle of the steel-spring trailers were much less than found at the rear. The same was true for air-ride trailers.

Horizontal accelerations were much less than those recorded in the vertical direction for trailers with both types of suspensions.

CONCLUSION

This study indicates that:

1. Vertical acceleration frequency and magnitude developed by a steel-spring suspension refrigerated trailer traveling Intertstate highways was similar for loads of packaged and palletized cherries, nectarines, pears, and tomatoes. The

center of the trailer developed much less severe accelerations than did the rear. The greatest acceleration occurred near 3.5 Hz. The top boxes in a stack were often subjected to acceleration amplification.

2. Vertical acceleration magnitudes developed by an air-ride suspension trailer traveling similar highways were much less than those for the steel-spring suspension. The high acceleration near 3.5 Hz was not present, but low to moderate accelerations at 6, 9, and 15-18 Hz were.

3. Horizontal accelerations were much less than vertical accelerations for both suspension types.

4. Controlled tests should be conducted with packaged fruits and vegetables to determine what vibration frequencies and magnitudes result in damage to produce. The combined results may show the less damaging suspension type for produce transport, how to improve either suspension type, or what packaging systems should be designed.

REFERENCES

Brandenburg, R. K. and J. J. Lee. 1985. Fundamentals of packaging engineering, 2nd Ed/ MTS Systems Corp. Minn. MN. P.68-69.

Caruso, H. and W. Silver. 1976. Advances in shipping damage prevention. Shock and Vibration Bulletin 46, part 4.

Ceponis, M.J. and J.E. Butterfield. 1974. Retail and consumer losses of western pears in metropolitan New York. HortScience 9(5):447-448.

Ceponis, M. J. and J. E. Butterfield. 1979. Losses in fresh market tomatoes at the retail and consumer levels in the greater New York area. J. Amer. Soc. Hort. Sci. 104(6):751-754.

Ceponis, M. J. and J. E. Butterfield. 1981. Cull losses in western sweet cherries at retail and consumer levels in Metropolitan New York. HortScience 16(3):324-326.

Ceponis, M. J. and R. A. Cappellini. 1985. Wholesale, retail, and consumer level losses of nectarines in metropolitan New York. HortScience 20(1):90-91.

Fischer, D., W.L. Craig, B.H. Ashby, A. Watada and W. Douglas. 1989. In-transit vibration damage to grapes and strawberries. ASAE paper 89-6617, ASAE, St. Joseph, MI 49085.

Goff, J. W. and D. Twede. 1979. Boxes, bags and cans: performance of packages for the transportation of agricultural products. Mich. State Univ. Special Report 14, 49 p.

O'Brien, M., L.L. Claypool, S.J. Leonard, G.K. York and J.H. MacGillivray. 1963. Causes of fruit bruising on transport trucks. Hilgardia, 35(6):113-124.

Ostrem, F. E. and W. D. Godshall. 1979. An assessment of the common carrier shipping environment. General Technical Report FPL 22, Forest Products Laboratory, USDA, Madison, WI.

Phillips, D.J. 1988. Reduction of transit injury-associated black discoloration of fresh peaches with EDTA treatments. Plant Disease 72(2):118-120.

Schoorl, D. and J. E. Holt. 1982. Fresh fruit and vegetable distribution-management of quality. Scientia Horticulturae 17:1-8.

Shulte-Pason, N.L., E.J. Timm, G.K. Brown, D.E. Marshall and C.L. Burton. 1990. Apple damage assessment during interstate transportation. Applied Engineering in Agriculture 6(6):753-758. 49085.

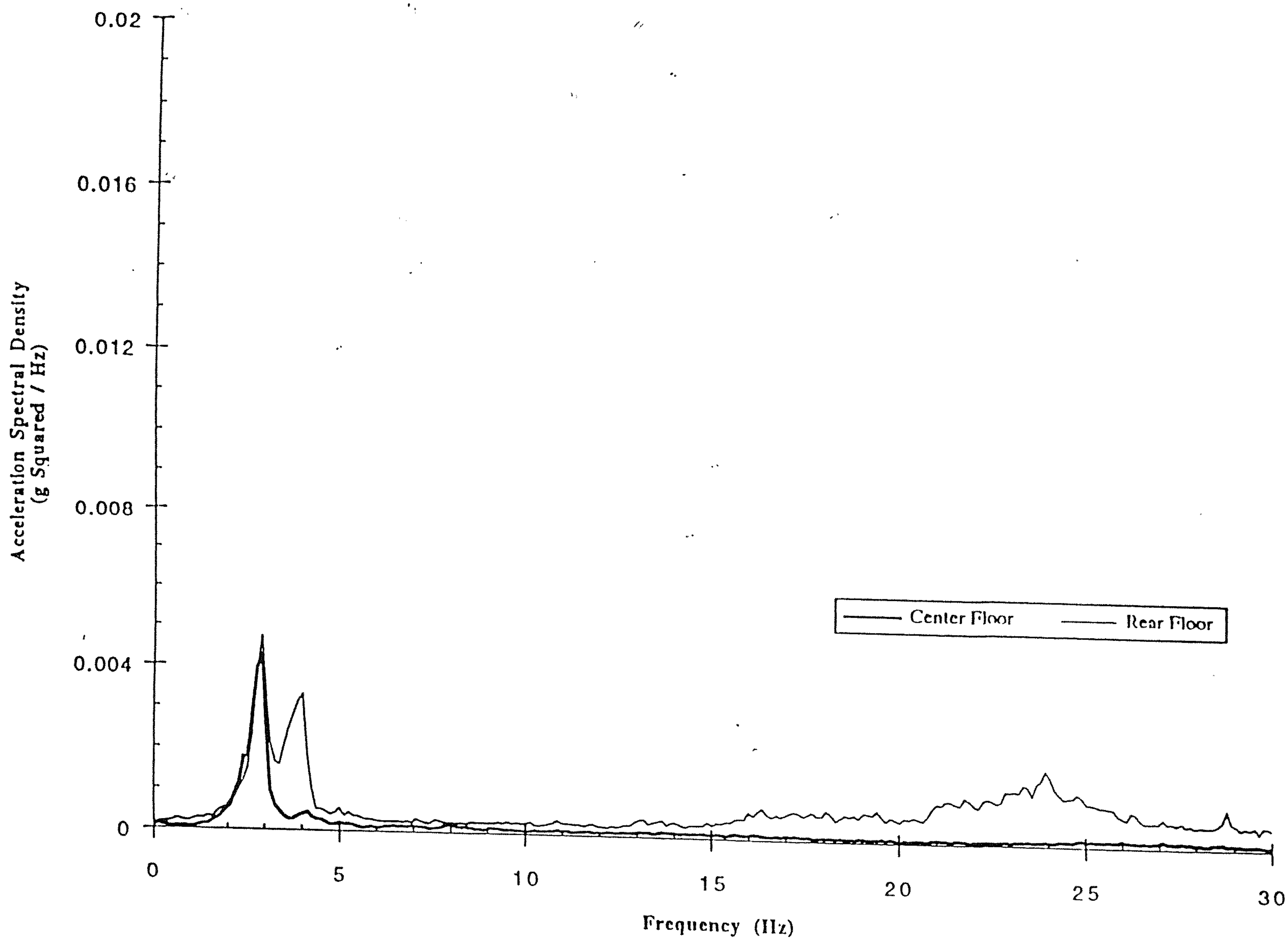

Figure 1a. In-transit vertical vibration at two locations on the floor of a refrigerated trailer equipped with a steel spring suspension and loaded with cherries, California to Baltimore, 1991.

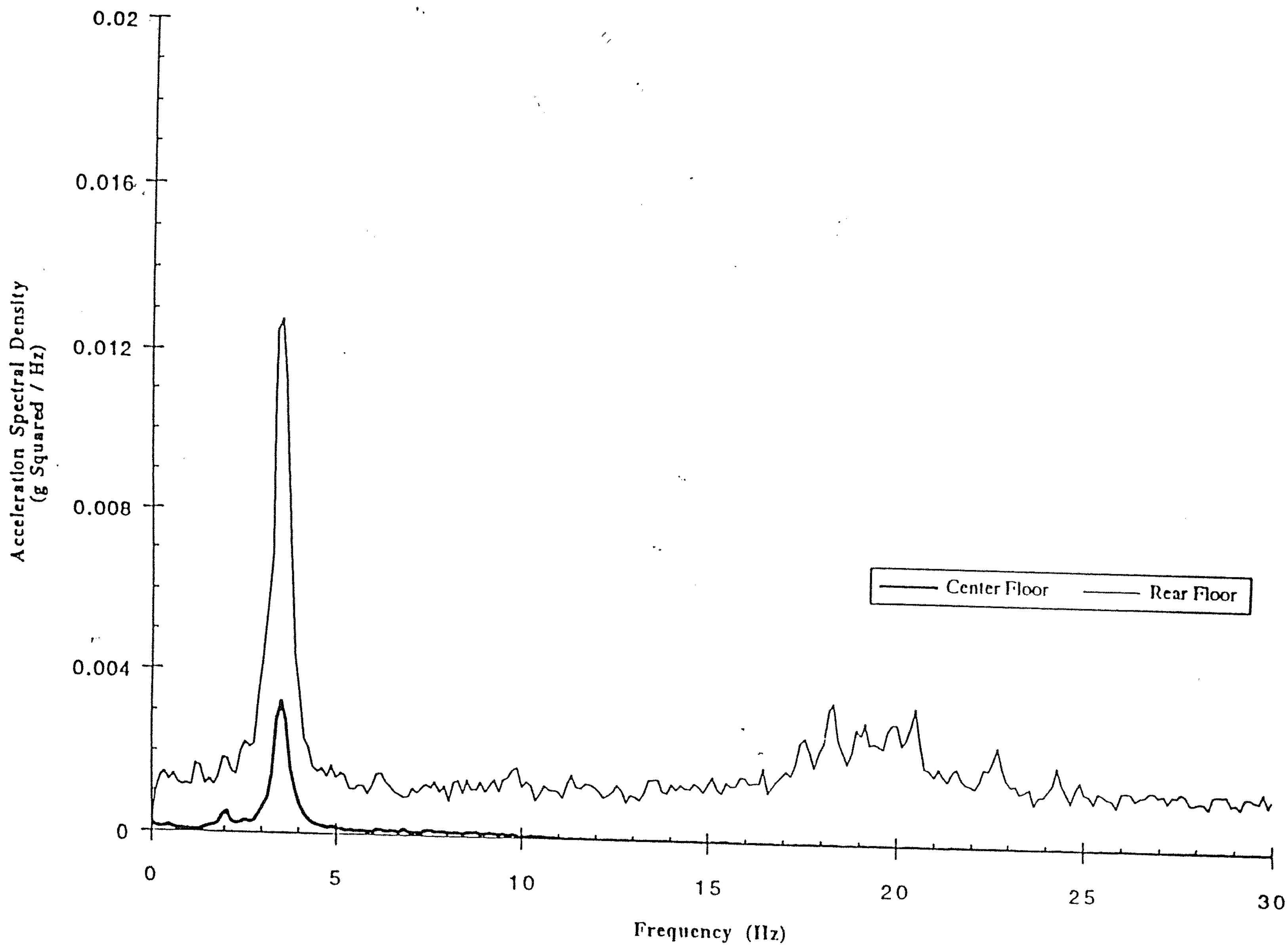

Figure 1b. In-transit vertical vibration at two locations on the floor of a refrigerated trailer equipped with a steel spring suspension loaded with nectarines, California to Philadelphia, 1991.

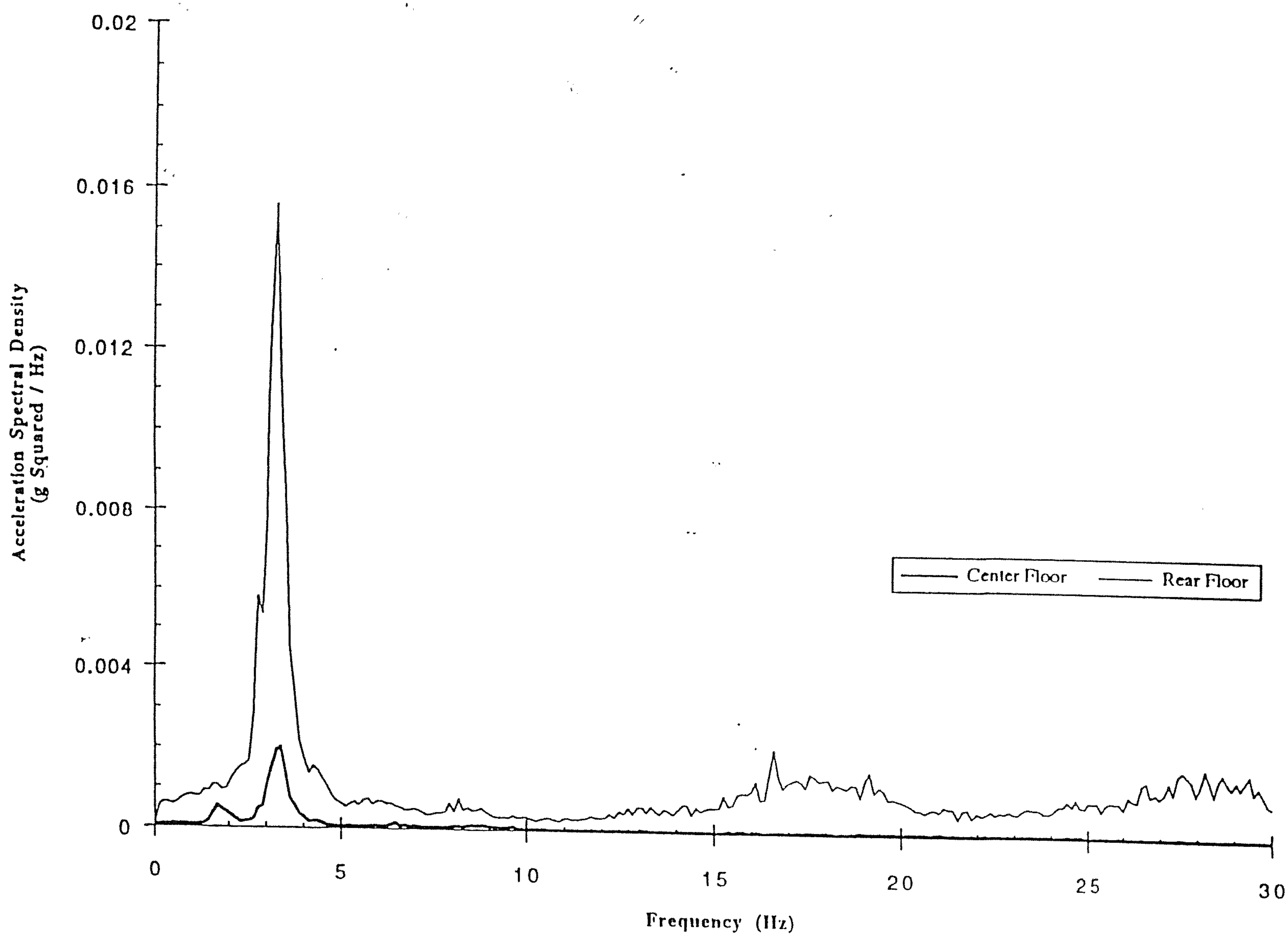

Figure 1c. In-transit vertical vibration at two locations on the floor of a refrigerated trailer equipped with a steel spring suspension and loaded with pears, California to New York, 1991.

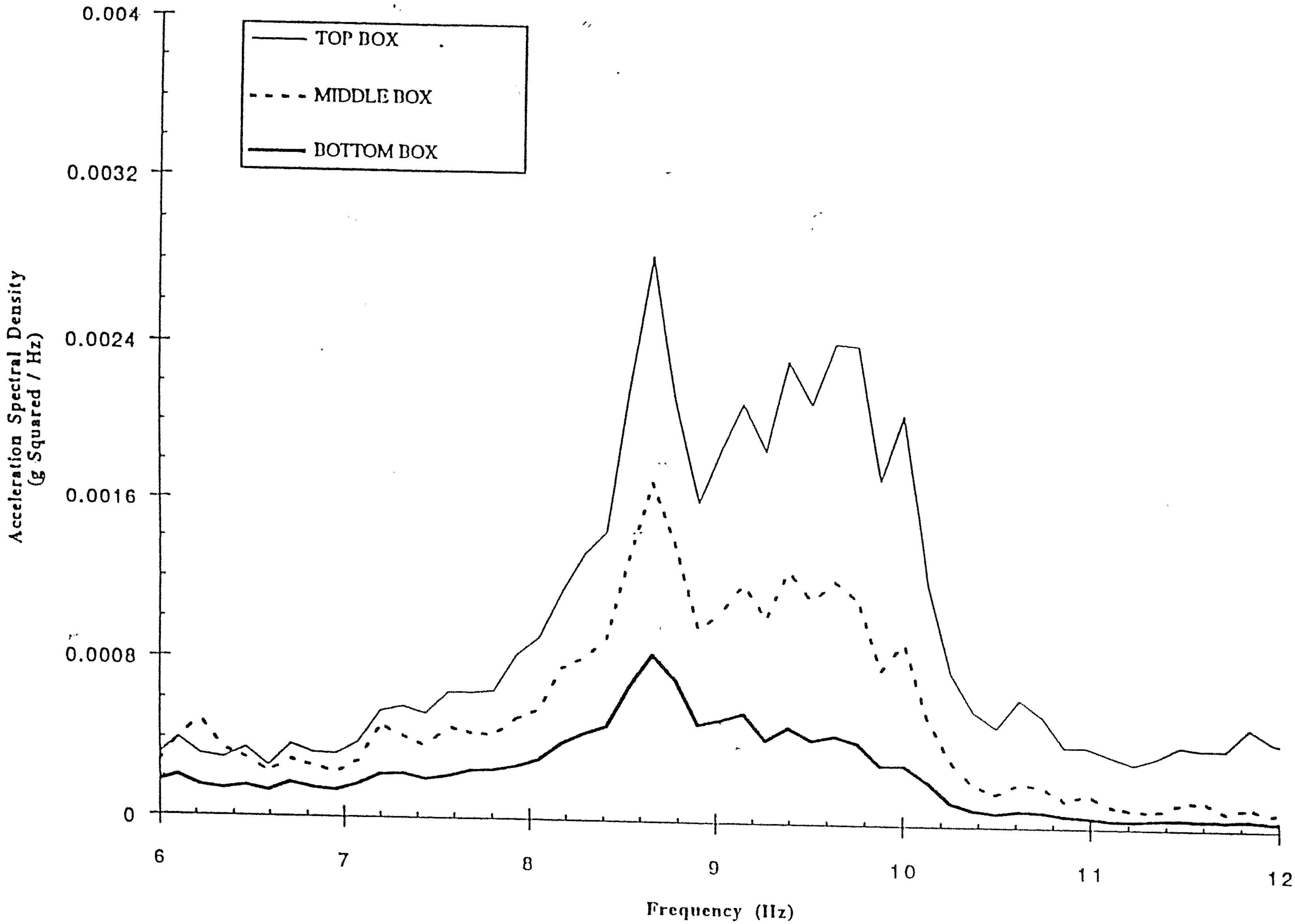

Figure 2. In-transit vertical vibration of three boxes of pears loaded on the rear pallet in a refrigerated trailer equipped with a steel spring suspension, California to New York, 1991.

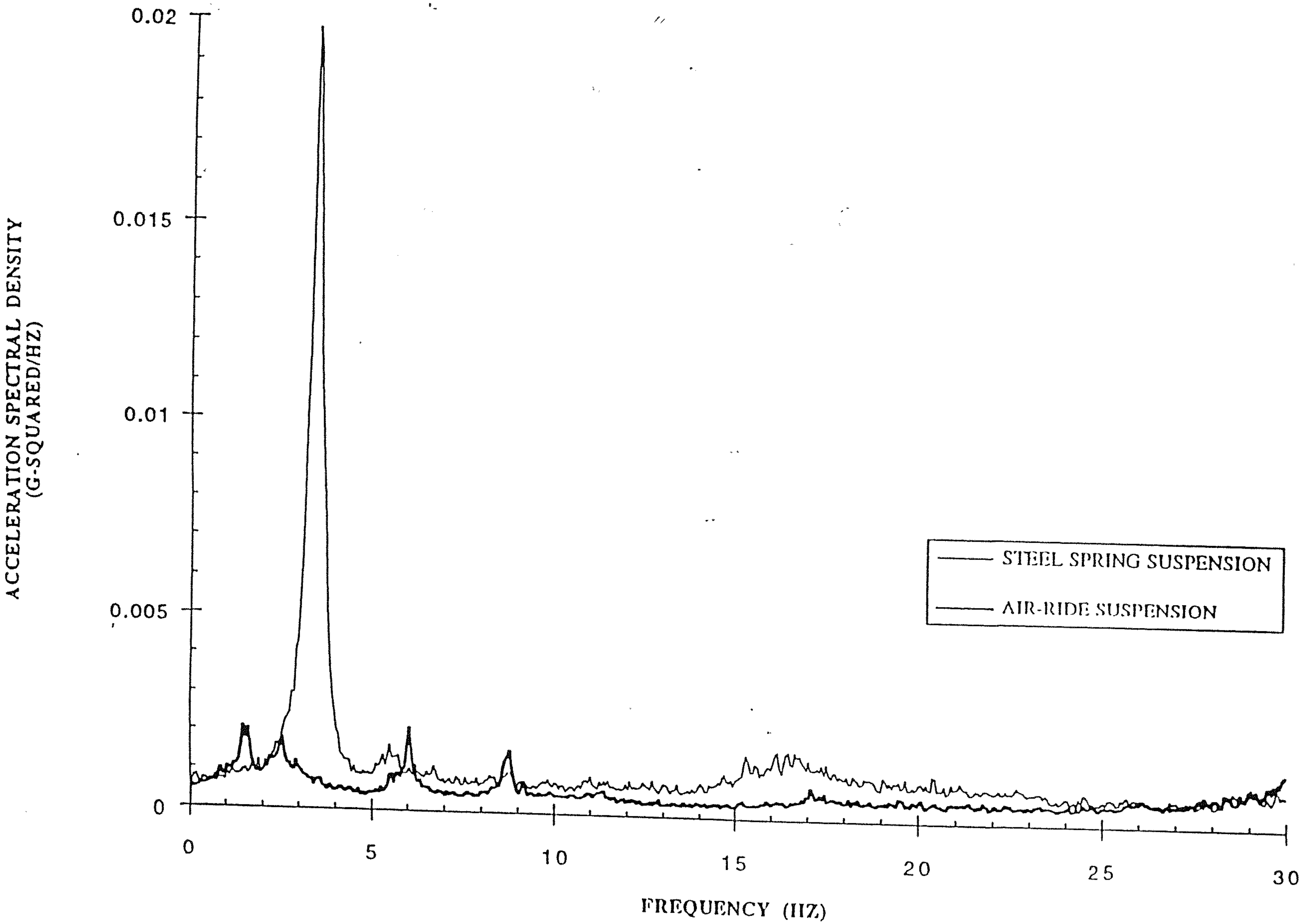

Figure 3. In-transit vertical vibration on the rear floor of refrigerated trailers loaded with tomatoes for two types of suspensions, Nogales to Los Angeles, 1992.

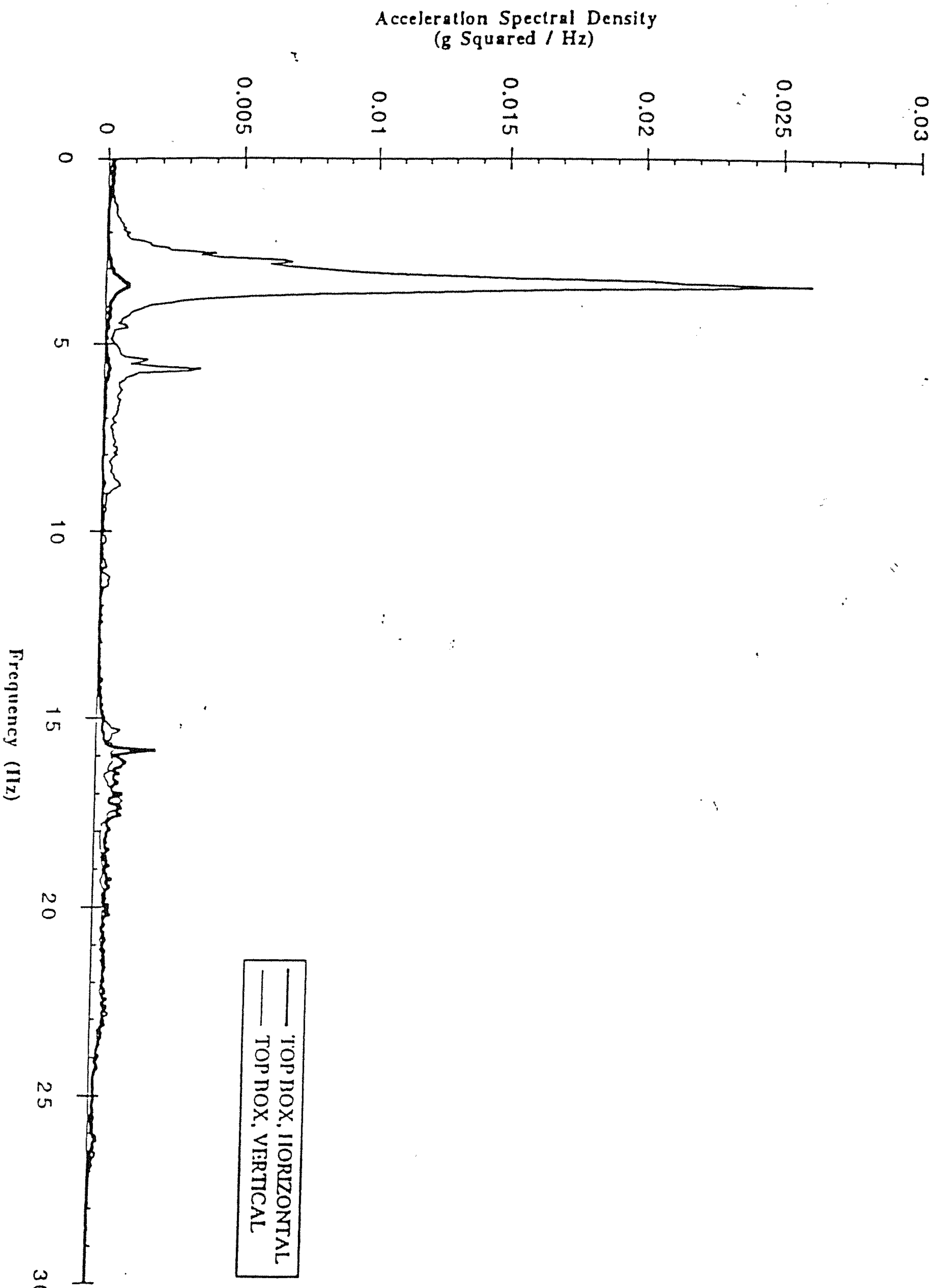

Figure 4a. In-transit vertical and horizontal vibration of the top rear box in a refrigerated trailer equipped with a steel spring suspension and loaded with tomatoes, Nogales to Los Angeles, 1992.

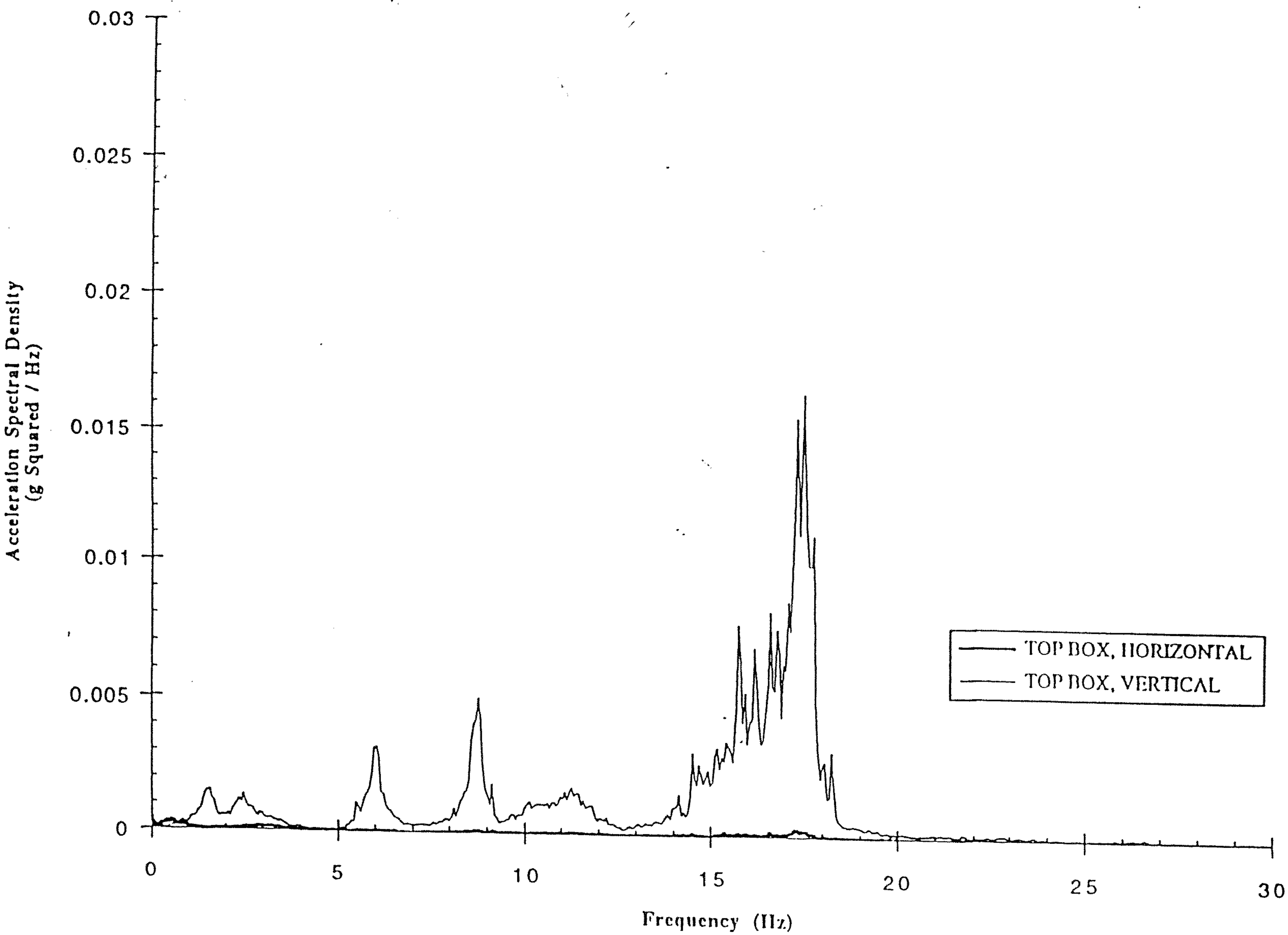

Figure 4b. In-transit vertical and horizontal vibration of the top rear box in a refrigerated trailer equipped with an air-ride suspension and loaded with tomatoes, Nogales to Los Angeles, 1992.