SANDIA REPORT SAND82-0819 • TTC-0298 • Unlimited Release • UC-71
Printed August 1982

Shock and Vibration Environments Encountered During Normal Rail Transportation of Heavy Cargo

Clifford F. Magnuson

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-76DP00789

DISCLAIMER

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: A02
Microfiche copy: A01

SAND82-0819
TTC-0298
Unlimited Release
Printed August 1982

Distribution
Category UC-71

Shock and Vibration Environments Encountered During Normal Rail Transportation of Heavy Cargo

Clifford F. Magnuson
Applied Mechanics Division III, 5523
Sandia National Laboratories
Albuquerque, NM 87185

Prepared for
Transportation Technology Center
Sandia National Laboratories
Albuquerque, NM 87185

Abstract

This study was conducted to obtain vibration and superimposed shock data during normal rail shipment of heavy cargo. The data were obtained during a regularly scheduled rail shipment of a 45-tonne (50-ton) cargo which consisted of an empty spent-fuel container, its supporting structure, and associated hoisting devices. The shipment was made over rail lines which are operated by the Atchison, Topeka, and Santa Fe Railway Company between Denver, Colorado and Albuquerque, New Mexico. The instrumented rail car was equipped with 0.38-m (15-in.) hydraulic end-of-car coupling devices. The 99 percentile levels of vibration acceleration amplitudes and single degree-of-freedom superimposed shock response spectra for the longitudinal, transverse, and vertical axes are presented.

Acknowledgments

In addition to M. B. Gens and R. C. Rentzsch, SNL, who participated in the instrumentation and data gathering, my thanks to the following persons who participated in and/or supported this project: W. N. Spears, J. W. Donalson, and R. Smith, AT&SF, Albuquerque, NM, and W. Purchase, DOE/ALO for their efforts during the planning and scheduling. W. H. Clark, Applied Research ,Assistant Manager, AT&SF, Topeka, KS; F. L. Sparks, Road Foreman, AT&SF, Pueblo, CO; S. L. Fruin, Road Foreman, AT&SF, La Junta, CO; H. G. Powers, Trainmaster, AT&SF, Raton, NM; and the engineers on the trains involved in the test for their assistance during the data gathering operation. R. W. Cecil and J. Lewis, Stearns-Roger, Denver, CO, for their cooperation during the loading of the test rail car and the installation of the instrumentation.

Contents

Figures

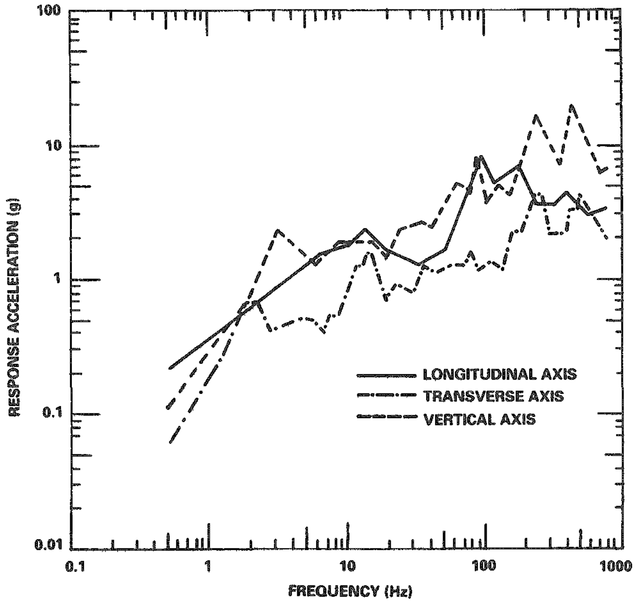
Summary

Shock and vibraton environments were measured during rail transport of a 45-tonne (50-ton) cargo mounted on a railroad flat car. The cargo was transported by regular railroad methods from Denver, Colorado to Albuquerque, New Mexico.

The maxima of the 99 percentile levels of acceleration amplitude vibration for a 45-tonne (50-ton) cargo over the frequency range of 0 to 750 Hz were

Axis	Zero-to-Peak Acceleration (g)
Longitudinal	0.10
Transverse	0.19
Vertical	0.52

The shock response spectra, using 3% damping, are shown in the following figure.



Mean Plus Three Standard Deviation Amplitude Envelopes of Shock Response Spectra; 3% Damping

Shock and Vibration Environments Encountered During Normal Rail Transportation of Heavy Cargo

Introduction

The packaging and transportation of fissile radioactive materials are regulated by the US Nuclear Regulatory Commission (NRC) by means of Federal Regulations Title 10, Part 71. Appendix A of these regulations specifies that the environmental conditions of transport be applied to determine their effects on packages of radioactive material. However, the appendix does not quantify the frequencies or amplitudes of vibration and shock environments, nor does it give their expected occurrence rate as a function of shipment time and/or mileage. As a result, when evaluating a package for licensing application, assumptions regarding the intensities of these environments must be made by each applicant.

Shock and vibration data were available for rail transport of 14 tonne (15 ton) cargo. Spent fuel shipping containers often weigh more than this, so data needed to be obtained during rail transport of heavier cargo. The investigation described in this report results in descriptions of shock and vibration for cargo weighing 45 tonnes (50 tons).

All data described in this report were taken in English units. The metric (SI) values presented result from rounding the English units to the nearest SI units.

Prior Studies

Sandia National Laboratories (SNL) has conducted other investigations to gather and evaluate data on the shock and vibration environments normally encountered during transport of heavy shipping containers by both rail and truck. These investigations were conducted under contract to the NRC.

Efforts in these areas to date have consisted of the following activities:

- Transportation shock and vibration data available up to 1975 in the Department of Energy (DOE)/Department of Defense (DoD) and the DOE transportation data banks were reviewed and are reported in Reference 1. Predictions of the influence of heavier cargo on these environments as well as predictions of the influence of shock-attenuating couplers on rail cars also were reported in Reference 1. These predictions were based on analytical studies.
  Truck data were based on cargo weights which varied from no-load to 14 tonnes (15 tons). Over-the-road rail data were based on a cargo weight of 14 tonnes (15 tons). Rail coupling-shock data were based on cargo weighing approximately 5 tonnes (5 tons).
- Data were gathered during truck transport of two spent-fuel shipping containers. One weighed 20 tonnes (22 tons) and the other weighed 25 tonnes (28 tons). These containers were transported over existing highways between Mercury, Nevada and Albuquerque, New Mexico. The definitions of the shock and vibration environments measured during these events were reported in References 2 and 3. Comparisons of the three sets of truck data are presented in Reference 3.
- Data were gathered during rail-coupling test operations conducted at the Savannah River Plant with cargo weighing 36 tonnes (40 tons) and 64 tonnes (70 tons). The impacting end of each instrumented rail car was equipped with a standard draft gear, a 0.38-m (15-in.) hydraulic end-of-car device, and a 0.51-m (20-in.) sliding center-sill cushion underframe. Impact velocity during these tests ranged from 4.44 km/hr (2.76 mph) to 17.98 km/hr (11.17 mph). The data resulting from these tests are reported in Reference 4.

Test Description

The test described in this report was conducted to obtain vibration and shock data which were superimposed on vibration data during regular rail shipment of cargo that was heavier than 14 tonnes (15 tons).

Test Procedure

This test was conducted during a regularly scheduled rail shipment of 45-tonne (50-ton) cargo over rail lines between Denver, Colorado and Albuquerque, New Mexico. These lines are operated by the Atchison, Topeka, and Santa Fe (AT&SF) Railway Company. The cargo consisted of an empty spent-fuel shipping container and skid along with the necessary hoisting devices. The cargo and rail car are shown in Figure 1 before a protective cover was placed over the spent-fuel container. An additional caboose was provided by AT&SF for SNL and AT&SF personnel who were involved in the test. This caboose was always adjacent to and immediately behind the instrumented rail car and immediately in front of the caboose which was occupied by the train crew at the rear of the train. The trains involved in the tests were those regularly operated by AT&SF for freight service.

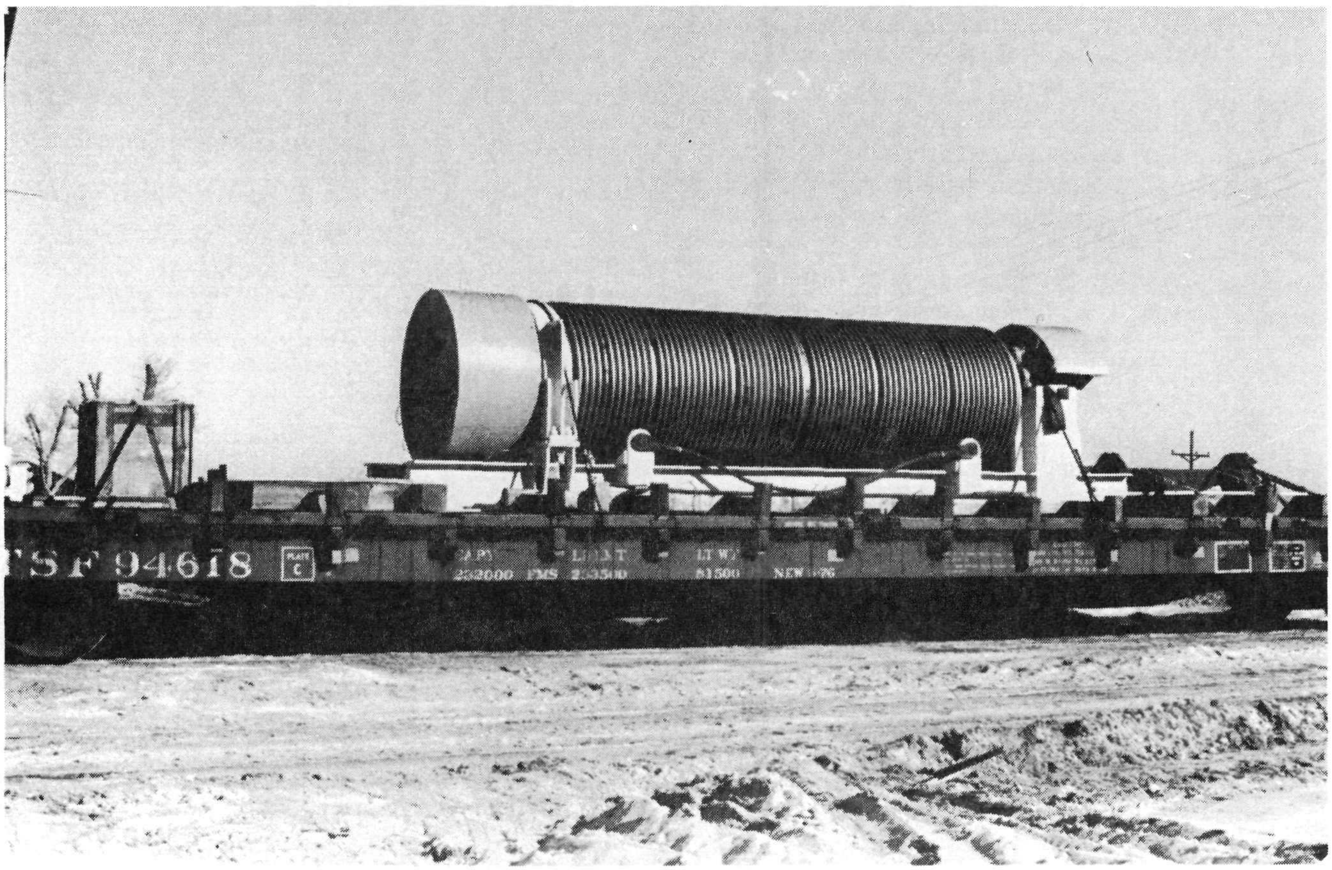


Figure 1. Rail Car and Cargo Before Protective Cover in Place

Train Configuration

Three separate trains were used during this test. The AT&SF 495 Extra South was used between Denver, Colorado and Pueblo, Colorado; it consisted of 43 cars having a total weight of 2603 tonnes (2869 tons) and was pulled by two diesel locomotives.

AT&SF 403 was used between Pueblo, Colorado and La Junta, Colorado; it consisted of 26 loaded rail cars and 27 empty rail cars. The total weight of Train 403 was 3397 tonnes (3744 tons). It was pulled by two diesel locomotives. There were two additional locomotives in the train that were not used for power; they were immediately behind the powered locomotives.

AT&SF 408 was used between La Junta, Colorado and Albuquerque, New Mexico; it consisted of 27 loaded rail cars and 19 empty rail cars from La Junta, Colorado to Trinidad, Colorado. The total weight of this train was 3154 tonnes (3477 tons). Nine additional loaded cars were attached at Trinidad, Colorado; the total weight of the train from Trinidad, Colorado to Albuquerque, New Mexico was 4173 tonnes (4600 tons). Train 408 was configured for mountainous terrain in that six locomotives were used. Four of the six locomotives were on the front of the train and were followed by loaded rail cars except for the instrumented rail car. The loaded rail cars were followed by two diesel locomotives controlled remotely by the engineer in the lead locomotive. The remote locomotives were followed by the 19 empty rail cars, the instrumented rail car, and the 2 cabooses.

Instrumented Rail Car

The rail car on which cargo and instrumentation were loaded was AT&SF Flat Car 94618. The car was manufactured by Thrall. It was 21 m (68 ft) long, weighed 37 tonnes (41 tons), and had a normal capacity of 105 tonnes (116 tons) and a maximum capacity of 106 tonnes (117 tons). It was equipped with trucks having two axles each and had wheels which were 1 m (38 in.) in diameter. The couplers were equipped with 0.38-m (15-in.) hydraulic end-of-car devices. The cargo floor was wood. The A-end of the car was forward during the entire shipment.

Cargo Tiedowns

The spent-fuel shipping container was tied to the instrumented rail car by two cables. Longitudinal and transverse motion was prevented by wood blocking (Figure 2).

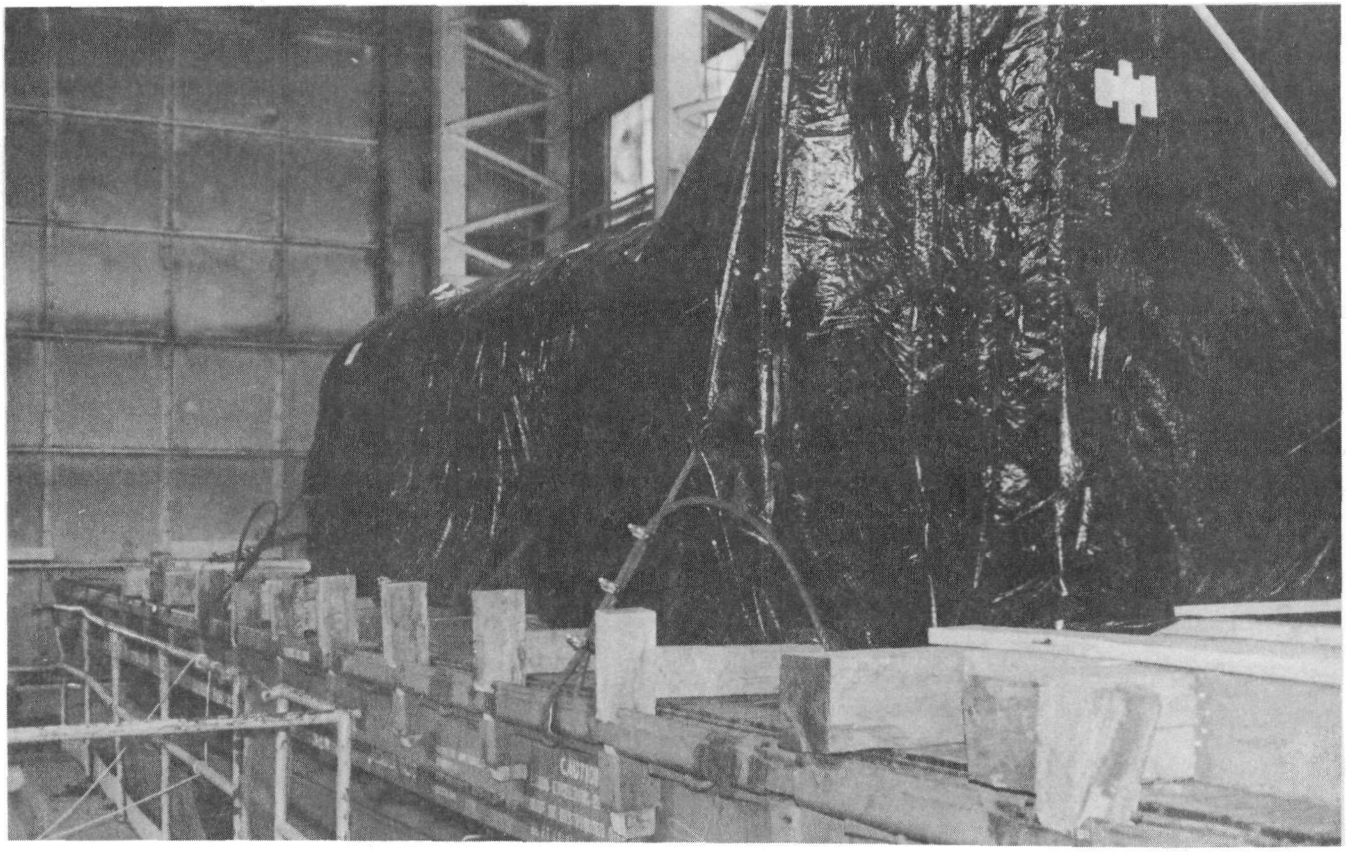


Figure 2. Cargo Tiedown and Blocking; Protective Cover in Place

Data Acquisition

Data measurements were obtained on a sampling basis. The data acquisition system was started and stopped remotely by SNL personnel in the caboose immediately to the rear of the instrumented rail car when the desired sampling locations were encountered. Sampling locations had been preselected by SNL personnel based on detailed track charts provided by AT&SF. Some of the sampling locations were changed during the test because of suggestions made by the AT&SF operational personnel who were participating in the test and were in the caboose with SNL personnel. AT&SF personnel had been briefed on the types of events to be sampled [coupler slack take-up (run-in or buff and run-out or draft), switches, road crossings, climbs, descents, flat track, undulating track, and rough track], and with their knowledge of local track conditions and how trains react to terrain variations, they were able to provide suggestions as to where such data samples could be obtained.

Train speeds were obtained from the train engineers while data samples were being taken.

Instrumentation

The instrumentation consisted of accelerometers with their associated cabling and a data acquisition system which was designed and fabricated at SNL.[5] The data acquisition system contained the necessary signal conditioning equipment and a tape recorder to provide an analog record of the output from the accelerometers. The system was started and stopped remotely by radio link, so that data sampling was controlled by SNL personnel who were riding in the caboose immediately behind the instrumented rail car.

Fourteen data channels were available on the data acquisition system. One channel was used to record IRIG time being generated by the system. By synchronizing a digital watch with the time generator, specific segments on the data tape were identified with specific events for data reduction purposes by recording the IRIG time and the event conditions during each event on event identification sheets. One channel was used as a noise-identification channel. Twelve channels were used to record the excitations being experienced by the accelerometers.

Eleven piezoresistive accelerometers having a frequency capability of 0 to 750 Hz and one piezoelectric accelerometer with a frequency capability of 3 to 2500 Hz were mounted on the rail car structure to measure the input from the rail car to the cargo. All of the accelerometers were mounted onto drilled and tapped 1-in. aluminum cubes. The cubes were attached to the rail car structure by dental cement. This method of mounting the accelerometers did not require any drilling and tapping of the rail-car structure. The resonant frequency of this mounting method is approximately 4000 Hz, which is well above the highest frequency of the instrumentation used.

Three piezoresistive accelerometers were mounted over the trucks on the forward end of the rail car to measure the excitations in the longitudinal (forward and aft), transverse (left and right), and vertical axes (Figure 3). Three piezoresistive accelerometers oriented to measure excitations in the longitudinal, transverse, and vertical axes were mounted on the lower flange of a longitudinal structural member (Figure 4) near the middle of the rail car.

Five piezoresistive and one piezoelectric accelerometer along with an inert accelerometer for noise detection were mounted over the trucks on the aft end of the rail car. These accelerometers and the data acquisition system are shown in Figure 5. Three of the five piezoresistive accelerometers mounted over the rear trucks were oriented to measure excitations in the longitudinal, transverse, and vertical axes. Two of the piezoresistive accelerometers at the rear position were oriented to measure excitations in the longitudinal and vertical axes. These two accelerometers were calibrated at higher amplitude levels than the others to provide data if the others overranged during an event. The piezoelectric accelerometer was mounted to measure excitations in the vertical axis. This accelerometer was included in the instrumentation to provide an indication of any significant excitation above the 750-Hz capability of the piezoresistive accelerometers.

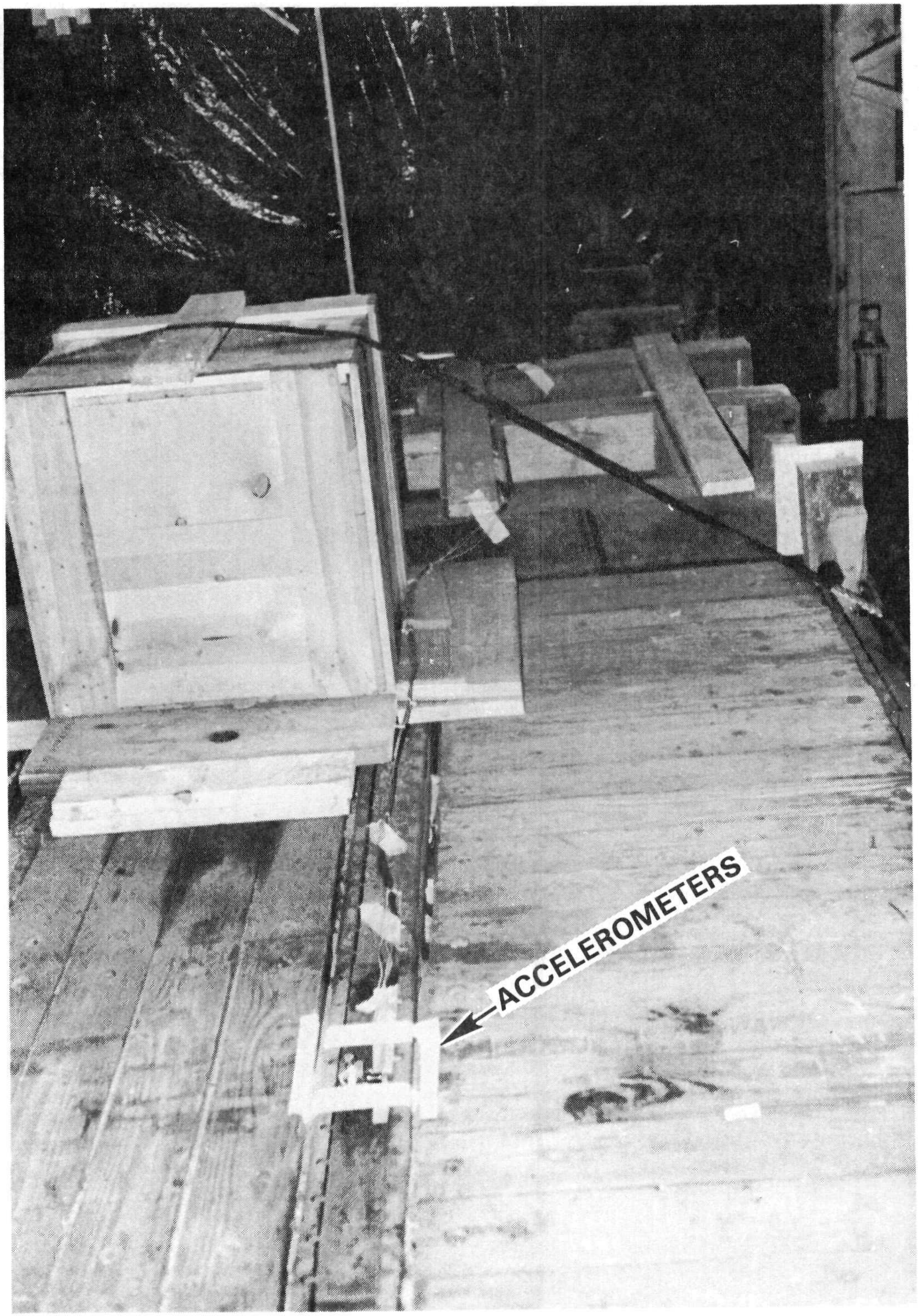


Figure 3. Accelerometer Mounting Over Forward Bolster

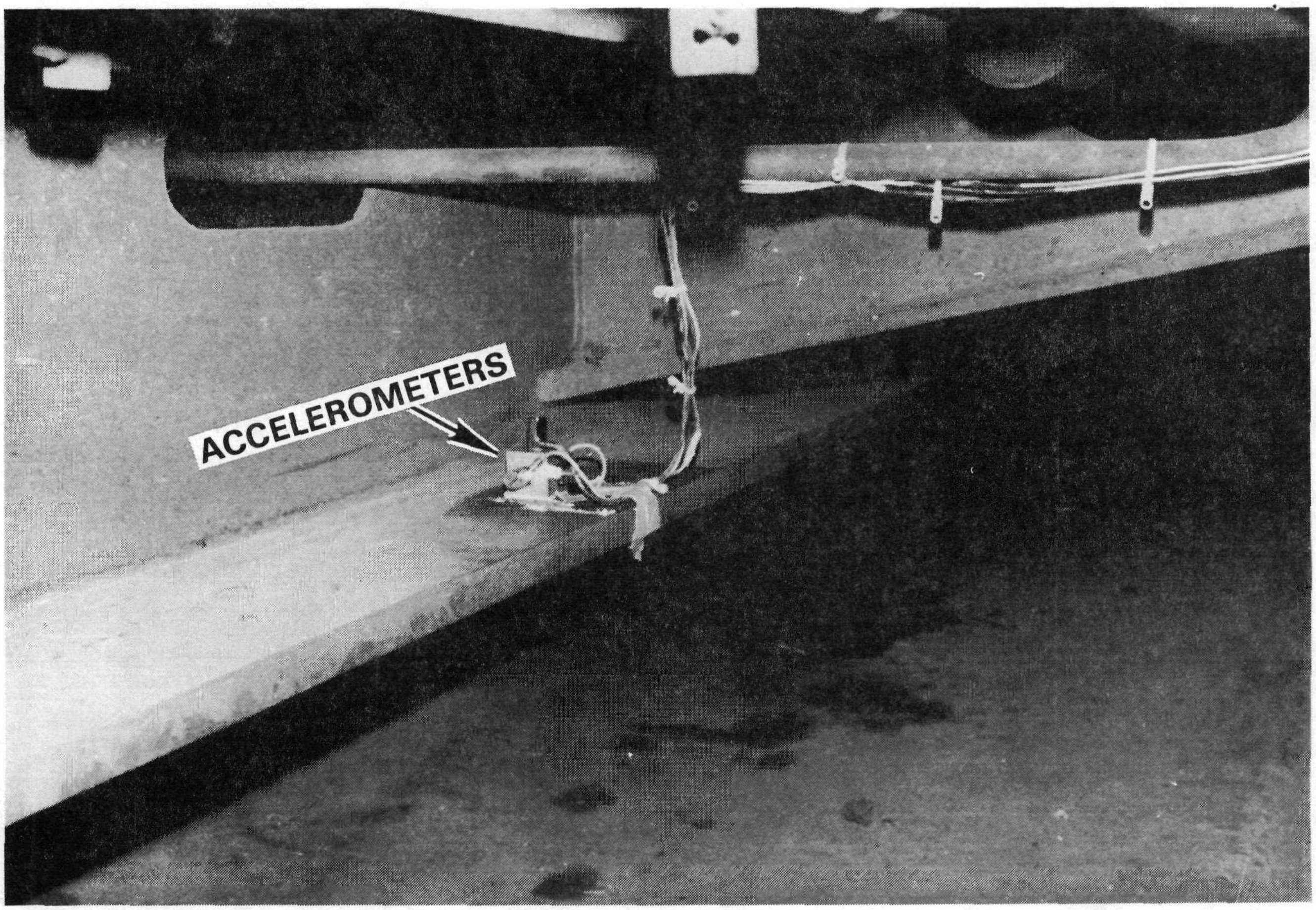


Figure 4. Accelerometer Mounting at Middle of Rail Car

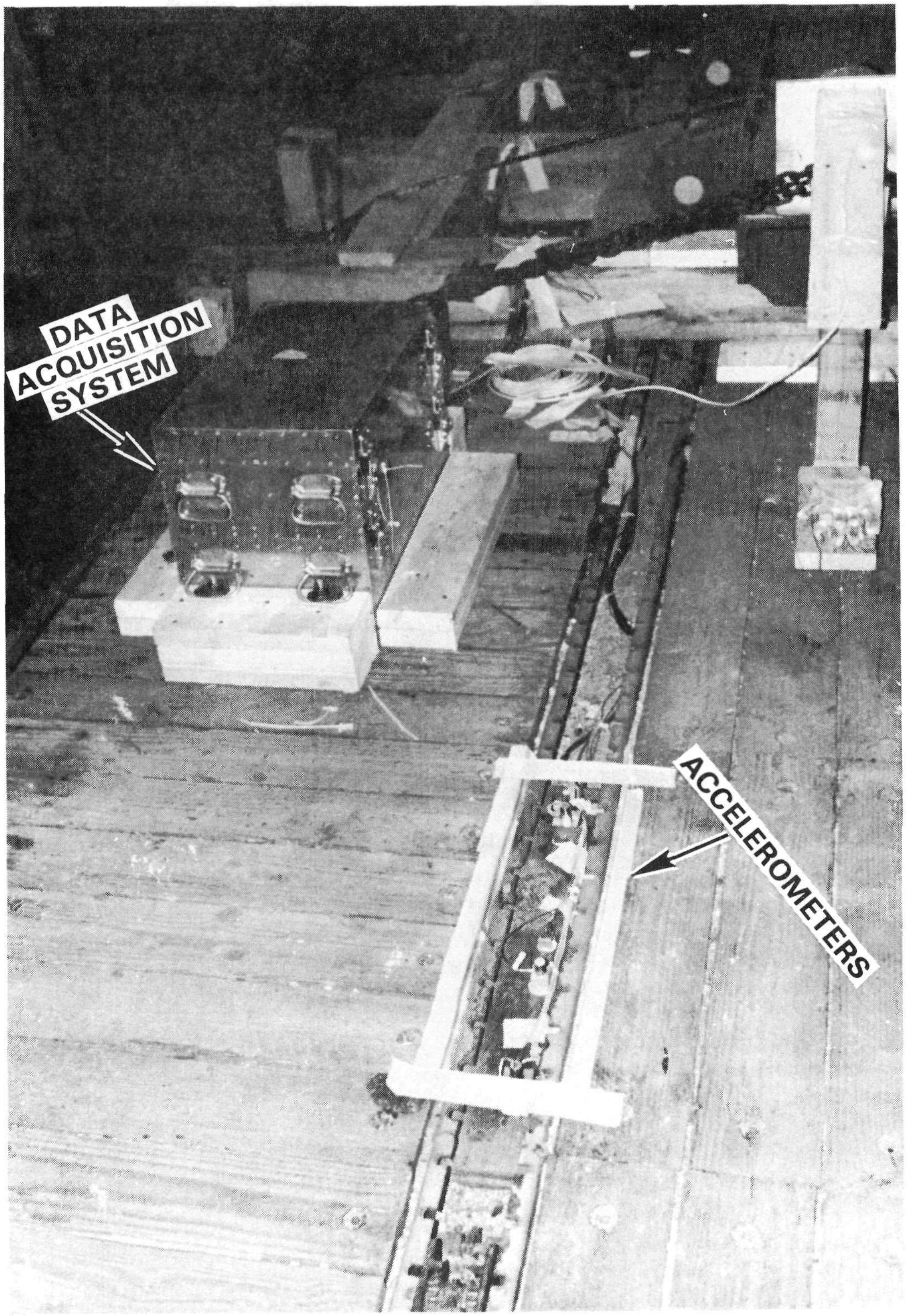


Figure 5. Accelerometer Mounting Over Rear Bolster Showing Data Acquisition System

Test Results

The environmental descriptions presented in this section summarize the data obtained during the rail shipment of a 45-tonne (50-ton) cargo from Denver, Colorado to Albuquerque, New Mexico.

Definitions of Dynamic Environments

Dynamic excitations delivered to cargo may be described as a mixture of vibration, occasional shock superimposed on the vibration, and shock that occurs in single isolated events such as rail coupling.

Vibration, the excitation that occurs whenever the carrier is in motion, is produced by the carrier's suspension system and frame members reacting to surface and/or wheel irregularities.

Superimposed shock is that short-duration excitation which often results in higher excitation amplitudes than those produced by vibration. This excitation results from specific occurrences during travel. Typical occurrences are (1) run-in; (2) run-out; and (3) crossing bridges, switches, and automobile cross roads. Characteristically, these excitations consist of decaying transient pulses intermixed with the vibration.

This report presents data fitting the above definitions only. Shock resulting from rail-coupling operations are reported in Reference 4.

Explanation of Data

The vibration data presented are zero-to-peak acceleration amplitude levels that include at least 99% of all amplitudes measured in each frequency band. The distribution of acceleration amplitudes in each frequency band is random, for which the probability distribution is nearly gaussian. This makes the reported amplitude levels approximately the three-sigma amplitude levels of excitations.

The superimposed shock data presented were reduced in single degree-of-freedom response spectra format. These spectra predict the maximum acceleration amplitudes to which single degree-of-freedom systems would respond when subjected to the complex transient pulse inputs. Response spectra were used because they permitted translation of complex input excitations into a more useful engineering format and permitted statistical summarization of different individual excitations. In generating these response spectra, 3% damping was used because experience has shown this to be representative of most hard-mounted systems.

Data Reduction

The data samples were recorded on magnetic tapes during shipment. An oscillograph record of all data tapes was produced to correlate specific events with the associated data tape segments to be used for data reduction. The events were identified for data reduction as either vibration or shock. Vibration data were reduced by data reduction program VIBRAN.[6] This program counts the number of zero-to-peak acceleration amplitudes in predetermined amplitude ranges in preselected frequency bands. After the VIBRAN records were available, appropriate records were combined into composite records by program VAIL.[7] The VAIL program combines VIBRAN records and displays the resulting distribution of zero-to-peak amplitudes in the same format as the individual VIBRAN records.

The shock records were reduced in response spectra format. The individual response spectra were then combined using program ZSHAIL.[8] This program produces new spectra which show (1) an estimate of the mean response spectrum of the spectra being combined, (2) the peak acceleration of all the records combined, and (3) the estimated mean plus three standard deviations at discrete frequencies. The estimate of the standard deviation at each frequency is equal to

$$\hat{\sigma} = \left[\frac{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}{n-1} \right]^{1/2} ,$$

where

x = acceleration amplitude at a discrete frequency

n = number of records being combined.

Recorded measurements from thirteen events were selected for data reduction for vibration descriptions. These events included flat track, undulating track, rough track, climbs, descents, curves, and multiple highway grade crossings. Train speeds during these events were between 40 and 89 km/hr (25 and 55 mph).

Recorded measurements from sixteen events were selected for data reduction for superimposed shock descriptions. These events included (1) run-in; (2) run-out; and (3) crossing switches, bridges, automobile cross roads, and a highway underpass. Train speeds during these events varied between 31 and 89 km/hr (19 and 55 mph).

Rail Car Data

Vibration

The vibration data presented herein are summaries of the cumulative zero-to-peak acceleration amplitude levels which include at least 99% of all accelerations measured in each frequency band. The summaries include data from all three accelerometer locations and represent a generic definition of input to cargo.

The highest of the cumulative 99% levels of zero-to-peak acceleration amplitudes occurred in the vertical axis across the entire frequency spectrum between 0 and 750 Hz. The vertical acceleration amplitudes were generally at or below 0.37 g except between 240 and 300 Hz where the acceleration amplitude was 0.52 g. Study of random vibration data which were reduced show that in this frequency band the concentration of energy was at approximately 250 Hz.

The vibration zero-to-peak acceleration amplitude levels in the transverse axis were equal to or higher than those in the longitudinal axis. The highest acceleration amplitude levels were 0.19 g in the 0- to 5- and 10- to 20-Hz frequency bands for the transverse axis and 0.10 g in the 180- to 240- and 500- to 750-Hz frequency bands in the longitudinal axis. Figure 6 is a histogram of the acceleration amplitude levels of vibration in all three axes. Details of the 99 percentile levels of zero-to-peak acceleration amplitudes in each frequency band and for each axis are given in Table 1.

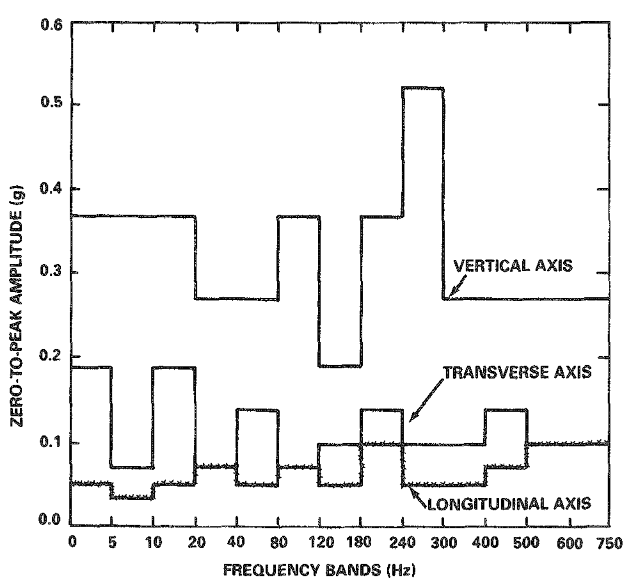


Figure 6. Rail Vibration-Input to Cargo (g) 99 Percentile Level of Zero-to-Peak Amplitudes

Table 1. Rail Vibration for 45-Tonne (50-Ton) Cargo

Frequency Band (Hz)	Input to Cargo at 99 Percentile Level of Zero-to-Peak Amplitude (g) Longitudinal Axis	Transverse Axis	Vertical Axis
0–5	0.052	0.190	0.37
5–10	0.037	0.072	0.37
10–20	0.052	0.190	0.37
20–40	0.072	0.072	0.27
40–80	0.052	0.140	0.27
80–120	0.072	0.072	0.37
120–180	0.052	0.100	0.19
180–240	0.100	0.140	0.37
240–300	0.052	0.100	0.52
300–400	0.052	0.100	0.27
400–500	0.072	0.140	0.27
500–600	0.100	0.100	0.27
600–750	0.100	0.100	0.27

Shock

The shock data presented were obtained during the same shipment as the vibration data but from specific, identifiable events. These data were obtained when the instrumented rail car experienced run-in and run-out as well as when it crossed rail switches, road crossings, bridges, and highway underpasses. Since the instrumented rail car was equipped with hydraulic end-of-car devices, run-in events were insignificant. Run-out events were much more noticeable to the SNL personnel in the adjacent caboose as well as on the data tapes.

When the summarized shock response spectra were overlayed and the peak and mean plus three standard deviation envelopes were examined, it was found that the transverse axis had the lowest response amplitude over most of the 0.5- to 750-Hz frequency range. The vertical axis response amplitude envelopes were generally equal to or slightly higher than the other two axes; however, the longitudinal axis response amplitudes were higher than the other two axes in the very low frequency between 0.5 and 1.5 Hz and again in the 80 to about 180 Hz range. Figure 7 shows the shock response spectra envelopes which envelop the peak and mean plus three standard deviation response spectra.

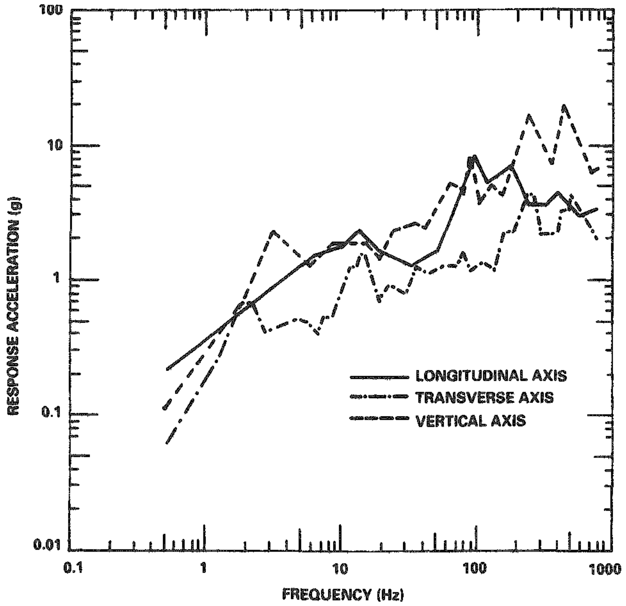


Figure 7. Mean Plus Three Standard Deviation Amplitude Envelopes of Shock Response Spectra; 3% Damping

References

[1]C. F. Magnuson and L. T. Wilson, *Shock and Vibration Environments for Large Shipping Containers on Rail Cars and Trucks,* SAND76-0427 (Albuquerque: Sandia Laboratories, July 1977).

[2]C. F. Magnuson, *Shock and Vibration Environments for Large Shipping Container During Truck Transport (Part I),* SAND77-1110 (Albuquerque: Sandia Laboratories, September 1977).

[3]C. F. Magnuson, *Shock and Vibration Environments for a Large Shipping Container During Truck Transport (Part II),* SAND78-0337 (Albuquerque: Sandia Laboratories, May 1978).

[4]C. F. Magnuson, *Shock Environments for Large Shipping Containers During Rail Coupling Operations,* SAND79-2168 (Albuquerque: Sandia National Laboratories, June 1980).

[5]R. C. Rentzsch, *In Situ Environmental Sampler Data Acquisition System,* SAND78-0046 (Albuquerque: Sandia Laboratories, January 1979).

[6]T. E. Smart, *Operation and Maintenance Documentation for Program VIBRAND,* SLA-73-0616 (Albuquerque: Sandia Laboratories, October 1973).

[7]L. A. Faw, *Program VAIL (User's Manual),* SC-M-71 0709 (Part 1) (Albuquerque: Sandia Laboratories, November 1971).

[8]Z. E. Beisinger, *Modification of ZSHAIL Program,* Informal Memorandum (Albuquerque: Sandia Laboratories, August 21, 1979).

Do Not Microfilm

DISTRIBUTION:

Atchison, Topeka, and Santa Fe Railway Co.
80 East Jackson Blvd
Chicago, IL 60604
Attn: D. G. Ruegt

Atchison, Topeka, and Santa Fe Railway Co.
Motive Power Building
1001 NE Atchison St
Topeka, KS 66616
Attn: W. H. Clark

Atchison, Topeka, and Santa Fe Railway Co.
Box 987
1st and Cook Sts
Raton, NM 87740
Attn: H. C. Powers

Atchison, Topeka, and Santa Fe Railway Co.
402 Santa Fe Ave
La Junta, CO 81050
Attn: S. L. Fruin

Atchison, Topeka, and Santa Fe Railway Co.
PO Box 1477
West 4th St R.R. Yards
Pueblo, CO 81002
Attn: F. L. Sparks

Atchison, Topeka, and Santa Fe Railway Co.
214 First St SW
Albuquerque, NM 87102
Attn: W. N. Spears

Allied General Nuclear Services
PO Box 847
Barnwell, SC 29812
Attn: R. T. Anderson

American Association of Railroads
1920 L St NW
Washington, DC 20036
Attn: C. P. Furber

American Trucking Association, Inc
1616 P St NW
Washington, DC 20036
Attn: R. M. Doyle

Argonne National Laboratory
PO Box 2528
Idaho Falls, ID 83401
Attn: C. S. Abrams

Argonne National Laboratory
9700 South Cass Ave
Argonne, IL 60439
Attn: C. J. Roberts

Atomic Industrial Forum
7101 Wisconsin Ave
Bethesda, MD 20014
Attn: E. Gordan

Battelle Memorial Institute
Columbus Laboratory
505 King Ave
Columbus, OH 43201
Attn: D. R. Ahlbeck

Battelle Memorial Institute
Columbus Laboratory
505 King Ave
Columbus, OH 43201
Attn: C. C. Kimm

Battelle Memorial Institute
Office of Nuclear Waste Isolation
505 King Ave
Columbus, OH 43201
Attn: R. W. Peterson

Battelle Memorial Institute
Pacific Northwest Laboratory
PO Box 999
Richland, WA 99352
Attn: K. J. Schneider

Brookhaven National Lab, NS Lib (DOE)
Brookhaven National Laboratory
Department of Nuclear Energy, Bldg 30
Upton, NY 11973
Attn: Nuclear Safety Library

Chem-Nuclear Systems, Inc
PO Box 726
Barnwell, SC 29812
Attn: D. Ebenhack, Manager
Health and Safety

Chem-Nuclear Systems, Inc
PO Box 1866
Bellevue, WA 98009
Attn: L. E. Reynolds,
Corporate Director of Regulatory Affairs

DISTRIBUTION (cont):

Edlow International Co.
1100 17th St NW, Suite 404
Washington, DC 20036
Attn: J. Edlow

EG&G
Idaho National Engineering Laboratory
PO Box 1625
Idaho Falls, ID 83415
Attn: T. H. Smith, TRU

E. I. duPont de Nemours and Company, Inc
Savannah River Plant
Aiken, SC 29801
Attn: Technical Library

Electric Power Research Institute
PO Box 10412
Palo Alto, CA 94303
Attn: R. E. Nickell

Energy Research Group, Inc
400-1 Totten Pond Rd
Waltham, MA 02154
Attn: J. L. Murphy

Federal Emergency Management Agency
1725 Eye St NW
Washington, DC 20472
Attn: J. D. Winkle, Director
Federal Response Coordination

General Atomic Co.
PO Box 81608
San Diego, CA 92138
Attn: R. Burgoyne

International Energy Associates, Ltd
600 New Hampshire Ave NW
Washington, DC 20037
Attn: M. Elliott

Lawrence Livermore Lab (DOE)
University of California
Lawrence Livermore Laboratory
PO Box 5500
Livermore, CA 94557
Attn: Technical Information Dept, L-53

Library of Congress
CRS-ENGR
Washington, DC 20540
Attn: C. Behrens

Los Alamos National Laboratory (2)
PO Box 1663
Los Alamos, NM 87545
Attn: J. L. Warren
T. A. Butler, WX8

Morgan State University
Center for Transportation Studies
Baltimore, MD 21239
Attn: R. P. Capelle, Jr

Mound Laboratory (DOE)
Monsanto Research Corp
Mound Lab
PO Box 32
Miamisburg, OH 45342
Attn: Library

National Academy of Sciences
Committee on Radioactive Waste Mgmt
2101 Constitution Ave NW
Room JH-826
Washington, DC 20418

National Highway Transportation Safety Administration
400 7th St SW
Washington, DC 20590

National Research Council
Transportation Research Board
2101 Constitution Ave NW
Washington, DC 20418

National Tank Truck Carriers, Inc
1616 P St NW
Washington, DC 20036
Attn: C. J. Harvison

National Transportation Safety Board
TE-40
Washington, DC 20594
Attn: L. Benner

DISTRIBUTION (cont):

New England Nuclear Corp
601 Treble Cove Rd
North Billerica, MA 01862
Attn: E. DeMaria

Northeast Utilities
PO Box 270
Hartford, CT 06101
Attn: R. W. Bishop
Secretary and Counsel

NUS Corp
4 Research Place
Rockville, MD 20850
Attn: N. B. McLeod

Nuclear Assurance Corp
24 Executive Park West
Atlanta, GA 30329
Attn: C. Thorup, Vice President

Oak Ridge National Laboratory (2)
PO Box X
Oak Ridge, TN 37830
Attn: C. Fore
L. B. Shappert

Rockwell International
Atomics International Division
Rocky Flats Plant
PO Box 464
Golden, CO 80401
Attn: W. S. Bennett

Rockwell International
PO Box 800
Richland, WA 99352
Attn: M. Bensky

The S. M. Stoller Corp
Colorado Bldg, Suite 800
Boulder, CO 80302
Attn: M. H. Raudenbush

Southern States Energy Board
One Exchange Place, Suite 1230
Atlanta, GA 30338
Attn: Library

State of New Mexico
Division of Health and Environment
PO Box 968
Santa Fe, NM 87503
Attn: A. Topp

Stearns-Roger Manufacturers, Inc (2)
Box 5888
4500 Cherry Creek Dr
Denver, CO 80217
Attn: R. W. Cecil
J. Lewis

Transnuclear, Inc
One North Broadway
White Plains, NY 10601
Attn: W. Teer

The Transport Environment
SR 285 Old Squaw Dr
Kitty Hawk, NC 27949
Attn: W. Brobst, President

Thomas Gray Associates
815 N Main St
Orange, CA 92668
Attn: T. Gray, President

Tri-State Motor Co.
PO Box 113
Joplin, MO 64801
Attn: C. H. Mayer, Vice President
Nuclear Division

Union Carbide Corp
270 Park Ave
New York, NY
Attn: S. Hoffman, Esq
Transportation Counsel

US Department of Energy
San Francisco Operations Office
1333 Broadway
Oakland, CA 94612
Attn: Traffic Manager

US Department of Energy
Rocky Flats Area Office
PO Box 298
Golden, CO 80401
Attn: D. M. Krieg, Traffic Manager

DISTRIBUTION (cont):

US Department of Energy (2)
Office of Nuclear Energy
Washington, DC 20545
Attn: E. Jordan, NE-320
E. F. Mastel, NE-313

US Department of Energy
Washington Library
Washington, DC 20545
Attn: Energy Library

US Department of Energy (3)
Idaho Operations Office
550 Second St
Idaho Falls, ID 83401
Attn: R. Long, Traffic Manager
S. Vorndran, Actg Program Manager
West Valley Project
J. Whitsett, Chief
Radioactive Waste Mgmt Branch

US Department of Energy
Chicago Operations Office
9800 South Cass Ave
Argonne, IL 60439
Attn: G. Ishmael, Traffic Manager

US Department of Energy
NWTS National Program Office
Columbus, OH 43201
Attn: J. O. Neff

US Department of Energy (6)
Albuquerque Operations Office
Albuquerque, NM 87115
Attn: R. H. Campbell
J. P. Crane, Director
Transp Safeguards Division
E. C. Hardin, Jr, Actg Deputy
Asst Mgr, Office of Projects and
Energy Programs
W. C. Purchase, Traffic Manager
K. Carlson
R. Y. Lowrey

US Department of Energy
Nevada Operations Office
PO Box 14100
Las Vegas, NV 89114
Attn: A. Neumann, Traffic Manager

US Department of Energy
Brookhaven Area Office
Upton, NY 11973
Attn: Traffic Manager

US Department of Energy (2)
Dayton Area Office
PO Box 66
Miamisburg, OH 45342
Attn: R. U. Blauvelt
Traffic Manager

US Department of Energy
Savannah River Operations Office
PO Box A
Aiken, SC 29801
Attn: L. Turner, Traffic Manager

US Department of Energy
Oak Ridge Operations Office
PO Box E
Oak Ridge, TN 37830
Attn: L. Blalock, Traffic Manager

US Department of Energy
Richland Operations Office
PO Box 999
Richland, WA 99352
Attn: J. Peterson, Traffic Manager

US Department of Transportation (4)
400 Seventh St SW
Washington, DC 20590
Attn: D. Crockett, DMT-1, Rm 8102
R. R. Rawl, MTB
L. Santman
D. Dancer

US Environmental Protection Agency
401 M St NW
Washington, DC 20460
Attn: R. Clark

US Nuclear Regulatory Commission (7)
Washington, DC 20555
Attn: K. Black, M/S 7217 MNB
N. L. Eisenberg, M/S NL-5650
D. R. Hopkins, M/S NL-5650
C. E. MacDonald, M/S 396-SS
D. O. Nellis, M/S NL-5650
W. R. Lahs, SAFER Division
J. C. Malaro, M/S NL-5650

DISTRIBUTION (cont):

US Department of Energy (6)
Nuclear Energy
Routing NE-340
Washington, DC 20545
Attn: G. Oertel
D. McGoff
F. P. Falci
R. F. Garrison
J. A. Sisler
T. Anderson

Westinghouse Hanford Co.
Hanford Engineering Development Lab
PO Box 1970
Richland, WA 99352
Attn: S. R. Fields

1000 J. K. Galt
1200 G. Yonas
1500 J. K. Galt (actg)
1510 D. B. Hayes
1520 T. B. Lane
Attn: R. D. Kreig
T. G. Priddy
L. W. Davison
1523 R. C. Reuter, Jr.
1523 C. F. Magnuson (40)
1530 W. Herrmann
3743 C. Summers
Attn: C. R. Freund

7000 O. E. Jones
7500 W. A. Gardner
7520 T. J. Hoban
Attn: G. L. West, 7522
8000 R. S. Claassen
9000 G. A. Fowler
9210 V. E. Blake, Jr.
Attn: J. T. Risse, 9213
M. R. Madsen, 9214
9300 R. L. Peurifoy, Jr.
9400 A. W. Snyder
9700 E. H. Beckner
Attn: W. D. Weart, 9730
R. W. Lynch, 9760
9780 R. M. Jefferson
Attn: TTC Master File
9780 E. W. Shepherd
9780 TTC Library, File Ref No. 3002.030 (3)
9781 R. E. Luna
9782 R. B. Pope
9782 J. M. Ortman
9782 A. A. Trujillo (5)
9783 G. C. Allen, Jr.
9783 M. G. Vigil
9783 H. R. Yoshimura
8214 M. A. Pound
3141 L. J. Erickson (5)
3151 W. L. Garner (3)
3154-3 C. H. Dalin (25)
For DOE/TIC (Unlimited Release)