SC-RR-66-677

THE ENVIRONMENT EXPERIENCED BY CARGO ON A
FLATBED TRACTOR-TRAILER COMBINATION

(Environmental Operations Analysis Study)

J. T. Foley, 1541
Sandia Laboratory, Albuquerque

December 1966

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ABSTRACT

Truck-transport dynamic environment was measured during the shipment of a 15-ton radioactive materials cask from Wilmington, Delaware, to Albuquerque, New Mexico. This report of the trip describes the instrumentation, road conditions, vehicle speeds, and weather conditions encountered. Representative examples of the shock/vibration magnitudes that were measured are presented in reduced form, and a means is provided to apply these data to other loads which might be carried on the vehicle.

ACKNOWLEDGMENTS

Many organizations and individuals outside and within Sandia Corporation participated in the planning, performance, and coordination of this test.

It is hoped that all who participated have been recognized in the various sections of this report.

Special recognition is due to those organizations and individuals at Sandia Corporation who assisted in the data-reduction/analysis efforts. Of particular note were the efforts of H S North and M. Bauder, 7216, J. Patrick, T Smart, R. H. Barnett, 7335, J L. Mortley, 7334, and L. A. Faw, 2223

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TABLE OF CONTENTS

	<u>Page</u>
Introduction	5
Environment Analysis	7
Results	9
Discussion	9
Conclusions	10
Recommendations	10
APPENDIX A - TEST PERFORMANCE (See Table of Contents on Page 15)	13
APPENDIX B - OCCURRENCE OF ROAD TYPES AND VEHICLE SPEEDS (See Table of Contents on Page 66)	65
APPENDIX C - TEST RESULTS AND ANALYSES (See Table of Contents on Page 74)	73
APPENDIX D - MEASUREMENT OF MECHANICAL IMPEDANCE (See Table of Contents on Page 121)	119
LIST OF REFERENCES	154

THE ENVIRONMENT EXPERIENCED BY CARGO ON A FLATBED TRACTOR-TRAILER COMBINATION

(Environmental Operations Analysis Study)

Introduction

Sandia Corporation Ancillary Equipment and Design Division, 1543, in conjunction with AEC Division of Reactor Development (AEC-DRD) sponsored the shipment of a 15-ton radioactive materials cask to Albuquerque, New Mexico. The cask was shipped from the Knapp-Mills Plant in Wilmington, Delaware, on a flatbed tractor-trailer, which provided an opportunity to measure the dynamic environment experienced by the cask over a wide variety of road conditions.

Before shipping the cask, Division 1543 contacted Sandia Corporation Dynamics Analysis Division 1541. The environmental operations analysis group in Division 1541 had been planning to conduct a series of measurements of the truck transport environment, and was assigned to coordinate Sandia participation in this over-the-road cask shipment as a part of their program.

During discussions with the personnel sponsoring the tests, Division 1541 learned that the Army Transportation Engineering Agency, Fort Eustis, Virginia (USATEA), was also working with AEC to measure the dynamic environment that would be experienced during the shipment. It was found that on similar transport tests USATEA had experienced difficulty with data-recording systems. For this reason they were planning to evaluate a mitigating pallet which would protect the instrumentation from the truck-bed environment, and indicated that they would welcome the use of a recording system on the pallet, which had experienced little difficulty in similar tests.

In the final arrangements for joint Sandia/AEC and TEA/DOD participation, USATEA:

1. Made static weight/deflection measurements of the tractor-trailer.
2. Accompanied the truck shipment in a "following" vehicle.
3. Recorded road conditions.
4. Made a documentary film of the trip.
5. Used an oscillograph recorder to obtain "spot" data at points on the frame of the truck and from the "input" of the truck bed to the mitigating instrumentation pallet.

Sandia

1. Instrumented the truck bed and the load.
2. Provided parallel instrumentation of the input to the USATEA pallet.
3. Measured the response of the Sandia recorder which was placed on the pallet.

The arrangements for information interchange were that:

1. USATEA would furnish Sandia with their reports on the static load tests, a copy of the documentary film, and their description of the conditions encountered as reported by their following team. A copy of the documentary film was received, and USATEA Report 65-9 was furnished, satisfying these arrangements.
2. Sandia would furnish USATEA with a report describing the results of Sandia's participation in the test, and, at a later time, dubs of those portions of the Sandia data tapes that USATEA might wish to analyze for their own purposes. This was accomplished through transmittal of SC-DR-65-278, and tape dubs were furnished as requested. The transmittal of this report will complete the interchange arrangements.

Purpose

This report documents the results of Sandia participation in the truck test.

Objectives

Sandia, in participating in the truck test, was to accomplish the following objectives:

1. Furnish instrumentation for the truck test

Instrumentation was furnished by Sandia Corporation Division 7334. Appendix A describes the recorder, its packaging, and the types of transducers used.

2. Report on the nature of the instrumentation and its performance during the test

The pickup locations and the performance of the instrumentation during the test are described in detail in Appendix A.

3. Report on the various road conditions, vehicle speeds, and weather conditions encountered during the trip

A commentary on road conditions, vehicle speeds, and weather conditions encountered is contained in Appendix A. The results of a detailed analysis of the road conditions and vehicle speeds encountered are presented in Appendix B.

4. Report on the environment measured as "input to cargo" during the test

Descriptions of the data analysis experiments performed and presentations of data from the truck test reduced in desired form are presented in Appendix C.

5. Report on measuring the apparent weight of the truck/load system

The results of apparent weight measurements by Division 7324 are reported in Appendix D.

6. Report on the environment experienced by the load tiedown system

This objective was not met, since time did not permit installation of load-measuring instruments in the tiedown system as planned. (Reference: page 24, Appendix A.)

Environment Analysis

The dynamic environmental input to cargo in truck transportation can be described in many ways. In this test, the environment is described in terms of probability of occurrence of input acceleration imparted to the cargo. The resultant forces produced are estimated. The vertical input was determined to be "governing," through evaluation of data now in the Sandia Corporation Data Bank. Substantiation was obtained from longitudinal and transverse axis data obtained during this test. The analysis, therefore, was restricted to the vertical axis. An "activity model" describing the assumed relationships for this evaluation was derived as follows:

$$E_i = F_i = f(W_a, G_T, \sim, T)$$

where

E_i , environmental input = F_i , input force

W_a = apparent weight

G_T = peak acceleration amplitude probability distribution for the trip

$\sim$ = frequency, and

T = trip duration.

The basic calculation desired is:

$$E_i = F_i = W_a \times G_T$$

However

$$W_a = f(\sim, L)$$

where

$\sim$ = frequency, and

L = load on the truck.

Through the test procedure described in Appendix D, W_a can be evaluated as a function of frequency for a given load condition. By evaluating the apparent weight for (1) the unloaded truck, and (2) the loaded truck, two advantages are obtained:

1. The evaluation of E_i , using W_a of the unloaded truck gives an estimate of E_i for a light load, the W_a of which is unknown.

2 The evaluation of E_1 using W_a of the loaded truck gives an estimate for E_1 of a heavily loaded truck for which the load W_a is unknown

A potential advantage is that, through measurement of W_a for other types of trucks and loads, the E_1 obtained from this test may ultimately be modified accordingly without the necessity of performing additional over the-road measurements. This advantage can only be realized through further W_a measurements on other truck types, and further validation of the assumptions inherent in the activity model developed for this environment

The second parameter G_T , as measured in the test, may be expressed as a function of the following

$$G_T = f(\Delta T, \sim, T, R, S, P)$$

where

G_T = an overall acceleration amplitude distribution

ΔT = time duration of data sample

$\sim$ = frequency

T = trip duration

R = road conditions

S = truck speed

P = load location on truck bed

Through the data reduction process described in Appendix C, a probability distribution of the acceleration amplitudes experienced during a ΔT period may be obtained as a function of narrow bands of frequency. The criterion for obtaining an appropriate ΔT length to obtain a representative distribution is also described in Appendix C.

As also discussed in Appendix C, the amplitude distribution $G_{\Delta T}$ can only be obtained in narrow bands of frequency. The W_a obtained, therefore, must be "averaged" within these bands, permitting the calculation of an "estimated" E_1 in all cases.

It was assumed that the trip duration, T , was long enough to allow a representative sampling of the frequency of occurrence of road types and road speeds to be encountered in commercial transport. On this assumption, the probability distributions of road conditions (R) and truck speeds (S) were evaluated (Appendix B).

These distributions were, in turn, used to "weight" the $G_{\Delta T}$ samples, to arrive at the composite description in Appendix C of the amplitude distribution, G_T , for the entire trip.

To account for variation in possible location of load on the truck bed (P), ΔT samples at the forward, center, and aft load bed locations in the test were "composited" for each of the road/speed conditions represented.

Results

Sixteen road conditions were recognized by observers during the test:

1. Level concrete	9. Parking lots
2. Level blacktop	10. Turnpike, asphalt
3. Bridge crossings	11. Overpass
4. Railroad crossings	12. Turnpike, concrete
5. Hills, blacktop	13. Hills, concrete
6. Bumps	14. Detours, paved
7. Blacktop over concrete	15. Sand and gravel
8. Tunnels	16. Brick.

Representative acceleration amplitude distributions for each condition are presented in Appendix C, Figures C-1 through C-23. Each condition represented is a composite which contains a measurement at the forward, central, and rear section of the trailer bed, taken at the speed or speeds which occurred most frequently during the trip.

The over-all trip composite amplitudes G_T for the unloaded and loaded truck, presented in Appendix C (Figures C-24 and C-25) are the result of computer-combining the data of Figures C-1 through C-23 with "weighting," based upon the frequency of occurrence of road types encountered. Also listed on these G_T figures are the "averaged" apparent weights measured in each frequency band for the lightly loaded and heavily loaded truck. Figures C-26 and C-27 present the resultant estimation of F_i (input force) for a lightly loaded and a heavily loaded truck.

Discussion

The application of the estimated environmental input computation $F_i = W_a \times G_T$ must be viewed with caution. The "true" computation of F_i is a vectorial one to evaluate the input force at the load/truck interface where $F_i = G_T \times W_{a_{truck}} + W_{a_{load}}$. In Figure C-24, the average W_a listed in each frequency band is $W_{a_{truck}}$. This means that in Figure C-26 the average $W_{a_{load}}$ was assumed to be negligible when estimating the input force for the lightly loaded truck. The W_a of any other load to be placed on the truck should be measured in a manner similar to that described in Appendix D, to determine if this assumption is warranted.

Similarly, the average W_a listed for the heavily loaded truck in Figure C-25 is $W_{a_{truck}} + W_{a_{15-ton load}}$. Use of this value is a good means of estimating F_i for the 15-ton cask load carried in this test, but the paucity of W_a data for cargo of this nature makes it questionable whether it is valid to assume that the 15-ton cask W_a is "typical." Figure C-27 is, however, based on this assumption. Note that the average W_a in both Figures C-24 and C-25 is listed for only those frequencies of 10 cps and higher, for two reasons:

1. Present W_a measurement techniques do not permit a good evaluation below 10 cps. The primary limitation is the "controllability" of the driving test equipment at low frequencies.

2. This inherent "control" limitation of test drivers is one of the reasons for beginning vibration tests at 10 cps. It is of little value to define input forces below this frequency, since the "state-of-the-art" limitation of most laboratory test equipment at present precludes the use of force information below this frequency.

Note further that this test provides a great deal of evidence that the largest force magnitudes in truck transport are encountered below 10 cps, and that, because of the state-of-the-art limitation in laboratory equipment, we may not be satisfactorily qualifying equipment to be transported by truck through the exclusive use of vibration test equipment in the laboratory.

Conclusions

At present, most dynamic data are being obtained by using accelerometers. In this test evaluation, an "effective mass" was measured as well, to permit us to estimate force inputs. This method shows promise in establishing reasonable force-controlled qualification test levels or estimating force magnitudes which a cargo/tiedown design must survive in normal truck transport. However, improvements in the method are indicated. Our conclusions, then, are:

1. Acceleration recording instrumentation of the type used in this road test is considered to be accurate and adequate. However, use of force transducers at the vehicle/load interface would provide a direct method of checking results of analyses.
2. Reducing accelerometer data to a statistical format and combining formats on an "activities analysis" basis is necessary for maximum usefulness.
3. Improvements in technique and equipment are required for future measurement of apparent weight.
4. The potential benefits from the analysis techniques developed in this program may be realized only after further measurements of W_a of other vehicles and cargo have been performed.

Recommendations

It is recommended that:

1. Efforts to improve methods of measuring apparent weight should be continued, specifically with regard to developing:
 - a. A uniform method of obtaining a measured average apparent weight in relatively narrow frequency bands.
 - b. A low-frequency apparent weight test driver, capable of being controllable to either 1 cps, or a frequency at which the measured W_a equals the static weight of the item being tested.

2. Further measurements should be taken of W_a of other loads and W_a of other vehicles which may be used as carriers.

3. A capability to qualify cargo to forces encountered below 10 cps should be developed. Consideration should be given to test equipment which can provide steady-state loads, and long-duration (0.5 to 1 second) impulsive loads of up to three times the weight of the cargo being qualified. Additionally, short-duration, repetitive shock pulses which have peaks on the order of 3 g and an excitation capability in the 125 to 300 cps frequency range should also be considered as being superimposed on the low-level, steady-state vibration which is encountered in the 10 to 300 cps frequency range.

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APPENDIX A
TEST PERFORMANCE

Extracted from

SC-DR-65-278

JOINT ARMY/AEC/SANDIA TEST OF TRUCK TRANSPORT
ENVIRONMENT, DECEMBER 7-17, 1964

(Test No. T-10767)

by

J. L. Mortley, 7334
Sandia Laboratory, Albuquerque

August 1965

ABSTRACT

The truck transportation environment test described here was a joint effort by the U. S. Army Transportation Engineering Agency, the AEC, and Sandia Corporation to measure the tie-down loads, vibration, shock, and temperatures in transporting a 15-ton radioactive-material cask from Wilmington, Delaware, to Albuquerque, New Mexico.

TABLE OF CONTENTS

	<u>Page</u>
Introduction	17
Preparations	17
Instrumentation System	18
Data Recording	18
Data Analysis	19
Enclosure 1	21
Enclosure 2	23
Enclosure 3	27
Enclosure 4	29
Enclosure 5 (Figure 5-1)	31
Enclosure 6 (Figure 6-1 through Figure 6-3)	33
Enclosure 7 (Figure 7-1 through Figure 7-12)	37
Enclosure 8 (Figure 8-1 through Figure 8-13)	51

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JOINT ARMY/AEC/SANDIA TEST OF TRUCK TRANSPORT
ENVIRONMENT, DECEMBER 7-17, 1964

(Test No. T-10767)

Introduction

The truck transportation environment test described herein, conducted by Division 7334 at the request of Divisions 1541 and 7331 (see Enclosure 1, "Environmental Test Request No. T-10767"), was a joint effort by Sandia Corporation, the AEC, and the U. S. Army Transportation Engineering Agency (USATEA). The following persons were involved directly in the planning (1) and/or performance (2) phases of this experiment:

Robert Kennedy (1) USATEA, Ft. Eustis, Va.
W. V. Johnson (1) USATEA, Ft. Eustis, Va.
B. Prothro (1) USATEA, Ft. Eustis, Va.
M. E. Bryan (1) (2) USATEA, Ft. Eustis, Va.
Capt. Emick (1) (2) USATEA, Ft. Eustis, Va.
Capt. Ingmaw (1) USATEA, Ft. Eustis, Va.
D. C. Costello (1) AEC HQS., Washington, D. C.
L. F. Pursifull (1) AEC HQS., Washington, D. C.
Paul E. Warren (1) (2) AEC Facility, Oak Ridge, Tenn.
J. A. Johnson (1) Consultant to USATEA, Short Hills, New Jersey
Otto Schmidt (1) Knapp-Mills Corporation, Wilmington, Delaware
J. T. Foley (1) Sandia Corporation
R. P. May (1) Sandia Corporation
J. L. Mortley (1) (2) Sandia Corporation

Preparations

An able discussion of the first four days of this test is given in the Trip Report from Mr. J. T. Foley, 1541, to Mr. S. A. Moore, 1540, dated January 6, 1965 (Enclosure 2). Instrumenting of the unloaded truck was finished at Ft. Eustis, Virginia, on the afternoon of December 10, 1964, and the actual recording of data was begun that afternoon at 7:00 p.m. Recordings were made on Reel No. 0 from Ft. Eustis to the Knapp-Mills plant in Wilmington, Delaware, to (1) check out the instrumentation system, (2) develop an orderly procedure for entering the voice data, (3) record the characteristics of the unloaded truck, and (4) to evaluate the transfer characteristics of the USATEA Isolation Mount on which the Sandia tape recording system was mounted at USATEA's request.

The White Company semitractor and trailer used for this test is shown in the photograph designated Enclosure 3; Enclosure 4 shows the loaded and instrumented truck. The complete route taken by the truck is traced on the map labeled Enclosure 5: in the dotted portion the truck was unloaded, without instruments; in the X-ed portion, it was unloaded, with instrumentation; and in the portion indicated by triangles, it was loaded, with instrumentation. The small circles shown on the traced route indicate where night stopovers were made. A "follow-on" car was provided by USATEA and was used over the portions of the trip indicated by X's and triangles to transport clothes, additional instrument accessories, photographer, and relief personnel.

Instrumentation System

The complete instrumentation system is shown in the block diagram of Enclosure 6 (Figure 6-1). The blocks depict the transducer and signal-conditioning amplifier model numbers, their respective tape recorder channels and the recorder, the remote control unit, and the Ft. Eustis USATEA instrumentation relationship to that of Sandia Corporation. Also included in Enclosure 6 is a magnetic tape record directory (Figure 6-2) which when used in conjunction with the block diagram and the transducer location diagram (Figure 6-3), describes the physical and electrical location of all instruments. Probably the most spectacular instrument used in this test was the Ampex Model CP-100 14-channel FM magnetic tape recorder, upon whose reliability success or failure of these tests rested; all 14 channels functioned within specifications through continuous operation for 7 days on the back of the semitrailer, over the fifth wheel, under extreme transportation and climatic environmental conditions.

The photographs in Enclosure 7 show the location of the instrumentation elements as they actually appeared on the test vehicle. The respective photographs have descriptive captions which, when used with the figures in Enclosure 6, completely describe the instrumentation shown therein.

Data Recording

The continuous recording of data from Ft. Eustis to Albuquerque, with the exception of short stretches between Ft. Eustis and Wilmington and about 15 minutes in Texas, yielded 13 rolls of recorded magnetic tape covering about 55 hours of actual moving-truck transportation environment. A data sheet log was kept for each roll of magnetic tape data; these data sheets contain information relating a specific reel number to: (1) physical coverage, (2) comments on road conditions and external environments, (3) items of interest, (4) notes regarding instrumentation performance and environment, and (5) the data and time span covered on the specific reel. All recordings were made at 1-7/8 ips. Copies of the original data sheets are shown in Enclosure 8 (Figures 8-1 through 8-13 inclusive).

main data sheets were kept by the USATEA representatives on this test. As will be noted in Figure 6-1, two channels of recorded data were played back simultaneously on to the Ft. Eustis oscillograph. These data, except for a time delay from the record head to the reproduce head of the tape recorder, were theoretically the same as the Ft. Eustis Statham input; the three transducers were within about 3 inches of each other, one being an identical transducer to the Ft. Eustis independent monitor and the other a crystal-type Endevco Model 2235C. The record numbers appearing on the Ft. Eustis log sheets were entered verbally on the magnetic-tape voice channel for future cross reference and analysis. It should be noted at this point that cross comparisons of the oscillograph-recorded Ft. Eustis transducer signal and the two separately generated Sandia transducer signals, correcting for magnetic tape recorder time delays, correlated in both shape and amplitude as closely as could be measured manually.

After arrival at Sandia, the loaded truck was taken to Technical Area 3 for controlled, induced vibration tests; these tests should ultimately yield the mechanical-impedance functions of the loaded truck. The tests were conducted by removing a storage box from the rear of the truck bed, an insignificant load of about 300 pounds, and then lowering a vibration-machine driver with a crane so that it could be physically attached to the truck bed. Photographs showing test setup appear in Appendix D.

Data Analysis

A first attempt at analyzing the recorded data was made on tape Reel No. 0. These data are the result of Mr. J. T. Foley's attempts to arrive at a consolidated and optimized approach at complete data analysis so that a maximum return of useful data is realized at a minimum man-hour expenditure, complete results of the tests will be forthcoming later from Mr. Foley. The rather tedious and time-consuming job of transcribing the voice log channel is in progress and should be of great help in the final data reduction.

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Enclosure 1

ENVIRONMENTAL TEST REQUEST

TO (LAST FIRST INITIAL) Patrick, J. D.		ORG 7334-1	CLASSIFICATION OF COMPLETED FORM Uncl.	
REQUESTER (LAST FIRST INITIAL) Foley, J. T.		ORG 1541	BLDG 836	PHONE 7112
TEST ITEM NAME Truck and RAM Cask		DATE 12/2/64		
DESCRIPTION OF TEST ITEM		NUMBER (XW TX MC SA PART NUMBER ETC)		
NUMBER OF UNITS One Each		SERIAL NUMBERS		
RESPONSIBLE DESIGN DIVISION		SOURCE (SUPPLIER TRADE NAME PURCHASE ORDER ETC)		
TEST PURPOSE				
- DEVELOPMENT INVESTIGATION		☐ QUALIFICATION TEST		
- COMMERCIAL ITEM EVALUATION		☐ QA SAMPLE		
- MDE INFORMATION		☐ LOT ACCEPTANCE		
		☒ OTHER (SPECIFY) Data Bank Information		
DATE ITEMS AVAILABLE 12/7/64		REQUIRED COMPLETION DATE 12/16/64		
SECURITY CLASSIFICATIONS	NAME Uncl.	MATERIAL Uncl.	VISUAL Uncl.	
HAZARDS - DOES TEST ITEM CONTAIN SS MATERIAL HE OR OTHER POSSIBLE HAZARDS?				
☒ YES ☐ NO IF YES EXPLAIN				

DESCRIBE OBJECT OF TEST
The test objective is to provide support for the measurement of a transportation environment. A truck will transport a 15-ton radioactive material cask from Wilmington, Delaware to Albuquerque and enroute measurements of tie-down loads, vibration, shock, and temperature will be made.

PROPOSED TEST (REF PS TR OR DOCUMENT -- NUMBER ISSUE AND PARAGRAPH)

Assistance is required to instrument and record the above measurements. 7334 should furnish the instrumentation and recording equipment and personnel at Ft. Eustace, Wilmington, and enroute to Albuquerque. Instrumentation will consist of load cells or strain gages in each of the four cask tie-downs and accelerometers on the corners of the cask mounting plate and at various locations on the truck flat-bed per instructions of the consultant. An accelerometer in the vertical direction is to be placed 24 inches in front and another 24 inches in back of the cask. This distance is necessary to allow a shaker to vibrate the truck with the cask mounted so that impedance data can be compared with enroute vibration data. The impedance measurements will be made by 7324 on T-10768.

A report is requested which should include all instrumentation details and both tie-down load data and vibration/shock data.

FOR 7300 USE ONLY

TEST NO T- 10767	FILE NO S-16	DATE ITEMS RECEIVED
APPROVED BY R. P. May	APPROVED BY E. White	BILLABLE PROJECT

SC 7370-AA (9 64)

Enclosure 1

Enclosure 2

January 6, 1965

Mr. S. A. Moore - 1540

Re Trip Report - Travel to Fort Eustis, Va. to Coordinate a
Joint Army/AEC/Sandia Test of Truck Transport Environment,
7-10 December 1964

Persons contacted at Ft. Eustis:

Robert Kennedy	U. S. Army Transportation Eng. Agency, Ft. Eustis
W. V. Johnson	" " " " " "
B. Prothro	" " " " " "
Capt. Emick	" " " " " "
Capt. Ingmaw	" " " " " "
David C. Costello	AEC HQS, Washington, D. C.
L F Pursifull	" " " "
Paul E. Warren	AEC Facility, Oak Ridge, Tennessee

I arrived at Fort Eustis the evening of 7 December accompanied by J. Mortley, 7334-1. We met Mr. Costello at the motel and discussed the purpose of the test and how we planned to instrument the truck to obtain the most useful data. We learned from Mr. Costello that the tape recorder and associated equipment for the test, which had left Sandia the previous week, had not arrived.

The following day we proceeded to Fort Eustis and met the above listed people, further discussed the test plan, determined where pickups were to be located, and spent the remainder of the day trying to find where our instruments were. They were finally located at Washington, D. C. National Airport.

After a number of phone calls and arrangements, we managed to get the instruments shipped to Newport News, Va. via truck during the evening of the 8th. We picked up the instrument crates at Newport News with a truck furnished by Mr. Kennedy's group on the 9th. We noted that the instrument crates had been shipped on end from Washington, in contradiction to all labels on the crates.

Upon opening the crates at Fort Eustis on 9 December, it was obvious that the instruments had been given a rough ride as a number of plug-in components from the tape recorder's circuit boards were scattered throughout the case, and a condenser which was originally welded to the recorder frame had been knocked loose.

When all loose parts were plugged back into the recorder however, it checked out fine. I photographed the broken and disarrayed equipment at J. Mortley's request. He has these pictures for reference in his trip report.

Since the truck was scheduled to leave Ft. Eustis on the 10th of December, J. Mortley and I spent the evening of the 9th installing pickups and calibrating the instrument system.

The morning of the 10th was spent in making final installation of test equipment on the truck. J. Mortley is accompanying the truck from Fort Eustis to Albuquerque, and the remainder of this venture is to be covered in his trip report after the truck arrives here on or about 17 December.

Miscellaneous: During the time we were trying to find our instruments, I was able to discuss transportation environmental criteria with Mr. Kennedy in some detail. He furnished me with his organization's latest efforts in this field (these are attached) and in return, I furnished him our latest analyses on this subject from the data bank.

We were in general agreement concerning the relative paucity of transport environmental data, but appear to differ in our description of vibration environment in that the Army's criteria appears to envelope some measured accelerations which we consider to be shocks. This is particularly evident in our estimates of truck transport environment.

J. T. Foley - 1541-1

Approved: _____
R. T. Othmer - 1541

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Enclosure 3

Semitractor and trailer used for test

Enclosure 4

Loaded and instrumented truck

Enclosure 5

Enclosure 6

Figure 6-1. Block diagram of transportation test instrumentation

T R Channel Number	Order of Priority	Transducer Input						Sensitive Axis	Amplifier Reference No	Location
		Mfgr	Type	Model	Serial No	Sensitivity	Calibrate			
1	7	1	A	2235C	FA-68	27 71 p-q/p-g	180 p-q _{p-p}	Vertical	4	Cask trunnion, driver's side (E)
2		-	-	-	-	-	-	-	-	Voice logging channel
3	5	1	A	2235C	FA-83	29.46 p-q/p-g	180 p-q _{p-p}	Vertical	5	Cask trunnion, right side (C)
4	9	2	B	A5A-12-120	1258	16 8 puv/v/g	+3 43 g	Longitudinal	B-1	Truck bed over rear axle (M)
5	8	2	B	A5A-12-120	1658	22 5 puv/v/g	+2.88 g	Vertical	B-3	Inside T.R.box at right rear mounting bolt (S)
6	1	1	A	2235C	FA-24	29 73 p-q/p-g	180 p-q _{p-p}	Longitudinal	6	Truck bed over 5th wheel (H)
7	3	1	A	2235C	FA-21	27 03 p-q/p-g	180 p-q _{p-p}	Vertical	7	Truck bed cross-member 2 feet forward of cask (R)
8	5	1	A	2235C	FA-62	28.88 p-q/p-g	180 p-q _{p-p}	Longitudinal	8	Cask trunnion, left (driver's) side (D)
9	4	1	A	2235C	FA-18	29 29 p-q/p-g	180 p-q _{p-p}	Vertical	3	Truck bed cross-member 2 feet aft of cask (P)
10	7	1	A	2235C	FB-28	29 49 p-q/p-g	180 p-q _{p-p}	Longitudinal	10	Cask trunnion, right side (B)
11	1	1	A	2235C	EA-52	27 88 p-q/p-g	180 p-q _{p-p}	Vertical	2	Truck bed over 5th wheel (J)
12	6	2	B	A73TC-4-350	178	118.7 puv/v/g	+0 918 g	Transverse	B-3	Top geometrical center of the cask (A)
13	2	2	B	A46C-15-350	624	Unknown	+2 97 g	Vertical	B-2	Truck bed over 5th wheel, transducer supplied by Ft Eustis (L)
14		-	-	-	-	-	-	-	-	Shorted reference channel

- 1 = Endevco Corporation
Pasadena, Calif.

2 = Statham Instruments, Inc
Los Angeles 64, Calif

* - A = Barium Titanate Crystal
B = Strain Gage

- - - - - Removed at Wilmington, Delaware due to excessive noise and crosstalk to other strain gage transducer systems, probably due to excessive input cable length.

* - Used to monitor the Ft Eustis shock isolation mount from Ft Eustis, Virginia to Wilmington, Delaware, removed at Knapp-Mills Corporation, channel held in reserve for balance of trip

- See Figure 3 for exact transducer locations by letter.

Figure 6-2

Figure 6-3. Transducer location diagram

Enclosure 7

Figure 7-1. Tape recorder remote control unit used in tractor cab

Figure 7-2. Tractor-to-trailer remote control wiring

Figure 7-3. Tape recorder and signal conditioning amplifiers as used in transit with heat lamps and lock downs, Position S

Figure 7-4. USATEA oscillograph remote control unit in tractor cab

Figure 7-5. Instrumentation cable inputs to tape recorder,
and USATEA isolation mount

Figure 7-6. Accelerometer Locations K and H

Figure 7-7. Accelerometer Locations H, J, and L

Figure 7-8. Accelerometer Locations D and E

Figure 7-9. Accelerometer Location R

Figure 7-10. Accelerometer Location A

Figure 7-11. Accelerometer Location N, on ground, after intentional removal

Figure 7-12. Accelerometer Location M

Enclosure 8

December 10, 1964

DATA

Tape Reel No. 0

Coverage: Ft. Eustis to KNAPP-MILLS in Wilmington, Delaware.

Comments: Very good data on unloaded truck (without 15T cask). Taken mostly on 4-lane divided black top roads in rain.

Last one hour of data was taken in Wilmington and should be good rough street data.

Did not record continuously.

Interest: One channel was devoted to monitoring inside the tape recorder case on the shock mount (see channel number record); Ft. Eustis is very interested in this. Several large drawbridges were crossed.

Instrumentation: Doing fine, approximately 50°F internal temperature.

Time: Approximately 7:00 PM, December 10, 1964 to 11:00 AM, December 11, 1964.

Figure 8-1.

December 12, 1964

DATA

Tape Reel No. 1

Coverage: KNAPP-MILLS, Wilmington, Delaware to Harrisburg, Pennsylvania.

Comments: First 1 to 1-1/2 hours should be good data on old Eastern city travel and narrow highway suburb type driving.

Rest of this reel is on Pennsylvania T.P.* driving consisting of older, sometimes rough divided 4-lane concrete highway.

Interest: First one hour when leaving KNAPP-MILLS, and in Wilmington and its suburbs.

Instrumentation: No change in calibration made at Ft. Eustis. Looks good after first 270 miles of unloaded truck travel.

Time: Approximately 11:00 AM to 7:00 PM.

Eustis Nos.: 2916- ?

*"Pennsylvania T.P." will be the abbreviation for "Pennsylvania Turn Pike."

Figure 8-2.

December 12, 1964

DATA

Tape Reel No. 2

Coverage: Harrisburg, Pennsylvania to Belle Vernon, Pennsylvania (21 miles east of Washington, Pennsylvania).

Comments: This reel was recorded almost wholly on the Pennsylvania T.P. (30-45 minutes on 4-lane divided Interstate). The weather was extremely foggy with considerable rain. Temperature was 30°F to 45°F external. The highway was almost totally a divided 4-lane road of either blacktop or concrete construction and quite rough in places.

Interest: Of particular interest will be the HIGH ACOUSTIC environment, and vibration monitored in some six TUNNELS in damp foggy weather.

Instrumentation: Performing great with good correlation on the Ft. Eustis oscillograph. Internal temperature was about 60 to 70°F. Covered wooden case with plastic for insulation and water repelling. Noise on microphone channel.

Time: 7:00 PM to 12 midnight.

Eustis Nos.: ? to 2960.

Figure 8-3.

December 13, 1964

DATA

Tape Reel No. 3

Coverage Belle Vernon, Pennsylvania to Jacksontown, Ohio (approximately 20 miles east of Columbus, Ohio).

Comments The weather started out balmy and clear but quite damp. It later turned to snow. We hit several minor detours and large sections of old blacktop.

Balmy morning about 50°F, dropped all during the recording period to 45°F.

Interest Particularly good section about the middle of the tape on narrow, mountain, rough, blacktop roads in West Virginia and through Wheeling, West Virginia.

Instrumentation T. R. calibrated perfectly, had internal temperature in the morning of about 65°F. Had to resolder a loose battery connection on the microphone circuit, this would explain the excessive noise noted earlier.

Time Approximately 11 00 AM to 5:00 PM.

Plustis Nos. 2963 to 3010

"T R" is the abbreviation for "Tape Recorder."

Figure 8-4

December 13, 1964

DATA

Tape Reel No. 4

Coverage: Jacksontown, Ohio to Richmond, Indiana.

Comments: The weather was cold, damp, and there had been snow flurries just ahead of us for the first two hours. The roads traveled were old, rough, and were city and suburb driving during this two hour period. This is a typical large, old Eastern town with terrible driving conditions. Temperature was 35 to 45°F and dropped to 25°F at night.

The second two hours on this tape are of fairly open country driving on two and four-lane divided blacktop highways. The weather turned clear and colder; our external thermometer read 25°F at 11:30 PM.

Interest: Some of the best Eastern city data on the first two hours.

Instrumentation: Performing fine, internal temperature dropped to about 50°F at 11:30 PM. Still using plastic for insulation and water repelling.

Time: Approximately 6:00 PM to 11:30 PM.

Flustis Nos.: 3013 to 3051

Figure 8-5.

December 11, 1964

DATA

Tape Reel No. 5

Coverage: Richmond, Indiana to Terre Haute, Indiana.

Comments: Most of the recording was done on smooth to slightly rough 4-lane blacktop road.

Last 45 minutes to one hour was recorded in and through the Terre Haute, Indiana suburbs.

The middle section was recorded on the Indianapolis truck bypass (4 lane good road), some was recorded in the town.

Tape recorder is holding around 65°F with external temperatures down to 30°F at reel change. I have blocked all adjustable external vents, placed a 50 watt bulb inside, and am still using the polyethelene cover for insulation and wind break.

Notes: Good records throughout of bumps.

Instrumentation: All VCO's and Discriminators check perfectly; all transducers look good. Internal temperature of T.R. dropped to about 40°F last night with no apparent bad effects; external temperature this morning was 25°F at 7:30 AM. Eustis blew a fuse on their CEC amplifiers. They could have lost data on reel No. 4.

Time: Approximately 11:00 AM to 5:00 PM.

Eustis Nos.: 3052 to 3092.

Figure 8-6.

December 14, 1964

DATA

Tape Reel No. 6

Coverage: Terre Haute, Indiana to St. Louis, Missouri.

Comments: Left gas station outside of Terre Haute, Indiana on 4-lane blacktop which immediately changed to 2-lane.

Majority of travel was on 4-lane highway in fair to excellent condition. Weather was clear, dry, and cold all the way.

Interest: The last one hour of recording was made in St. Louis and the immediate suburbs; scattered throughout the record are some good high level recordings of railroad crossings and bumps.

Instrumentation: Checked out very good and seemed to calibrate properly. Temperature started out at about 60°F internal and 30°F external at the end of roll 5. At St. Louis the weather had dropped to 28°F external and was 55°F internal; the T.R. apparently never recovered in temperature from being opened for tape changing. Temperature 22°F at 8:00 AM the morning of December 15, 1964.

Time: 5:00 PM to 11:00 PM.

Eustis Nos.: 3095 to 3140

Figure 8-7.

December 15, 1964

DATA

Tape Reel No. 7

Coverage: St. Louis, Missouri to Springfield, Missouri (-25 miles).

Comments: All recordings made on this reel were taken on dry highway, mostly 4-lane, in clear cold weather.

There should be good records throughout of bumps and "raised concrete slabs" highway traveled at relatively high truck speeds (50 to 65 mph).

Due to extreme weather conditions and the availability of only outdoor working facilities, some of the normal morning checkout procedure was dropped (see notes under "Instrumentation" below).

Interest: Of particular interest will be some 45 minutes of recordings made, starting 40 minutes after calibrate, of a very rough section of old 66 on our 1/2 of a divided 4-lane road; the first 1/3 of the 45 minutes was very rough at about 60 mph.

Instrumentation: Changed tape in 22°F weather this morning. Will not calibrate the T.R. VCO's and discriminators this morning with the TC-10; history so far indicates that they are all right (have not had to adjust them once), and I am afraid the 22°F weather will cause more error in the TC-10 than is in the T.R. Also, I do not want to keep the TR open too long.

Time: 11:00 AM to 4:00 PM.

Eustis Nos.: 3133 to 3175

Figure 8-8.

December 15, 1964

DATA

Tape Reel No. 8

Coverage: Springfield, Missouri (-25 miles) to Tulsa, Oklahoma.

Comments: Nearly all freeway and turnpike driving except for small stretches through Joplin, Missouri and about 50 miles leading into it.

Interest: There are a few good recordings of bumps and "raised slab" concrete freeway at 50 to 65 mph.

Instrumentation: Seemed to calibrate right and ran well; weather warmed as we moved southwest. Internal temperature ranged from approximately 60 to 70°F without plastic covering.

Time: 4:00 PM to 11:45 PM.

Eustis Nos.: 3176 to 3215

Figure 8-9.

October 16, 1964

DATA

Tape Reel No. 9

Coverage: Tulsa, Oklahoma to Clinton, Oklahoma (+5 miles).

Comments: Almost 100% of this reel was recorded on 4-lane divided smooth highway by Mr. Max E. Bryan, Ft. Eustis.

There will be a few scattered bumps throughout and some short stretches of rough highway.

The external temperature started about 30 to 35°F and rose to a maximum of about 45°F external, and then dropped to approximately 20°F by the end of the reel. The internal temperature never got below 56°F under the top lid.

Interest: Ran out of tape about 5 miles out of town and due to weather had to go on in. Experienced cross winds of an estimated 20 to 30 mph through the last half of reel.

Instrumentation: Completely checked out T.R. VCO's and discriminators in use and found them all well in tolerance since checkout originally made at Ft. Eustis and all other night stops except St. Louis. All signal conditioning was checked and does not seem to have changed since Albuquerque.

Time: 9:45 AM to 5:30 PM.

Eustis Nos.: 3218 to 3239.

Figure 8-10.

December 16, 1964

DATA

Tape Reel No. 10

Coverage: Clinton, Oklahoma to Amarillo, Texas.

Comments: These records were taken on some rough highways, mostly 4-lane, under strong cross winds and low temperatures.

Cross winds seemed to range over 30 mph out of the north.

Temperature was about 20°F at start and +8°F when we stopped for the night; about 20 minutes recording time was left on the reel.

Interest: Some of the roughest concrete slab pavement encountered in this trip occurs about 1 hour after the start of this reel and lasts for approximately one hour and 20 minutes (appeared to be shock at 1 to 5 cps); other good bump data throughout tape.

Instrumentation: Checked out and calibrated well at tape change. Internal temperature immediately under top cover was near 50°F when we shut down for the night. Predicted low for December 17, 1964 morning is 5 to 10°F.

Time: 6:00 PM to 11:00 PM.

Eustis Nos.: 3341 to 3360.

Figure 8-11.

December 17, 1964

DATA

Tape Reel No. 11

Coverage: Amarillo, Texas to Santa Rosa, New Mexico.

Comments: Weather was partly cloudy, temperature outside the T.R. was -3°F at 8:00 AM and rose to -2°F at 8:30 AM. Predict a maximum for Amarillo, Texas of $+13^{\circ}\text{F}$ with snow flurries.

The temperature did not exceed 22°F throughout this reel. The internal temperature was at about 65°F when changed; this was accomplished with weather stripping seals, tape, and a 75W and 100W lamp. Purchased a new drop cord at an auto parts store for the second lamp.

Interest: External temperature ranged from -3°F to a maximum of $+22^{\circ}\text{F}$ at end of reel.

Instrumentation: I am not going to check the VCO's and discriminators today due to the adverse temperature effects on the calibrator and T.R. Internal temperature ranged from $+20^{\circ}\text{F}$ to $+65^{\circ}\text{F}$. Charge calibrator apparently developed short and burned one wire; Eustis Oscillograph indicated excessive noise, cause unknown.

Time: 12:30 AM to 5:30 PM.

Eustis Nos. 3264 to 3283.

Figure 8-12.

December 17, 1964

DATA

Tape Reel No. 12

Coverage: Santa Rosa, New Mexico to Albuquerque, New Mexico.

Comments: Left Santa Rosa on good roads, dry and cold. External temperature in Santa Rosa was $+22^{\circ}\text{F}$.

Smooth to slightly rough 4-lane highway most of the record. A few bumps were recorded.

Interest: External temperature conditions.

Instrumentation: Replaced modules in Charge Calibrators and did not develop any more smoke; however, Ft. Eustis oscillograph still indicated excessive noise in the system (could be in CEC Amplifier). Internal temperature about $+68^{\circ}\text{F}$.

Time: 5:30 PM to 9:00 PM.

Eustis Nos.: 3284 to 3300.

Figure 8-13.

APPENDIX B
OCCURRENCE OF ROAD TYPES AND VEHICLE SPEEDS

TABLE OF CONTENTS

	<u>Page</u>
Road Conditions	67
Road Speeds	68
Figures B1 through B3	70

Road Conditions

Sixteen road conditions were recognized by the observers accompanying the shipment. These conditions, in the decreasing order of their frequency of occurrence were:

1. Level concrete
2. Level blacktop
3. Bridge crossings
4. Railroad crossings
5. Hills, blacktop
6. Bumps
7. Blacktop over concrete
8. Tunnels
9. Parking lots
10. Asphalt turnpike
11. Overpasses
12. Concrete turnpike
13. Concrete hills
14. Detours, paved
15. Unpaved roads
16. Brick roads

Their frequencies of occurrence in increasing order were:

	<u>Frequency of Occurrence</u>
1. Unobserved (estimated) (includes accidents)	0.006
2. Brick and unpaved roads (tie)	0.006
3. Concrete hills and detours (tie)	0.012
4. Concrete overpasses and turnpikes (tie)	0.018
5. Parking lots and asphalt turnpikes (tie)	0.024

	<u>Frequency of Occurrence</u>
6 Tunnels, bumps, and blacktop over concrete (tie)	0 036
7 Blacktop hills	0 070
8 Railroad crossings	0 126
9 Bridge crossings	0 162
10 Level concrete and level blacktop (tie)	0 215

Figure B1 presents these frequencies of occurrence in graphical form

The cumulative frequencies of occurrence, in percent, in decreasing order were

1 Level concrete and blacktop	43
2 Bridge crossing	59 2
3 Railroad crossing	71 8
4 Blacktop hills	78 8
5 Tunnels, bumps, and blacktop over concrete	86 0
6 Parking lots and asphalt turnpike	90 8
7 Concrete turnpikes and overpasses	94 4
8 Concrete hills and detours	96 8
9 Brick and unpaved roads	98 0
10 Unobserved	100

Road Speeds

During the 16 road conditions encountered, the road speeds observed were

<u>Condition</u>	<u>Speed Range, Mph</u>
1 Level concrete	30 - 65
2 Level blacktop	10 - 65
3 Bridge crossings	5 - 60
4 Railroad crossings	5 - 50
5 Blacktop hills	5 - 10 uphill 35 - 58 downhill

<u>Condition</u>	<u>Speed Range, Mph</u>
6. Bumps	20 - 50
7. Blacktop over concrete	20 - 50
8. Tunnels	? - 50
9. Parking lots	10 - 25
10. Asphalt turnpike	55 - 60
11. Overpasses	? - 30
12. Concrete turnpike	50 - 65
13. Concrete hills	20 (uphill) 40 (downhill)
14. Detours (paved)	5 - 15
15. Unpaved roads	30
16. Brick roads	15 - 20

Figure B-2 plots the frequencies of occurrence of road speeds encountered within these speed ranges.

Figure B1

Speed Frequency Analysis

Figure B2

Figure B3

APPENDIX C
TEST RESULTS AND ANALYSES

TABLE OF CONTENTS

	<u>Page</u>
SECTION I -- Preliminary Analysis of Data	75
Oscillograph Records	76
Acceleration Spectral Density Versus Frequency Plots	76
Figures C-A through Figure C-E	77
Cumulative Instantaneous Amplitude Distribution Plots	83
Figure C-G	84
Peak Amplitude Probability Distribution Versus Frequency	85
Figures C-H through Figure C-J	86
SECTION II -- Construction of a Composite Description of Environment	89
Summary of Preliminary Analysis	90
SECTION III -- Reduced Data	91
Figures C-1 through Figure C-27	91

APPENDIX C

SECTION I

Preliminary Analysis of Data

Data obtained by Sandia in this joint test is ultimately deposited in the Sandia Corporation Environmental Data Bank. Designers, dynamicists, laboratory test engineers, and others, use such data to determine what to design against, and what to test to, with respect to the expected environment. The Environmental Operations Analysis group which maintains the data bank will use all test results in the bank to determine standard transportation environmental test levels for Sandia Corporation products.

The results of a user survey, about four years ago, of environmental data requirements within Sandia Corporation indicated that, ideally, environmental data should meet the following criteria:

- 1 Data should be statistical
- 2 Data should be graphical
- 3 Data should present those parameters that can be measured in the test laboratory as well as in the field
- 4 Data should lend themselves to various means of "combination" by numerical or graphical means or both

The following four methods of reducing and presenting dynamic data were evaluated to determine the best one to meet the requirements:

- 1 Oscillograph records
- 2 Acceleration spectral density versus frequency plots
- 3 Cumulative instantaneous amplitude distribution plots
- 4 Peak amplitude distribution versus frequency plots.

The data used here to illustrate the evaluations made in the preliminary analyses were taken from the truck test, under the following conditions:

- 1 Concrete highway (HIGH speed) (unloaded)
- 2 Blacktop highway (LOW speed) (unloaded)
- 3 Concrete highway (LOW speed) (loaded)
- 4 Blacktop highway (HIGH speed) (loaded)

The pickup location illustrated in this section is in all cases the vertical "input to load" measured on the truck bed to the rear of the cask location.

Oscillograph Records

Figure C-A shows representative traces obtained from the input location near the load. These representations are graphical and present parameters (amplitudes and times) which can be measured in the laboratory as well as in the field. They are not, however, statistical, nor do they lend themselves to combination by numerical or graphical means. By choosing a faster playback rate (expanding the record), some estimates of frequency could be made and amplitude could be measured, but this method would be not only time-consuming and tedious, but also would be subject to human error.

An alternative method of data presentation by oscillograph trace was also considered. This method consists of playing back the data through fixed band-pass filters, which "separates" the amplitudes encountered into regions or bands of frequency. This was considered an improvement over the use of simple amplitude/time presentations, but still would require a considerable amount of hand-reduction and interpretation with respect to the amplitude magnitudes encountered. This presentation is illustrated in Figure C-B.

It was considered, therefore, that as a "quick-look" method of reduction/presentation the oscillograph traces and band pass analyses were useful tools, but would not be an adequate means of final presentation. Any tabulations of amplitude values as hand-read from such records would not be accurate enough or provide a sufficient description of the environment.

Acceleration Spectral Density Versus Frequency Plots

Data samples were then reduced and presented in Acceleration Spectral Density (ASD) form (Figures C-C through C-F). Since the data in the test were obtained continuously, it was possible to use a tape loop for ASD analysis that was of long duration. The filter bandwidth selected for good amplitude resolution was 5 cps, the minimum recorded time length for using this bandwidth to approach stationarity was estimated to be 20 seconds. The time length of record used initially for loop analysis was approximately 300 seconds.

A problem in the use of an ASD presentation format immediately became apparent. The root-mean-square (rms) signal from the record of Condition A varied so that it was impossible to obtain an ASD plot over the 300-second time length. It was necessary to use one-third of this tape loop length (100 seconds) in order to obtain an ASD-versus-frequency plot. It appeared that we would be involved in analysis of a nonstationary process during some road/load conditions.

Subsequent comparisons of ASD plots obtained under varying truck speed, road, and load conditions indicated not only that amplitude magnitudes changed, but that the shape of the power spectrum changed with respect to truck speed, load, and road condition. Although the ASD format

CONDITION A
UNLOADED TRUCK TRAVEL ON CONCRETE
HIGHWAY AT HIGH SPEED

CONDITION B
UNLOADED TRUCK TRAVEL ON BLACKTOP
HIGHWAY AT LOW SPEED

Figure C-A. Examples of oscillograph traces

- NOTES: 1. FIRST LISTING OF FILTER BANDWIDTH IS REAL TIME PLAYBACK
 2. BRACKETED VALUE IS "EFFECTIVE" BANDWIDTH @ 8 x REAL TIME PLAYBACK
 3. THIS RECORD IS A PLAYBACK @ 8 x REAL TIME OF TRUCK TRAVEL OVER A ROUGH CONCRETE HIGHWAY @ 50 MPH

Figure C-B. Bandpass oscillograph playback

Figure C-C. Vibration test of tractor/trailer, unloaded

Figure C-D. Vibration test of tractor/trailer, unloaded

Figure C-E. Vibration test of tractor/trailer, loaded

Figure C-F. Vibration test of tractor/trailer, loaded

Good graphical data description and the parameters could be reproduced in the test laboratory. A disadvantage was that, statistically, any one of the ASD analyses might not characterize a reasonable picture of the environment.

An alternative considered was to make up a composite tape of samples from many sections of the continuous recording, from which an ensemble of records could be analyzed. It would then be possible to obtain a composite ASD versus frequency plot containing representative road types, speeds, and/or variation in load which would provide a statistically appropriate composite summary description of the environment. The major disadvantage of this approach was that the contribution of individual characteristics, such as concrete road versus blacktop, would be lost. If at a later date it was desired to exclude some conditions encountered and then derive a new composite, there would be no way this could be done from the data as presented. The original data tapes would have to be obtained and reprocessed to arrive at a new result. The ASD format, although offering many advantages, was therefore felt to be unsatisfactory for alternative analyses. Further, because of the nonstationary conditions encountered, it was felt that ASD presentations of some individual conditions could be misleading.

Cumulative Instantaneous Amplitude Distribution Plots

Figure C-G illustrates the third means of analysis and presentation investigated. This system presents the data on the ordinate in terms of its time-cumulative instantaneous amplitude density in a selected bandwidth. Figure C-G presents "A" conditions using a 5-cps bandwidth. The abscissa is the variation of the signal from a normalized reference rms (σ/σ) value. The solid line superimposed on this plot is the result of a Gaussian random (white noise) signal input to this reduction. It is used to illustrate the deviation of the measured data from the theoretical statistical normal distribution.

This system of analysis/presentation approaches the criteria for "good" presentation, because it is both statistical and graphical, but it offers difficulties in that the parameters are not normally those controlled in the laboratory or measured in the field. Further, the combination of individual increments of data from the truck test would pose problems similar to those which would be encountered in obtaining a composite ASD plot, that is, one would have to obtain the original tape records to perform additional analyses. This data presentation, however, gives further information concerning the nature of the amplitude distribution. From these data plots, non-Gaussian distributed phenomena were deduced. From the data characteristics exhibited, it was determined that the environment over most roads consisted of a low-level complex vibration upon which were superimposed a great number of repetitive shock pulses.

Figure C-G. Vibration test of tractor/trailer, unloaded

Peak Amplitude Probability Distribution Versus Frequency

A fourth system of data presentation, peak amplitude probability distribution versus frequency, was then employed. Figures C-H through C-J show the presentation format. This system is an automated extension of the fixed bandpass filter oscillograph record system illustrated in Figure C-B. The data are presented as the number and magnitude of the acceleration peaks encountered in each bandpass. In essence, then, the data are a probability distribution of acceleration peaks, the total number of peaks encountered, and the number of peaks encountered in each bandpass so measured.

This analysis/presentation system best satisfied the requirements because it was statistical in nature, yet graphical in format; the parameters measured (g versus frequency) could be measured in the test laboratory as well as in the field; and the format of the data would lend itself to a number of means of comparison by numerical or graphical methods.

As shown in the illustrated formats of Figures C-H, C-I, and C-J, however, the bandwidth is rather wide for the purpose of describing the environment encountered in truck transportation. Our previous evaluations, as well as this data presentation, indicate that one area of great interest lies primarily in the 0 to 20 cps band. Further, it would be desirable to measure at least one more amplitude increment between 0 and 1 g.

Two procedures were developed to improve this format. The first was to obtain peak counts below the 1.0 g level. The second was to drive the data tape into the fixed filter system at a multiple of real time to produce a narrow band analysis. This resulted, then, in obtaining the final formats in the form, as illustrated in Section C-III, Figures C-1 through C-23.

Vibration, File(1), Count(141120)
(Acceleration Distribution in Percent)

Acceleration, 0-PK G

Truck Vibration
Trk 9
Sample duration: 80 seconds
Truck bed cross member
2 feet to rear of cask, blacktop
highway, low speed, unloaded

3 7	100 00	0 94	50 00	0.03				0.01		0.01	0.04
2 7			29 17	0.15	0.07	0.03	0.01	0.01	0.02	0.01	0.00
1 9		0.09	8.33	0.18	0.11	0.03	0.08	0.03	0.00	0.01	0.01
1.4		0.09	4.17	0.05	0.16	0 10	0.06	0.06	0.04	0.04	0.02
1 0		98.88	8 33	99.59	99.66	99.85	99.84	99.90	99.94	99.93	99.93

Frequency(cps)

0-	5-	10-	20-	30-	45-	60-	87.5-	125-	175-	250-
5	10	20	30	45	60	87.5	125	175	250	350

Samples Per Channel

2	1068	24	3910	4420	7277	10840	15891	21998	30320	44857
---	------	----	------	------	------	-------	-------	-------	-------	-------

NOTE - Values in the table show the percentage of accelerations at the corresponding magnitude.

Figure C-H
Modified VIBRAN (low frequency)

Vibration, File(3), Count(254700)

(Acceleration Distribution in Percent*)

Acceleration, 0-PK G

Truck Vibration

Trk 9

Sample duration: 80 seconds

Truck bed cross member

2 feet to rear of cask, blacktop
highway, high speed, loaded

3.7	0.11	42.86						0.00	0.01	0.04
2.7		14.29	0.03							
1.9		14.29				0.00				
1.4		14.29	0.01	0.04	0.01	0.00	0.01	0.01	0.01	0.00
1.0	99.89	14.29	99.96	99.96	99.99	99.99	99.99	99.99	99.99	99.96

Frequency(cps)

0-	5-	10-	20-	30-	45-	60-	87.5-	125-	175-	250-
5	10	20	30	45	60	87.5	125	175	250	350

Samples Per Channel

0	1863	7	7043	8147	12958	20216	26564	35525	56704	83673
---	------	---	------	------	-------	-------	-------	-------	-------	-------

NOTE - Values in the table show the percentage of accelerations at the corresponding magnitude.

Figure C-I

Modified VIBRAN

Vibration, File(2), Count(266040)

(Acceleration Distribution in Percent)

Acceleration, 0-PK G

Truck Vibration

Trk 9

Sample duration 80 seconds

Truck bed cross member

2 feet to rear of cask, concrete
highway, low speed, loaded.

3 7	0 10	33 33				0 00	0 00		0.01	0.03
2 7		16 67	0.03						0.00	
1 9		16.67				0.00			0.00	0.00
1 4		16 67	0.01	0.03	0.01	0.00	0 01	0.01	0.01	0.00
1 0	99.90	16 67	99 96	99.97	99.99	99.99	99.99	99.99	99.98	99.96

Frequency(cps)

0-	5-	10-	20-	30-	45-	60-	87.5-	125-	175-	250-
5	10	20	30	45	60	87.5	125	175	250	350

Samples Per Channel

2052	6	6678	7033	13290	20533	30415	40560	58796	85127
------	---	------	------	-------	-------	-------	-------	-------	-------

NOTE - Values in the table show the percentage of accelerations at the corresponding magnitude.

Figure C-J

Modified VIBRAN

SECTION II

Construction of a Composite Description of Environment

As described, in Section I, we arrived at a method of obtaining and describing a statistical sample of the dynamic environment in terms of its peak acceleration probability density versus frequency. The length of time during which to take this sample is a sufficient period of sampling time for obtaining a statistically representative number of peaks counted in a bandpass of interest.

For a general guideline, we have adopted the rule that at least 30 peaks must be counted in a given pass-band for the sample distribution to be considered representative. Thirty peaks counted provides 99 percent confidence that the maximum deviation of a measured g value from the true population distribution is 29 percent. To illustrate the degree of confidence to be placed on measurements where greater numbers of peaks are counted, a bandpass where 10,000 peaks were counted provides 99 percent confidence that the maximum deviation of a measured g value from the true population distribution is 0.16 percent. This statistical probability description is nonparametric -- that is, it does not presuppose a normal (Gaussian) distribution, or any other. Preliminary samples taken over a 60-second real time period appear to more than fulfill the 30 counts minimum requirement for the truck transportation environment data.

Our next problem was how to relate, in a composite picture of the environment, the effects of road type, truck speed, and load. This was done in the following manner.

- 1 A composite peak amplitude probability density was obtained for (a) the unloaded and (b) the loaded truck. These composites used in conjunction with the appropriate apparent weight measurements which were obtained at these two load conditions were used to obtain estimates of the input force versus frequency conditions. These estimates can be used for derivation of force-controlled laboratory vibration tests or to estimate the probable force magnitudes being delivered to the cargo.

Since acceleration amplitudes are in terms of probability of occurrence, analytical techniques may be used to determine what amplitude values should be selected as appropriate in each pass-band for a random vibration test or a sinusoidal vibration test, and what amplitude values may be more appropriately accounted for in shock tests.

- 2 Within each of these two load condition composites, the number of samples taken is based on the frequency of occurrence of each road type as encountered during the trip, and the frequency of occurrence of road speeds achieved. These frequencies of occurrence were obtained from the voice transcript and activity logs recorded throughout the trip, and are analyzed in Appendix B.

Summary of Preliminary Analysis

It was determined that the environmental description provided as a result of this truck test should be composed of

- 1 Individual acceleration amplitude probability distribution versus frequency presentations representative of the various road types and speeds encountered for the (a) unloaded and (b) loaded truck
- 2 A composite amplitude probability distribution for the two load conditions based on probability of occurrence of road type and vehicle speed
- 3 Plots of apparent weight of the loaded and unloaded truck versus frequency.
- 4 Resultant combination of 2 and 3 above to derive estimates of force input to cargo.

The method of environmental measurement and description outlined here is believed to be one which, at the present state-of-the-art of environmental analysis, will be most useful for customers of the Sandia Corporation Environmental Data Bank. We hope to extend this approach of combining measurement and activity analysis to other types of truck, train, aircraft and missile applications, and perhaps to apply this method of analysis to direct force measurements obtained during operational activities.

It is further believed that replications of this method in other tests provides a consistent basis for comparison and/or combination of environmental measurements in a manner superior to that of just "enveloping" data taken from a number of tests.

SECTION III

Reduced Data

Figure C-1

Composite of Vertical Axis
Front, Center, Aft Locations

Composite Plot
Truck on Level Concrete, 50 Mph, Unloaded

Acceleration Distribution, Percent

3.2	0.96						0.01	0.01	0.01	0.03	0.18	0.13	2.62
2.3								0.01	0.02	0.01	0.00		
1.65							0.02	0.02		0.03	0.04		0.05
1.2							0.02	0.01	0.02	0.05	0.05	0.08	0.08
0.86						0.01	0.01	0.01	0.04	0.11	0.09	0.34	0.19
0.62				0.12	0.10	0.06	0.05	0.02	0.02	0.19	0.09	0.58	0.27
0.45			0.66	0.16	0.16	0.03	0.09	0.13	0.06	0.52	0.23	0.59	0.57
0.32		0.41	0.51	0.73	0.40	0.09	0.06	0.21	0.11	1.17	0.32	0.83	0.90
0.23	0.96	1.24	1.48	1.74	0.91	0.26	0.22	0.44	0.24	3.85	1.01	2.31	2.0
0.17	0.96	7.87	6.59	3.11	2.37	0.63	1.48	0.98	0.37	6.5	3.30	4.61	4.05
0.12	2.89	15.33	10.44	8.58	8.24	2.47	9.11	1.47	0.62	8.25	7.78	7.74	8.53
0.1	94.20	75.13	80.29	85.54	87.78	96.41	88.88	96.65	98.45	79.21	86.91	82.29	80.69
Frequency, cps	0- 2 1/2	2 1/2- 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No. Peaks Counted	207	965	1350	2470	2948	6169	7561	10952	9923	22851	27771	13041	24736

Total Peaks Counted: 130,944

Figure C-2

Vertical Axis
Front, Center, Aft Locations

Composite Plot
Truck on Level Blacktop, 30 And 50 Mph, Unloaded

Acceleration Distribution, Percent

3.2	6.8					0.01	0.01		0.1	0.1	1.5	0.04	2.7
2.3													
1.65													
1.2													
0.86													
0.62													
0.45	3.5									0.2	0.01		0.02
0.32		0.3			0.1					0.9	0.04	0.02	0.05
0.23		2.0	0.6	0.1	0.4	0.3				4.2	0.4	0.9	0.5
0.17		8.3	5.3	0.6	2.8	1.6	0.9	0.02		8.1	2.9	3.3	2.1
0.12		14.2	7.7	3.9	5.9	4.3	8.0	0.1		9.8	6.5	5.6	6.9
0.1	89.8	75.4	86.9	95.5	91.0	93.9	91.1	99.9	99.9	76.9	90.5	90.0	87.7
Frequency, cps:	0- 2 1/2	2 1/2- 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No. Peaks Counted:	150	1689	2405	4818	6149	16638	12821	18538	17544	38981	50880	25069	48561

Total Peaks Counted: 244,243

Figure C-3

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Bridge Crossing, Unloaded Truck, 45 Mph

Acceleration Distribution, Percent

3.2	2.92							0.03	0.01	0.07	0.30		2.56
2.3										0.02			0.01
1.65								0.01		0.02		0.01	
1.2						0.02	0.03	0.04	0.04	0.04	0.02	0.03	0.01
0.86						0.05	0.03	0.09	0.04	0.04	0.02	0.06	0.06
0.62					0.03	0.05	0.07	0.06	0.12	0.04	0.08	0.05	
0.45	0.64				0.12	0.08	0.14	0.10	0.05	0.64	0.03	0.09	0.08
0.32		0.40	0.19	0.10	0.52	0.08	0.02	0.01	0.08	2.54	0.07	0.10	0.25
0.23	0.32	7.56	1.96	1.22	4.19	0.94	0.27	0.13	0.08	7.12	1.24	1.38	1.36
0.17		22.00	10.37	5.39	8.01	2.9	2.35	0.47	0.12	8.97	4.48	6.85	4.35
0.12	1.30	25.93	18.93	15.84	10.31	6.39	11.75	1.41	0.35	8.08	10.69	10.51	10.21
0.1	95.13	44.09	68.53	77.43	76.78	89.56	85.31	97.64	99.07	71.95	83.05	80.61	80.99
Frequency, percent	0- 2 1/2	2 1/2- 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
Peaks counted:	308	991	1532	2947	3955	6132	7707	11288	13335	23572	33089	17878	27373

Total Peaks Counted: 150,107

Figure C-4

Composite Plot
Vertical Axis
Front, Center, Aft Location

Truck over Railroad Crossing at 50 Mph, Unloaded

Acceleration Distribution, Percent

0	3 2	2 14						0 01	0 02	0 04	0 15	0 30	0 17	1 47
	2 3							0 04	0 01	0 03	0 03	0 01		
	1 65	0 10			0 04	0 03	0 04	0 08	0 06	0 09	0 01	0 03	0 02	
	1 2	0 42		0 06		0 04	0 03	0 09	0 05	0 06	0 11	0 06	0 12	0 04
	0 86	0 85	0 20	0 06		0 07	0 06	0 05	0 11	0 10	0 11	0 07	0 16	0 09
	0 62	0 85	0 20	0 12	0 09	0 02	0 04	0 09	0 07	0 11	0 37	0 11	0 19	0 12
	0 45	0 42	0 21	0 37	0 16	0 29	0 06	0 18	0 21	0 20	1 75	0 15	0 51	0 33
	0 32		0 52	0 31	0 36	0 61	0 27	0 24	0 19	0 24	4 27	0 37	1 77	1 15
	0 23	0 85	3 99	2 75	2 53	3 79	0 95	0 46	0 24	0 22	8 70	2 31	7 19	4 78
	0 17	5 58	7 78	11 95	7 42	9 18	4 49	2 62	0 54	0 28	9 53	6 89	14 03	10 04
	0 12	7 29	17 13	19 03	15 12	11 39	7 88	13 29	2 34	0 95	8 65	12 39	13 72	15 13
	0 1	81 54	69 81	65 31	74 28	74 51	85 81	82 87	96 06	97 65	66 19	77 23	62 09	66 54
Frequency														
cps	0-	2 1/2-	5-	10-	15-	23-	30-	44-	63-	88-	125-	175-	238-	
	2 1/2	5	10	15	23	30	44	63	88	125	175	238	313	
No Peaks														
Counted	233	951	1597	3002	4081	6149	7764	11451	14496	24219	34032	25819	41831	

Total Peaks Counted 175,625

Figure C-5

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Level Concrete at 50 Mph, Loaded

Acceleration Distribution, Percent

0.2							0.03	0.04	0.11	0.04	0.13	0.28	0.47
0.3													
1.65													
1.2													
0.66										0.02			
0.62	20.00			0.05						0.38	0.23	0.01	0.06
0.45				0.42	0.30	0.15	0.01			2.68	2.52	0.99	0.81
0.32			0.07	1.89	0.83	0.32	0.03			7.48	8.07	7.17	5.32
0.23	20.00	1.38	1.54	7.86	5.06	2.84	0.60	0.07		12.28	16.14	23.81	18.40
0.17	20.00	6.38	6.74	11.69	15.62	8.93	3.90	1.22	0.13	10.19	17.08	24.11	26.40
0.12		6.63	8.91	7.92	17.22	8.80	5.19	2.80	0.49	4.91	9.29	13.87	15.99
0.1	40.00	85.62	82.74	70.16	60.96	78.96	90.25	95.87	99.27	62.02	46.54	29.76	32.55
at City,	0-	2 1/2-	5-	10-	15-	23-	30-	44-	63-	88-	125-	175-	238-
15	2 1/2	5	10	15	23	30	44	63	88	125	175	238	313
CARS	5	800	1425	1907	1678	4045	7652	10825	9156	19735	15750	13968	17055

Total Peaks Counted: 104,000

Figure C-6

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Level Blacktop at 30 Mph, Loaded

Acceleration Distribution, Percent

3.2										0.03	0.07		0.99
2.3													0.01
1.65													0.01
1.2													
0.86										0.01			
0.62	2.86			0.18						0.13	0.01		
0.45				0.36	0.03	0.02				1.05	0.04	0.06	0.01
0.32			0.29	1.22	0.25	0.04			0.01	4.57	0.30	0.36	0.11
0.23	2.86	0.45	0.95	3.94	1.25	0.37	0.20	0.35	0.12	9.65	2.06	5.06	1.23
0.17	25.71	3.63	3.65	7.33	2.00	0.99	1.54	0.52	0.23	8.38	4.47	9.60	4.03
0.12	22.85	11.33	13.13	12.22	8.26	5.31	9.82	2.10	1.09	14.15	10.55	16.89	13.91
0.1	45.72	84.58	81.99	74.74	88.20	93.28	88.41	97.00	98.52	61.98	82.33	67.93	78.39
Frequency, cps:	0- 2 1/2	2 1/2- 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No Peaks Counted:	35	882	1371	2209	2797	5891	7517	10306	10284	23538	32913	21175	35057

Total Peaks Counted: 153,975

Figure C-7

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Level Blacktop at 50 Mph, Loaded

Acceleration Distribution, Percent

1.2	1.45					0.02		0.04	0.04	0.09	0.31	0.28	1.21
2.3													
1.65							0.01	0.04	0.04	0.01			
1.2	1.45						0.05	0.01	0.04	0.02	0.02	0.01	
0.86	2.90					0.02	0.01	0.02	0.01	0.17	0.01	0.01	0.02
0.62	15.95				0.07	0.05	0.03	0.04	0.01	1.82	0.03	0.02	0.23
0.45	15.95				0.24	0.09	0.05		0.03	6.98	0.26	3.65	3.55
0.32	14.50		0.43	0.32	0.10	0.09	0.07	0.03	0.04	9.04	1.83	9.90	9.93
0.23	13.04	0.39	6.12	3.39	0.90	1.50	1.04	0.47	0.04	11.23	7.04	18.14	15.26
0.17	2.90	0.78	11.30	5.68	3.66	3.69	2.98	1.30	0.04	9.54	8.39	11.79	9.57
0.12	14.49	8.46	18.96	11.13	10.97	9.26	10.53	3.47	0.54	13.21	11.63	15.17	11.01
0.1	17.39	90.37	63.19	79.48	84.06	85.28	85.23	94.57	99.19	47.89	70.49	40.84	49.21
Frequency, cps:	0- 2 1/2	2 1/2- 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
Peaks Counted	69	768	1619	2184	2899	5796	7590	10920	11694	22151	23807	22584	30203

Total Peaks Counted: 142,254

Figure C-8

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Bridge Crossing at 45 Mph, Loaded

Acceleration Distribution, Percent

3 2	33 33						0.01		0.18	0.06	0.19	0.39	0.45
2 3													
1 65											0.01		0.01
1 2													
0 86													
0 62	33 33									0.14	0.12	0.06	0.01
0 45				0.36						1.40	0.81	2.36	0.24
0 32				1 33	0.13	0.29				5.10	4.90	10.76	3.64
0 23	33 33	0.13	0.15	4.95	1.29	2.47	0.23	0.01	0.03	11.26	14.51	27.90	19.20
0 17		0.87	2 34	11.96	6.25	6.40	2.10	0.01	0.03	10.67	18.39	22.40	24.71
0 12		3 62	8 19	15.70	16 65	10.43	5.95	0.22	0 20	7.92	15.89	16.85	21.75
0 1		95 38	89 33	65.70	75 69	80.42		91.71	99.57	63.46	45.27	19.30	29.99
Frequency, cps	0- 2 1/2	2 1/2- 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313

No Peaks Counted	3	801	1368	1656	1633	4499	7332	10364	7883	19435	14175	14935	15949
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Total Peaks Counted: 100,033

Figure C-9

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Railroad Crossing at 25 Mph, Loaded

Acceleration Distribution, Percent

3.2								0.01	0.05	0.09	0.18	0.20	1.35
2.3										0.01			
1.65										0.01		0.01	
1.2			0.17	0.12	0.09		0.01	0.01	0.01	0.05			
0.86		0.12			0.17	0.05	0.07	0.02	0.01	0.11	0.05	0.09	
0.62	14.29	0.00	0.17	0.36	0.26	0.03	0.03	0.04	0.09	0.28	0.25	0.17	0.12
0.45		0.24		0.91	0.09	0.08	0.03	0.03	0.05	0.73	0.74	0.61	0.39
0.32	14.29	0.00	0.67	0.73	0.27	0.30	0.03	0.09	0.03	2.25	1.70	1.38	0.93
0.23	14.29	0.71	0.92	1.70	1.92	0.57	0.12	0.57	0.12	6.89	7.59	5.36	2.47
0.17	14.29	0.60	2.09	4.61	2.61	0.77	0.49	0.82	0.31	10.73	15.92	14.31	7.08
0.12	14.29	2.38	4.92	8.55	3.66	1.24	1.23	1.29	0.94	10.58	18.59	18.66	17.39
0.1	28.57	95.95	91.07	83.02	90.94	96.98	98.00	97.12	98.39	68.28	54.99	59.18	70.24
Frequency, cps	0- 2 1/2	2 1/2- 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No. Peaks Counted	7	841	1199	1649	1148	4034	7404	9682	7785	19367	14056	11031	15421

Total Peaks Counted: 93,624

Figure C-10

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Uphill Blacktop at 5 Mph, Loaded

Acceleration Distribution, Percent

3.2						0.02		0.03	0.14	0.08	0.28		1.73	
2.3														
1.65													0.01	
1.2	6.66													
0.86	6.67													
0.62	6.66									0.01				
0.45										0.41				
0.32	13.33									3.67	0.05	0.08	0.05	
0.23										10.18	0.59	5.08	0.90	
0.17							0.04			7.30	2.21	8.90	3.25	
0.12		1.88	0.42	1.00			2.80			10.26	8.26	27.01	10.98	
0.1	66.66	98.12	99.58	99.00	100.00	99.98	97.16	99.97	99.86	68.08	88.54	58.93	82.14	
Frequency, cps:	0- 2 1/2	2 1/2- 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313	
No. Peaks Counted:	15	906	11.94			937	4899	7500	8954	7933	25065	32083	29107	34373

Total Peaks Counted: 154,566

Figure C-11

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Downhill on Blacktop at 50 Mph, Loaded

Acceleration Distribution, Percent

G - Peak Acceleration, G	3.2								0.11	0.04	0.23	0.24	0.55
	2.3												
	1.65												
	1.2									0.01			
	0.86									0.05			
	0.62	33.33								0.46	0.01	0.05	0.04
	0.45			0.50						3.35	0.07	1.08	1.07
	0.32	33.33		0.08	1.24		0.08	0.01		7.02	0.58	5.84	4.98
	0.23		1.13	0.31	3.96	1.53	1.01	0.59	0.28	10.24	4.37	20.43	12.57
	0.17		1.51	2.18	4.40	4.98	2.34	1.85	0.85	0.05	6.85	7.34	17.18
0.12		5.55	8.03	9.10	18.14	5.70	6.75	1.45	0.58	7.01	13.82	19.13	20.27
0.1		91.80	89.40	80.81	75.36	90.87	90.79	97.43	99.25	65.00	73.57	36.07	47.38
Frequency, cps:	0- 2 1/2	2 1/2- 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No. Peaks Counted:	3	793	1283	1615	1246	4952	7405	10092	7090	17831	13835	11145	13670

Total Peaks Counted: 90,960

Figure C-12

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Bumps at 50 Mph, Loaded

Acceleration Distribution, Percent

3.2								0.14	0.09	0.13	0.32	0.02	2.18
2.3							0.03	0.02	0.01	0.03		0.02	0.02
1.65				0.04					0.01	0.09	0.01	0.06	0.01
1.2			0.07	0.13	0.04	0.04		0.01		0.17	0.10	0.08	0.04
0.86	2.33		0.21	0.09	0.04	0.02	0.03	0.01	0.01	0.35	0.25	0.17	0.16
0.62		0.23	0.28	0.29	0.04	0.02		0.06	0.03	1.01	0.40	0.41	0.26
0.45	6.97	0.12	0.14	0.50	0.36	0.07	0.04	0.07	0.10	2.57	0.98	1.11	0.54
0.32	13.96	0.68	0.35	1.58	0.73	0.29	0.18	0.21	0.29	5.05	2.81	2.79	1.27
0.23	15.12	1.25	0.69	4.84	2.05	1.82	0.95	0.27	0.39	9.36	7.16	9.02	4.47
0.17	8.14	5.57	3.60	8.18	8.37	3.43	4.38	0.26	0.47	11.02	10.70	12.76	10.63
0.12	12.80	10.34	8.43	6.59	9.33	3.85	7.58	0.49	1.03	10.19	8.50	18.20	11.41
0.1	40.70	81.82	86.25	77.77	79.04	90.46	86.82	98.44	97.57	60.03	68.75	55.35	69.01

Frequency,
cps:

0 -	2 1/2 -	5 -	10 -	15 -	23 -	30 -	44 -	63 -	88 -	125 -	175 -	238 -
2 1/2	5	10	15	23	30	44	63	88	125	175	238	313

No. Peaks

Counted: 86 880 1447 2398 2486 5503 7733 10698 10945 22060 23534 22276 27769

Total Peaks Counted: 137,815

Figure C-13

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Blacktop over Concrete at 20 Mph, Loaded

Acceleration Distribution, Percent

3.2								0.02	0.11	0.02	0.26	0.15	0.81
2.3													
1.65										0.01			
1.2												0.01	0.01
0.86										0.05		0.01	
0.62	33.33			0.06						0.55	0.03	0.01	0.05
0.45				0.24	0.09					3.22	0.07	0.12	0.12
0.32				0.86	0.17	0.08			0.02	7.69	0.45	1.33	0.77
0.23	33.33		0.38	1.97	1.34	0.30	0.10	0.02	0.06	12.35	2.82	11.29	4.38
0.17	33.33	0.24	1.25	4.32	0.98	0.45	0.21	0.24	0.06	9.68	6.16	16.82	8.69
0.12		2.89	4.90	9.37	3.64	1.48	1.22	0.65	0.25	9.98	16.55	21.56	20.46
0.1		96.88	93.47	83.17	93.79	97.69	98.47	99.07	99.51	56.46	73.66	48.71	64.72
Frequency, cps:	0- 2 1/2	2 1/2 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No. Peaks Counted:	3	832	1041	1622	1127	2637	7070	9236	6500	15320	11930	12922	15129

Total Peaks Counted: 85,369

Figure C-14

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Tunnels at 50 Mph, Loaded

Acceleration Distribution, Percent

0 - Pk G	3.2	4.31					0.01		0.05	0.04	0.11	0.16	1.03
	2.3												
	1.65												
	1.2									0.02			0.02
	0.86				0.28					0.04	0.01		0.01
	0.62				0.47					0.40	0.09	0.04	0.06
	0.45	1.08	0.12		2.81	0.66				1.69	0.65	0.50	0.19
	0.32		0.12	0.51	3.89	2.93	0.05	0.03	0.08	3.89	1.88	1.32	0.77
	0.23	1.08	1.39	2.54	6.56	5.44	0.67	0.43	1.37	0.09	8.84	7.56	5.97
	0.17		4.16	5.30	9.00	7.95	2.17	2.38	3.34	0.27	9.56	14.98	16.47
	0.12		6.35	8.34	8.58	13.51	4.76	9.09	6.76	1.41	8.90	16.81	19.45
	0.1	93.54	87.88	83.32	68.40	69.52	92.35	88.06	88.45	98.19	66.63	57.91	56.09
Frequency, cps:		0- 2 1/2	2 1/2 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238
No. Peaks Counted:		93	866	1379	2133	1673	6219	7731	11012	9748	20646	15291	11145
													16227

Total Peaks Counted: 104,163

Figure C-15

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Parking Lot at 25 Mph, Loaded

Acceleration Distribution, Percent

0 - Peak Acceleration, g	3.2					0.02	0.01	0.03	0.04	0.12	0.23	0.03	2.52
	2.3												0.01
	1.65											0.01	0.02
	1.2									0.10	0.01	0.03	0.02
	0.86	1.61			0.28			0.06		0.21	0.07	0.18	0.09
	0.62			0.09	0.21			0.09		0.34	0.19	0.47	0.37
	0.45	1.61	0.36	0.55	0.64	0.47	0.04	0.01	0.36	0.05	0.64	0.53	0.89
	0.32	17.74	1.46	0.99	1.36	0.67	0.08	0.05	0.60	0.20	1.49	0.85	1.26
	0.23	51.62	4.76	2.35	2.36	1.07	0.25	0.36	1.53	0.45	3.74	1.90	3.22
	0.17	20.97	9.64	4.15	6.51	4.13	0.56	1.46	1.93	0.77	5.94	3.83	6.20
	0.12	6.45	10.37	5.15	4.93	3.73	1.04	3.52	2.56	1.37	5.58	4.94	11.22
	0.1		73.41	86.72	83.69	89.94	98.00	94.59	92.84	97.12	81.84	87.44	77.40
Frequency, cps:	0- 2 1/2	2 1/2 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No. Peaks Counted:	62	820	1107	1398	1500	4804	7557	9755	7528	20767	26420	14600	24477

Total Peaks Counted: 120,795

Figure C-16

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Asphalt Turnpike at 60 Mph, Loaded

Acceleration Distribution, Percent

3.2							0.03	0.01	0.06	0.01	0.27	0.11	0.39
2.3												0.01	0.01
1.65												0.01	
1.2												0.01	
0.86										0.06			
0.62	33.33									0.59		0.22	0.16
0.45	33.33									4.57	0.08	2.27	2.70
0.32	33.33			0.06			0.01	0.02		9.83	0.76	9.42	9.41
0.23		0.71	1.19	2.79	0.33	1.37	0.86	0.63	0.01	12.52	5.52	27.37	21.65
0.17		1.07	2.79	4.67	3.91	3.84	3.24	2.47	0.16	6.89	9.57	16.50	17.11
0.12		3.21	8.96	10.14	18.65	10.50	9.09	4.03	1.50	5.80	17.26	18.38	19.51
0.1		95.01	87.06	82.34	77.11	84.29	86.77	92.84	98.27	59.72	66.54	25.72	29.06
Frequency, cps	0- 2 1/2	2 1/2 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No Peaks Counted.	3	842	1507	1755	1507	4817	7779	10842	9915	18933	14576	15027	17232

Total Peaks Counted: 104,735

Figure C-17

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Overpass at 30 Mph, Loaded

Acceleration Distribution, Percent

3.2						0.03	0.02	0.05	0.13	0.07	0.23	0.11	0.53
2.3													
1.65													
1.2													
0.86										0.01			
0.62	33.33									0.20			
0.45				0.07						2.75	0.05	0.99	0.13
0.32	33.33			0.81						7.73	0.90	6.80	1.71
0.23	33.33	0.12	0.20	7.05	1.14	0.20	0.13			13.93	7.99	23.37	11.45
0.17		1.11	1.62	13.36	3.57	1.91	0.98			9.57	12.70	16.87	15.72
0.12		3.44	7.40	15.33	16.42	8.41	4.02	0.03	0.04	9.80	21.72	19.66	25.28
0.1		95.34	90.77	63.36	78.87	89.45	94.85	99.91	99.82	55.94	56.42	32.20	45.19
Frequency, cps:	0- 2 1/2	2 1/2 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No. Peaks Counted:	3	815	986	1474	1486	3042	6831	9204	7365	16369	12166	14292	15837

Total Peaks Counted: 89,870

Figure C-18

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Concrete Turnpike, at 50 Mph, Loaded

Acceleration Distribution, Percent

3.2					0.04			0.08	0.14	0.11	0.39	0.04	1.46
2.3													0.01
1.65													
1.2													
0.86										0.10	0.02	0.01	0.02
0.62	2.63									1.06	0.26	0.12	0.13
0.45				0.33	0.18					3.99	1.47	0.85	0.87
0.32	2.63	4.37	0.07	3.25	0.99	0.29	0.17	0.05		8.00	4.33	3.54	2.65
0.23	31.58	18.02	1.71	9.71	4.30	2.46	1.49	0.16	0.04	12.06	9.86	12.87	7.85
0.17	36.84	14.37	6.86	9.42	9.65	6.27	5.67	0.66	0.23	11.44	11.32	17.23	13.20
0.12	21.05	13.23	9.44	6.01	8.84	5.61	8.10	1.91	0.99	11.24	9.51	20.99	14.32
0.1	5.27	50.00	81.91	71.28	75.99	85.38	84.57	97.14	98.60	52.00	62.85	44.37	59.49
Frequency, cps	0- 2 1/2	2 1/2 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No. Peaks Counted	38	960	1399	2430	2724	5615	7707	11380	12918	22881	24229	26237	30862

Total Peaks Counted: 149,380

Figure C-19

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Uphill, Concrete, at 20 Mph, Loaded

Acceleration Distribution, Percent

3.2							0.01	0.01	0.09	0.03	0.26	0.11	0.70
2.3													0.01
1.65													0.01
1.2										0.01			
0.86				0.29						0.16		0.01	
0.62	33.33			1.44						1.10	0.07	0.07	0.03
0.45			0.22	2.92	0.94			0.16		4.02	0.39	0.82	0.31
0.32			2.40	4.26	3.13	0.11		0.59	0.08	6.70	1.49	3.86	2.12
0.23	33.33	1.64	4.65	5.70	4.76	0.95	0.28	2.53	0.19	10.67	5.56	15.34	8.73
0.17	33.33	5.21	7.88	5.74	3.82	1.96	0.76	3.88	0.55	7.33	7.72	16.09	11.43
0.12		7.43	7.43	7.70	7.70	4.57	3.28	7.95	2.18	7.68	13.61	19.68	20.43
0.1		85.71	77.42	71.96	79.65	92.40	95.67	84.88	96.91	62.30	70.88	44.03	56.25
Frequency, cps	0- 2 1/2	2 1/2 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No. Peaks Counted	3	1036	1333	2090	1597	3567	9143	12827	10051	19593	16319	14207	16274

Total Peaks Counted: 108,040

Figure C-20

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Downhill, Concrete, at 40 Mph, Loaded

Acceleration Distribution, Percent

0 - Peak Acceleration, G	3.2							0.07	0.13	0.11	0.14	0.16	1.00
	2.3												0.01
	1.65											0.01	0.01
	1.2												
	0.86												
	0.62	33.33								0.25			
	0.45									2.19	0.18		0.05
	0.32		0.73		0.90	0.28				7.79	2.21	0.20	0.45
	0.23	33.33	11.41	0.10	4.08	2.88	0.70	0.19		14.70	11.25	6.78	5.23
	0.17	33.33	8.38	1.96	8.60	7.15	2.61	1.30		10.01	14.02	14.86	11.15
0.12		4.73	8.02	16.08	17.87	7.81	4.20	0.22	0.18	9.80	20.14	20.96	23.47
0.1		74.76	89.92	70.34	71.83	88.88	94.31	99.70	99.70	55.15	52.06	57.03	58.64
Frequency, cps:	0- 2 1/2	2 1/2- 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No. Peaks Counted:	3	824	1022	1325	1427	2995	6858	9383	6331	15804	12073	11896	16356

Total Peaks Counted: 86,297

Figure C-21

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Paved Detour at 5 Mph, Loaded

Acceleration Distribution, Percent

3.2	1.24						0.01	0.02	0.11	0.06	0.23	0.16	1.92
2.3	--								0.01		0.01		0.01
1.65	--									0.01		0.01	
1.2	1.24			0.05									
0.86	3.71			0.09						0.06		0.02	0.02
0.62	7.41			0.09						0.17	0.04	0.07	0.06
0.45	9.88			0.18	0.05				0.02	1.14	0.12	0.33	0.10
0.32	19.75			1.88	0.59	0.09	0.04	0.04	0.05	4.77	1.04	2.05	0.36
0.23	8.64	2.78	0.49	5.78	2.57	0.69	0.38	0.25	0.03	10.79	5.10	11.34	3.26
0.17	11.11	6.76	2.10	6.65	4.88	1.50	1.60	0.57	0.15	9.17	7.18	14.11	7.40
0.12	16.05	16.04	9.38	9.63	13.56	5.42	7.70	1.98	0.59	13.47	11.54	16.03	15.94
0.1	20.99	74.43	88.03	75.64	78.35	92.30	90.26	97.14	99.04	60.35	74.74	55.91	70.94
Frequency, cps:	0- 2 1/2	2 1/2 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No. Peaks Counted:	81	829	1236	2180	2212	5775	7633	10813	10221	22010	22573	16931	25038

Total Peaks Counted: 127, 532

Figure C-22

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Unpaved Road at 30 Mph, Loaded

Acceleration Distribution, Percent

3.2						0.02	0.01	0.08	0.05	0.08	0.22	0.01	1.39
2.3													
1.65										0.03			
1.2													
0.86										0.21	0.02		0.02
0.62	12.50			0.05						1.16	0.12	0.03	0.18
0.45	12.50			0.19				0.03		3.42	0.89	0.25	0.77
0.32			0.07	1.10	0.16	0.02	0.03	0.35		5.60	2.82	1.41	2.47
0.23	37.50	1.09	1.54	3.36	1.29	0.35	0.66	1.36	0.14	8.85	7.33	6.44	7.88
0.17	37.50	3.29	5.58	3.50	2.30	0.95	1.91	2.70	0.58	8.50	9.54	10.10	9.71
0.12		12.17	17.21	7.68	4.09	2.80	8.81	5.26	3.22	11.97	14.72	20.76	17.46
0.1		83.46	75.59	84.13	92.17	95.85	88.60	90.22	96.00	60.15	64.27	61.01	59.68
Frequency, cps	0- 2 1/2	2 1/2 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
No Peaks Counted	8	822	1487	2085	2567	5135	7802	11035	12291	23950	31372	25285	37036

Total Peaks Counted 160,875

Figure C-23

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Brick Road at 15-20 Mph, Loaded

Acceleration Distribution, Percent

3.2					0.04			0.04	0.10	0.10	0.35		2.22
2.3													0.01
1.65													
1.2													
0.86										0.02			
0.62	0.67									0.45	0.05		0.01
0.45		0.12		0.36	0.04	0.04				2.43	0.45	0.06	0.12
0.32	22.15	2.50		1.76	0.54	0.04	0.03			5.77	2.14	0.74	1.30
0.23	53.02	14.05	0.27	7.18	2.83	0.85	0.65		0.04	10.44	7.31	4.67	6.36
0.17	10.73	15.95	2.63	9.93	7.40	2.88	2.92	0.19	0.09	11.02	11.12	10.89	12.13
0.12	8.72	10.00	6.60	6.86	6.78	3.70	6.83	1.03	0.40	10.28	8.40	20.57	11.53
0.1	4.70	57.38	90.51	73.92	82.37	92.50	89.57	98.74	99.37	59.49	70.20	63.07	66.32
Frequency, cps	0- 2 1/2	2 1/2- 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
Count	149	840	1485	2216	2405	5563	7670	11225	11340	22408	23582	22400	27597

Total Peaks Counted: 138,880

Figure C-24

Composite Plot
Vertical Axis
Front, Center, Aft Locations

Overall Trip Composite Amplitude Distribution
 G_T for the Unloaded Truck

Probability of Occurrence, Percent
(-) (Probability less than 0.1% is not reported)

3.2	4.18						-	-	-	-	0.25	0.14	2.48
2.3	-						-	-	-	-	-	-	-
1.65	-	-			-		-	-	-	-	-	-	-
1.2	-	-	-		-		-	-	-	-	-	-	-
0.86	0.12	-	-		-	-	-	-	-	-	-	0.12	-
0.62	0.12	-	-	-	-	-	-	-	-	0.12	-	0.18	-
0.45	1.89	-	0.20	-	0.10	-	-	-	-	0.54	-	0.23	0.19
0.32	-	0.33	0.20	0.24	0.28	-	-	-	-	1.67	0.16	0.47	0.44
0.23	0.51	3.03	1.33	0.99	1.63	0.47	0.17	0.16	0.10	5.22	0.93	2.14	1.57
0.17	0.86	10.52	7.33	2.91	4.46	1.97	1.52	0.40	0.15	8.12	3.55	5.67	4.06
0.12	2.05	16.87	11.68	8.56	7.94	4.69	9.61	0.96	0.34	9.11	8.34	8.06	9.26
0.1	90.21	69.12	79.23	87.21	85.55	92.70	88.48	98.21	99.14	74.99	86.57	82.94	81.80
Frequency, cps:	0- 2 1/2	2 1/2- 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313
Average Apparent Weight, lbs:	--	--	--	3000	4750	2250	1150	290	320	150	100	60	50

Total Peak Accelerations Used in this Summary: 700,909

- Notes: 1. This summary accounts for probability of occurrence of road speeds and road types encountered in a typical transcontinental trip.
2. The circled values are those which may be considered to be "shocks." The uncircled values are those considered to be "vibration."

Figure C-25

Overall Trip Composite Amplitude Distribution
for
The Loaded Truck

Acceleration Distribution Expected for the Loaded
Truck in Commercial Transport

Probability of Occurrence Percent, (-) (Probability less than 0.1% is not reported)

0 - Peak Acceleration, G	3.2	(3.85)						-	-	-	-	(0.20)	(0.19)	(0.90)
	2.3	-												
	1.65	-						-	-					-
	1.2	(0.52)		-	-	-		-		-		-		
	0.86	(0.82)	-	-	-	-	-	-		0.12	-	-	-	
	0.62	(19.06)	-	-	0.11	-	-	-	-	0.91	0.10	-	0.17	
	0.45	3.11	-	-	0.70	0.15	-	-	-	3.58	0.83	1.36	1.60	
	0.32	7.16	0.21	0.26	1.99	0.71	0.32	-	-	6.71	3.12	5.51	4.92	
	0.23	18.14	1.35	2.05	5.66	3.33	2.12	0.66	0.53	-	10.59	8.92	16.48	11.86
	0.17	15.24	3.24	4.87	7.71	6.85	4.54	2.47	1.24	0.19	8.89	11.28	15.97	13.51
	0.12	7.24	7.02	10.27	10.01	12.82	7.52	6.88	2.86	0.95	9.17	12.87	17.65	16.12
	0.1	23.33	88.11	82.50	73.78	76.09	85.42	89.90	95.25	98.65	59.96	62.63	42.71	50.66
Frequency, cps:	0- 2 1/2	2 1/2- 5	5- 10	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313	
Average Apparent Weight, lbs:				150	140	140	150	200	500	300	30	0.6	0.5	

Total Peak Accelerations Used in this Summary: 2,253,493

- Notes: 1. This summary accounts for probability of occurrence of road speeds and road types encountered in a typical transcontinental trip.
2. The circled values are those which may be considered to be "shocks." The uncircled values are those considered to be "vibration."

Figure C-26

Estimated Force Inputs, Lightly Loaded Truck

		Produced Force, Lbs									
0 - Peak Acceleration, G	0.86	130									
	0.62	92									
	0.45	1350	2100	1000	520	130	145	68	50	27	23
	0.32	960	1500	720	370	93	100	48	30	19	16
	0.23	690	1100	520	270	67	82	35	20	14	12
	0.17	510	810	460	195	60	55	26	17	10	9
	0.12	360	570	270	138	35	39	18	12	7	6
	0.1	300	475	225	115	29	32	15	10	6	5
		10-	15-	23-	30-	44-	63-	88-	125-	175-	238-
		15	23	30	44	63	88	125	175	238	313

Frequency, cps

Example of table usage:

From Figure C-24, 87.21% of accelerations in the 10-15 cps band occur at the 0.1 g level. The estimated input force for this condition is 300 pounds as read from the above table. Similarly, in this 10-15 cps band, 95.77% of the g peaks occur at or below 0.12 g. The estimated force for this condition is 360 pounds. Finally, in this band, 99.91% of the peaks occur at or below 0.32 g. The estimated force for this condition is 960 pounds.

Figure C-27

Estimated Force Inputs, Heavily Loaded Truck

0-Pk Acc, G	Produced Force, Lbs									
0.86	258									
0.62	93						186	19		
0.45	68	63	63				135	14	0.5	0.5
0.32	48	45	45				96	10	0.3	0.3
0.23	35	32	32	35	46		69	7	0.2	0.2
0.17	26	24	24	26	34	85	51	5	0.2	0.2
0.12	18	17	17	18	24	60	36	4	0.1	0.1
0.1	15	14	14	15	20	50	30	3	0.1	0.1
	10- 15	15- 23	23- 30	30- 44	44- 63	63- 88	88- 125	125- 175	175- 238	238- 313

Frequency, cps

See example on C-26.

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APPENDIX D
MEASUREMENT OF MECHANICAL IMPEDANCE

T-10768

March 31, 1965

IMPEDANCE MEASUREMENT OF A
FLAT-BED TRUCK

Organization 7300 Environmental Test Report

J. V. Otts, Org. 7324

TABLE OF CONTENTS

	<u>Page</u>
IMPEDANCE MEASUREMENT OF A FLAT-BED TRUCK	123
Introduction	123
Summary	123
Procedure and Results	123
Figure 1	124
Figure 2	126
Discussion of Results	127
Figures 3A, 3B, and 3C	130
Figures 4 through Figure 23	131

IMPEDANCE MEASUREMENT OF A FLAT-BED TRUCK

Introduction

The object of this test was to determine the apparent weight at several points on a flat bed trailer which was used to transport a 15-ton radioactive material cask from Wilmington, Delaware to Sandia Corporation, Albuquerque, New Mexico. This apparent weight data is intended to assist Division 1541 in the analysis of enroute vibration and shock data which was recorded on magnetic tape.

During each of the four investigations the acceleration (g) input was controlled at a variable level across the frequency test range (10 to 2500 cps). This magnitude was sufficient to obtain a readable input force level, and ranged between 0.1 and 2.5g.

This test followed a road test (T-10767), during which Sandia obtained road vibration measurements. The tests were conducted jointly with the U. S. Army Transportation Agency of Fort Eustis, Virginia and the Division of Reactor Development, AEC Hq., Washington, D. C.

The test was requested by J. T. Foley, 1541, on December 7, 1964. R. P. May, 7331, was the Test Project Engineer. The test item was received on December 21, 1964 and testing was completed on December 29, 1964.

Summary

Four tests were performed on the truck and trailer, each test for the purpose of determining the apparent weight at one of two points and under different loading conditions. The input for Test No. 1 was applied aft of the cask and at a point where enroute vibration was measured the cask and mounting plate were on the truck. Test No. 2 was identical to Test No. 1 except that the cask was removed. The input for Test No. 3 was applied to the center of the cask mounting plate with the cask off. Test No. 4 was identical to Test No. 3 except the mounting plate was removed and the input was applied directly to the truck frame. For each run frequency is plotted against g, force, apparent weight, and phase angle.

Procedure and Results

During transportation of the radioactive materials cask, the flat bed trailer was loaded as shown on Figure 1, with one exception. An instrument crate, similar to the one on the front of the truck, was removed to allow the shaker to be positioned for vibration. A typical test setup

Figure 1

is depicted in Figure 1. The tractor (not shown) was connected to the flat bed trailer during all tests. As can be seen in Figure 2, the vibration machine was hung into place by a crane. Bungee cord provided a low frequency suspension for the shaker.

Each apparent weight test was run with the input being acceleration controlled. In each case the control accelerometer was mounted adjacent to the force transducer as illustrated in Figures 3A and 3B.

The accelerometer control signal was filtered prior to being fed to the B & K servo. Both the accelerometer and force transducer outputs were recorded on a portable Ampex magnetic tape machine (SN No. 148162). The data were reduced in the forms of acceleration (g) vs frequency, force vs frequency, ratio of force to g (apparent weight W_A) vs frequency, and phase angle (g vs force) vs frequency. All of the above plots were obtained using filtered g and force signals. The amplitude and ratio plots were produced using standard data center procedures. The phase angle plots were produced by plotting the DC output (proportional to phase) of an Ad Yu phase meter.

A series of four tests were performed on the trailer, each for the purpose of determining the apparent weight at some particular point under different loading conditions. The tests are outlined below in their order of occurrence. For illustrative purposes, a sketch of the trailer is shown in Figure 3A. Note in particular, points A and B which were the two points investigated during the test series.

Test No. 1

Test No. 1 was performed at point B, with the radioactive cask and steel plate mounted on the trailer. This setup is shown in Figure 1. The force transducer was bolted to the channel beam cross member which supports the wooden flooring of the trailer. In order to gain access to this beam, it was necessary to drill a 2-1/2 inch hole through the flooring (Figure 4). The control accelerometer was adjacent to the force transducer, only on the opposite side of the channel. A sketch of this setup is shown in Figure 3B.

Plots of the control acceleration and resultant force input are shown in Figures 8 and 9 respectively. The apparent weight magnitude is plotted in Figure 10, while the phase angle is plotted in Figure 11.

Test No. 2

Test 2 was identical to Test 1 in location (point B) and gage setup (Figure 3B). The difference was that the radioactive cask was removed as shown in Figure 5.

Plots of control acceleration, resultant force, apparent weight magnitude, and phase angle are shown in Figures 12 through 15 respectively. Figure 14A has been included to provide high frequency magnification of the apparent weight.

Figure 2

3

Test No. 3

Test 3 was performed at point A (Figure 3A), without the radioactive cask being mounted. This test setup is shown in Figure 6.

The purpose of this test was to determine the dynamic characteristics at point A on the steel plate. The force transducer and accelerometer were mounted as shown in Figure 3C

The input g control, input force, apparent weight magnitude, and phase angle are depicted in Figures 16 through 19 respectively. Figure 18A is used to magnify the apparent weight at the higher frequencies. The right hand scale should be used after the discontinuity in the plot.

Test No. 4

Test No. 4 was run at point A, without the steel plate or radioactive cask mounted on the trailer. The force transducer and control accelerometer were mounted on the channel below the flooring at point A. Some of the cross channels are shown in Figure 7. Again it was necessary to drill a 2-1/2 inch hole through the flooring. The gage setup was again as shown in Figure 3B. The acceleration control signal and resulting force magnitude are shown in Figures 20 and 21 respectively. The apparent weight magnitude and phase are shown in Figures 22 and 23. Figure 22A is used to magnify the apparent weight at the higher frequencies.

Discussion of Results

The dynamic characteristics at points A and B on the trailer are presented in terms of apparent weight magnitude (W_A) and the associated phase angle. Both of these functions are plotted against frequency. Apparent weight is the complex ratio of applied force to the resultant acceleration (g), thus having the dimension of pounds. The measurement of dynamic characteristics in terms of apparent weight is preferred over that of mechanical impedance due to the convenience and experience in measuring motion in terms of g.

Equation 1 relates W_A to mechanical impedance (Z), where Z is defined as the complex ratio of applied force to the resultant velocity.

$$W_A = j \frac{386 Z}{2\pi f} \text{ - - - - - (1)}$$

f = frequency

The results from each test are presented below. In interpreting the data, the following fundamental relationships were used as a guide. W_A of a rigid mass is constant across the frequency range, the W_A of a spring has a 12 db/octave roll off as frequency increases, and the W_A of a viscous damper has a 6 db/octave roll off as frequency increases. The phase angle will fluctuate between 0 to 180°, being 0° for an ideal mass, -90° for a viscous damper, and 180° for a spring.

Test No. 1 (Figures 8 through 11)

Antiresonance occurs at 70 cps as indicated by the W_A peak (Figure 10) and the approximate 180° phase shift. This is followed at about 190 cps by a resonance as indicated by the W_A valley and phase shift from 180° to -30° .

The low W_A magnitude between 10 - 70 cps suggests that the 15-ton material cask has little (if any) influence upon the dynamic characteristics at point B. The trailer floor, particularly the area where the cask is mounted, has apparently decoupled from point B at a frequency below 10 cps.

Test No. 2 (Figures 12 through 15)

The characteristics at point B, without the cask, are quite similar to those with the cask mounted (Test 1). This further substantiates the fact that the material cask has decoupled from point B prior to 10 cps.

Test No. 3 (Figures 16 through 19 - W_A at point A - no cask)

An antiresonance occurs at 13 cps as indicated by the W_A peak and -90° phase shift. There also appears to be a resonance and antiresonance at 15 and 20 cps respectively.

Between 20 and 70 cps the characteristics approach that of a spring. The data suggests another resonant condition at 70 cps.

Test No. 4 (Figures 20 through 23 - W_A at point A - no cask or steel plate)

Since the phase angle is at 180° , and the W_A magnitude appears to have peaked, an antiresonance undoubtedly occurred below 10 cps.

A resonant condition occurs at 15 cps. This resonance was visually apparent during the test. There was an extremely high displacement of the tractor-trailer combination. The approximate 12 db/octave roll off and 180° phase angle between 15 and 110 cps strongly suggests spring like characteristics.

Although Tests 3 and 4 are at the same location (point A) it should be remembered that Test 4 exhibits the W_A characteristics of the channel while Test 3 exhibits that of the steel plate.

Considerable time was spent in obtaining accurate phase plots from the tapes. Visual analysis of the phase confirms the general trend shown in the phase plots. However, if sensitive calculations are to be made for discrete frequencies, it is recommended that the phase angle be determined by playback of the tape. The phase data up to about 600 cps is felt to be quite reliable. Above this frequency, the force amplitude was sometimes quite low, thus complicating the phase measurements.

On one occasion a rerun of a particular test was recorded and the data compared to that obtained previously. It was found to be quite repeatable, thus giving further assurance that the data presented herein is valid.

As is many times the case, reservation should be used on drawing conclusions from the amplitude and phase data at the higher frequencies. For example, when the force and acceleration are not measured at the same point (which was the case), it is possible that the measured acceleration will not be the same at high frequencies due to the modal pattern of the response.

JVO:mw

T-10768

Figure 3A Test Points on Trailer

Figure 3B Instrumentation for Tests 1, 2 and 4

Figure 3C Instrumentation for Test 3

Figure 4 - 2 1/2 inch hole drilled in floor--tests 1, 2, 4

Figure 5 - Setup for test 2 (cask removed)

Figure 6 - Setup for test 3 (cask removed)

Figure 7 - Crossbeams under trailer floor

Figure 8 - Trailer, point B - control accelerometer

Figure 9 - Trailer, point B - force transducer

Figure 10 - Trailer, point B - apparent weight

Figure 11 - Truck bed, point B - phase angle

Figure 12 - Trailer, point B (no cask) - control accelerometer

Figure 13 - Trailer, point B (no cask) - force transducer

Figure 14 - Trailer, point B (no cask) - apparent weight

Figure 14A - Trailer, point B (no cask) - apparent weight

Figure 15 - Truck bed, point B (no cask) - phase angle

Figure 16 - Trailer, point A (no cask) - control accelerometer

Figure 17 - Trailer, point A (no cask) - force transducer

Figure 18 - Trailer, point A (no cask) - apparent weight

Figure 18A - Trailer, point A (no cask) - apparent weight

Figure 19 - Truck bed, point A (no cask) - phase angle

Figure 20 - Trailer point A (no cask or plate) - control accelerometer

Figure 21 - Trailer, point A (no cask or plate) - force transducer

Figure 22 - Trailer, point A (no cask or plate) - apparent weight

Figure 22A - Trailer, point A (no cask or plate) - apparent weight

Figure 23 - Truck bed, point A (no cask or plate) - phase angle

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