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An Operational Field Test Of Long Combination Vehicles Using ABS And C-Dollies

Volume II

Appendices

UMTRI-95-45-2

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16. Abstract

The objective of this study was to evaluate the stability enhancing characteristics, practicality, reliability, maintenance costs and fleet personnel reactions to ABS and double-drawbar dollies. To do this, a fleet of double- and triple-trailer LCVs in actual commercial service was equipped with ABS and with C-dollies and monitored for a period of one and one-half years. The fleet of test vehicles was distributed among five commercial fleets operating in the northwestern region of the country where the use of LCVs is most prevalent. The fleet accumulated 1.4 million miles on trips, and the individual units accumulated over 10.5 million unit-miles. All maintenance work done on the vehicles during the study was monitored, and the physical behavior of the vehicles on the road was measured with on-board instrumentation systems. Findings include: (1) ABS can be expected to play a significant, stability-enhancing role in some ten to twenty severe braking events per 100,000 miles (roughly a year for a professional driver). (2) ABS on LCVs can be powered through the brake-light circuit provided that several important conditions are met. (3) ABS increases the total maintenance costs of an LCV by about 1 percent but reduces costs due to flat-spotting of tires. (4) The use of C-dollies on LCVs reduces rearward amplification in normal use. (5) Using C-dollies increases the total maintenance costs of an LCV by 3 to 5 percent, due mostly to increased tire wear. (6) Drivers, mechanics and fleet managers favor the use of ABS and C-dollies in LCV operations. Drivers especially favor C-dollies

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CONTENTS

VOLUME I - FINAL TECHNICAL REPORT

APPENDIX A
DATA FORMS

This appendix contains examples of the data forms supplied to the participating fleets. They include:

- ABS Problem/Failure Report
- C-dolly Problem Report
- Driver Trip Form
- Accident Investigation Form

The first two of these forms were used by mechanics to document the types and causes of problems encountered with ABS and C-dollies. Drivers completed a trip form for each trip taken during the study. The accident investigation form was completed by UMTRI's field representative.

NHTSA/UMTRI LCV Study
ABS Problem/Failure Report

Fleet:______________________________ Vehicle Number:______________

ABS Manufacturer:______________________ Mileage at Failure:____________

Date of Failure:________________________ Date of Repair:______________

Failure reported by:_____________________ Repaired by:________________

General Description of Failure:____

____

Please check all appropriate blanks to best describe the ABS problem

Wheel Speed Pulse Ring(s) problem caused by:

______ mechanical damage to the ring.

______ foreign matter caught between the ring teeth. (ice, dirt/dust, road tar, etc.)

______ looseness.

______ has the wheel hub been removed or replaced recently (Y/N)?

______ a wheel bearing out-of-tolerance.

______ other: ____

Wheel Speed Sensor(s) problem caused by:

______ mechanical damage to the sensor.

______ a cable defect.

______ a connector defect. If the connector defect was caused by moisture, has the unit recently been exposed to a high pressure wash or an extreme moisture operation (heavy rain, spray, slush, thawing conditions, etc.)?

______ a sensor attachment problem.

______ an electrical/electronic fault.

______ other: ____

Electronic Control Module problem caused by:

______ an internal failure.

______ damage due to (high/low) temperature.

______ damage due to moisture.

______ damage due to corrosion.

______ a cable defect.

______ a connector defect. If the connector defect was caused by moisture, has the unit recently been exposed to a high pressure wash or an extreme moisture operation (heavy rain, spray, slush, thawing conditions, etc.)?

______ damage due to (high/low) current/voltage.

______ other: ____

Solenoid Valve problem caused by:

______ contamination of the air supply.

______ an electrical malfunction.

______ an internal mechanical defect.

______ a cable defect.

______ a connector defect. If the connector defect was caused by moisture, has the unit recently been exposed to a high pressure wash or an extreme moisture operation (heavy rain, spray, slush, thawing conditions, etc.)?

______ other: ____

Display and Warning Equipment problem caused by:

______ a wiring error(s) or failure.

______ a connector defect.

______ a cable defect.

______ a lamp failure.

______ a relay failure.

______ other: ____

Other Wiring problems caused by:

______ a cable defect. (Describe location and nature of defect below)

______ a connector defect. (Describe location and nature of defect below)

How was the problem discovered? Did the ABS system alert you to the problem or did you have to discover the problem some other way? ______________________________

____

____

What was done to repair the problem? ______________________________

____

____

How long did the repair process take and were ABS parts readily available? __________

____

____

How long was the vehicle out-of-service?______________________________

ADDITIONAL COMMENTS:______________________________

____

____

____

____

____

____

____

NHTSA/UMTRI LCV Study

C-dolly Problem Report

Fleet:______________________________ Unit Number:_______________

Current Mileage:________________________ Date of Repair:______________

Problem Reported by:________________________ Repaired by:____________

General Description of Problem:__________________________________

____

Please indicate which dolly system(s) has the problem and answer the questions below.

______ Brake System including: Air Lines, Valves, Glad hands, and Connections

______ Tires, Tubes, Liners, and Valves

______ Wheels, Rims, Hubs, and Bearings

______ Lighting or Electrical System

______ Vehicle Coupling System

______ Dolly Frame and Support

______ Dolly Steering System

______ Trim and Miscellaneous Hardware

______ Other, Please indicate: ______________________________

How was the problem discovered (Driver Report, PM, etc.)? __________________

____

____

What was done to repair the problem? _______________________________

____

____

How long did the repair process take and were parts readily available? ____________

____

____

How long was the unit out-of-service?_______________________________

ADDITIONAL COMMENTS:_______________________________________

____

____

____

____

____

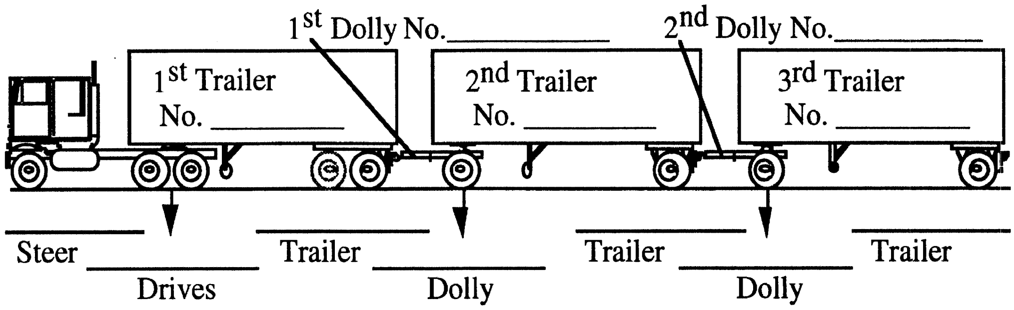
Driver Trip Form

Name	Tractor No.	Date	Time*

Start Location	End Location	Tractor Odometer Reading*

*Beginning of trip

UNIT NUMBERS and WEIGHTS - Please fill in the picture below with the unit numbers and weights for this trip. (Double: leave the 2nd dolly and 3rd trailer blank.)



WEATHER AND ROAD CONDITIONS - How was the weather for this trip? For each question please circle the closest answer.

How much rain was there during this trip?	none	some	heavy
How much snow was there during this trip?	none	some	heavy
How much fog was there during this trip?	none	some	heavy
How were the winds during this trip?	calm	normal	strong
How were the roads during this trip?	good	fair	poor
If there was snow on this trip how many times did you use chains?_________			

DATA OFFLOAD - When offloading a unit's data, enter its odometer or hubometer number in the corresponding space below.

Tractor	1st Trailer	1st Dolly	2nd Trailer	2nd Dolly	3rd Trailer

CRITICAL VEHICLE CONTROL OR VEHICLE PROBLEM - Please indicate with a (√) the nature of any significant incident(s) or problems.

___Sudden stop or aggressive braking
___Surprise maneuvering/steering to avoid an obstacle or vehicle
___ABS Warning light stays on or other ABS problem; unit number_______
___C-Dolly Problem; Please indicate unit number ___________________
___Other problem with the vehicle; please indicate ___________________

When did this occur? Please indicate the time and circle the appropriate conditions.

Approximate time:	_____________	am	pm		
Climate condition:	Clear	Fog	Rain	Snow/Ice	Windy
Road condition:	Dry	Wet	Snow	Ice	
Load condition:	Full		Empty		Mix

Please use the back of this form to describe the event in as much detail as possible.

ACCIDENT INVESTIGATION FORM

Fleet ________________ Case No.______ Tractor Unit No.______________

Trailer Unit Numbers: 1st________ 2nd__________ 3rd__________

Converter Dolly Unit Numbers 1st________ 2nd__________

Driver:____

ACCIDENT DESCRIPTION

Location:____

____

Date:__________________Time:__________

Other Vehicle(s)/Object(s) Involved:_______________________________

____

Driver(s) of Other Vehicle(s):_____________________________________

Description of Accident:____

____

____

____

PROPERTY DAMAGE

Subject Vehicle: Minor_____ Major_____

Other Vehicle(s): Minor_____ Major_____

INJURIES

Minor______ Major_____ Fatal_____

Person(s) Injured:____

Description of Injuries:____

____

____

____

CONDITIONS

WEATHER

The weather was: Clear_____ Cloudy/Overcast______ Rain_____ Snow______

Sleet______ Fog/Smog_____ Other____________________________________

The temperature was approximately ______ degrees F at the time of the accident.

LIGHT

Light conditions at the time of the accident were: Daylight_____ Dawn_____

Dusk_____ Dark_______ Other____

ROAD SURFACE

The road surface was: Dry______ Wet______Icy______ Snow Covered________

Other____

COMMENTS ON CONDITIONS

____
____
____
____

HIGHWAY (Use one for each roadway involved)

____is a_________ft wide, ___________

(roadway name)

lane,________way roadway with a______________surface in__________condition.

The road __________divided with a______ft wide, _________________type median.

(is, is not)

The traffic lanes are bounded on______________________by a______________________

(specify which side) (shoulder,

________________________and by a__________________________on the other side.

curb, etc.) (shoulder, curb, etc.)

________________________runs______________. The road is______________________

(roadway name) (direction) (straight/curved)

and_________________________ _____________% to ___________%. It is

level/slopes up/down) (percentage range)

________________________and has a maximum cross slope of approximately (crowned/not crowned)

___________in./ft.

(Discuss overhead lighting or other appropriate features and pertinent roadside terrain)

____
____
____
____
____
____
____
____
____
____
____

TRAFFIC CONTROLS (Use one for each roadway involved)

The posted speed limit on____________________ is__________mph. Traffic
(roadway name)

control devices consist of____
(pavement markings, regulatory, warning and guide signs)

They contributed to the accident as follows:______________________________

____

____

____

____

____

There__________________traffic control signal(s) in the area. They contributed to this
(are, are not)

accident/as follows____

____

____

____

____

____

____

____

____

____

VEHICLE LOADING

1st trailer:	Empty_____	Partial Load_____	Full Load_____
2nd trailer:	Empty_____	Partial Load_____	Full Load_____
3rd trailer:	Empty_____	Partial Load_____	Full Load_____

Axle weights (as appropriate):

Tractor

Steering axle________

1st drive axle________

2nd drive axle________

1st trailer

1st axle________

2nd axle________

Converter dolly________

2nd trailer

1st axle________

2nd axle________

Converter dolly________

3rd trailer

1st axle________

2nd axle________

Type of Load ____

____

DRIVER COMMENTS

Describe the accident:____

____

____

____

____

____

What was the approximate speed of your vehicle at beginning of the incident?______mph

What caused the accident?____

____

____

____

Was there any loss of braking control, such as wheel lockup? Yes_____ No______

If Yes, describe:____

____

____

Was there any loss of directional control such as trailer swing, jackknife or skidding?

Yes______ No_______ If Yes, describe:_____________________________________

____

____

____

Did the ABS cycle during the accident? Yes______ No_____ Don't know_______

Other comments?____

____

____

____

VEHICLE DAMAGE (Use one for each vehicle involved)

Identification: Unit Number (subject vehicle)________________________________

Other Vehicle:

Model Year________________________

Make & Model______________________

Type_____________________________

Damaged vehicle components include:____

____

____

____

____

____

____

Trailer damage(if applicable) includes:______________________________________

____

____

Vehicle braking components_______________suffer damage. Describe damage:
(did/did not)

____

____

____

____

Vehicle braking components played the following role in the accident:______________

____

____

____

____

Retail replacement value/repair cost of the damaged components is approx. $________.

SKETCH OF SCENE

Show any skid marks (indicate length), point of impact, final position of all vehicles involved. Supplement with photographs.

POLICE INVESTIGATION

Was the accident reported to a police agency? Yes_____ No_____ If Yes, which agency?____

Was a Police Report prepared? Yes_____ No_____ If Yes, attach a copy of the report.

CONCLUSIONS

Is there any indication that the ABS failed to function during this accident event?

Yes_____ No______

What role did ABS play in this accident, based on this investigation?

Not involved______

Caused the accident_____Explain______________________________________

____

____

Minimized the severity of the accident______ Basis for conclusion:__________

____

____

Failed to perform well enough to avoid the accident_____ Explain:___________

____

____

What role did the C-dollies play in this accident?

Not involved_____

Caused the accident_____ Explain:____________________________________

____

____

Minimized the severity of the accident_____ Basis for conclusion:___________

____

____

Failed to perform well enough to avoid the accident_____ Explain:___________

____

____

INVESTIGATOR

____ Date______________________

APPENDIX B

Instrumentation And Data Reduction

This appendix contains details of the electronic instrumentation system and data reduction procedures used in this study.

Contents:

Instrumentation System

A thorough set of specifications for the electronic data collection systems was established in the *Planning Study* and refined in the early stages of the *Field Tests* program.[1][1] These specifications follow at the end of this appendix.

In brief, each instrumented vehicle unit in the field study—tractor, trailer or C-dolly—carried its own, independent instrumentation system. The systems measured and recorded activity on their own units, and did not communicate with other units of the vehicle except to draw power from the auxiliary circuit of the seven-wire bundle that runs the length of the LCV.

The instrumentation system was equipped to monitor the items indicated in the following table.

The instrumentation systems operated in two basic modes. (1) The majority of the time they monitored vehicle activity and recorded data largely in the form of histograms and/or counts of specific events. For example, time and voltage was noted each time the driver applied the brakes supplying power to the brake light circuit. During brake applications, longitudinal accelerations and brake pressure activity were recorded in the

[1] Numbers in brackets refer to bibliographic references given in volume 1 of this report.

Table B-1. Channels of the Vehicle Instrumentation Systems

Channels	*Tractors*	*Trailers*	*C-dollies*
Lateral acceleration	X	X	
Longitudinal acceleration	X		
Wheel speeds	X	X	X
ABS voltage	X	X	X
ABS warning light	X	X	X
ABS modulator current	X	X	X
Brake line pressure	X	X	X
ABS modulator pressure	X	X	X
Steering activity			X

form of histograms. Similar histogram recordings of lateral acceleration were made continually. (2) When the monitoring function indicated an unusual event, continuous time histories were recorded. Triggers for time histories were based on high levels of lateral or longitudinal acceleration and/or substantial antilock activity.

Histograms were collected for the following variables:

- brake actuation pressure when brake lights were on (treadle pressure on tractors, service line pressure on trailers and dollies)
- longitudinal deceleration when brake lights were on
- absolute value of lateral acceleration when brake lights were not on
- absolute value of lateral acceleration when brake lights were on

The collection of all histogram-like data was subdivided by vehicle speed such that the histogram matrices can be thought of as two-dimensional: one dimension for the base variable (pressure or acceleration) and one for vehicle speed. The following seven speed ranges (all in mph) were used for all histograms: <5, 5–15, 15–25, 25–35, 35–45, 45–55, 55–65, >65. The matrix cell sizes for the primary variables are given in the specifications. The variable recorded in each matrix position was, of course, cumulative time spent with the vehicle operating under the conditions of speed and primary variable specified for the cell.

The *power spectral density* of lateral acceleration was also determined. It, too, was collected in two-dimensional matrix form with the same subdivision of vehicle speed forming one dimension. The second dimension was cumulative power of the lateral acceleration signal within specified frequency ranges. Seven frequency ranges were specified with center frequencies ranging from 0.25 hz to 1.0 hz. Division of the data in the frequency domain was actually accomplished by feeding the accelerometer signal to a

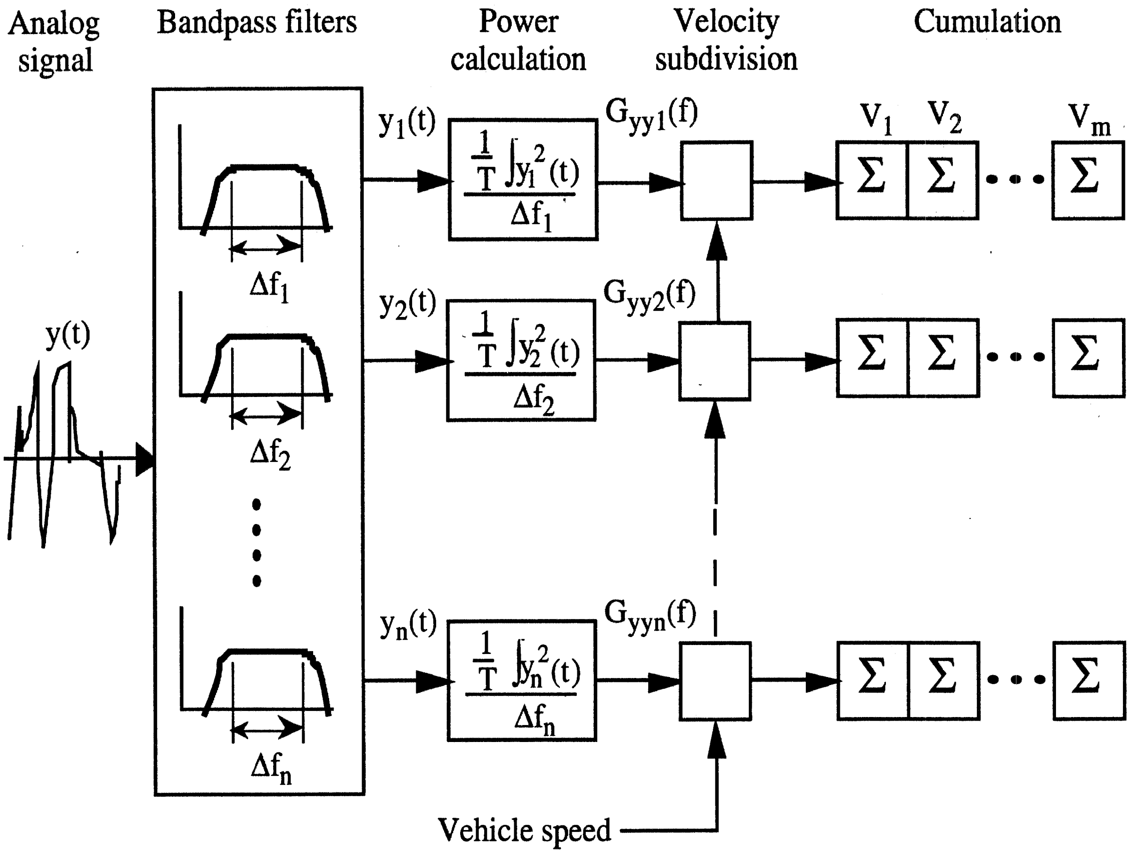


Figure B-1. Schematic of lateral acceleration PSD data collection system

bank of seven analog, bandpass filters. Output of the seven filters was then handled as seven individual signals for analog-to-digital transformation. These data channels were sampled continuously, subdivided according to vehicle speed and stored in cumulative fashion. Figure B-1 shows a schematic diagram of the system concept.

Data Collection System

Along with the instruments and data loggers mounted on the vehicles, the instrumentation system also included hand-held *devices for downloading data*, and communication computers in the fleet offices and at UMTRI and VMC. These items made up the hardware of the data collection system shown in figure B-2.

Drivers or fleet maintenance personnel were responsible for downloading data from the vehicles using the data downloading device. This device transfers the data to a memory card that is approximately the size of a credit card. These cards were then inserted into the fleet's communications computer and the data were downloaded from the card into the computer's memory. At night, the computer contacted VMC via telephone lines, and transferred the data to that office. Certain phases of data decompression and quality checking were undertaken by VMC prior to transferring it, again by phone line, to UMTRI. Final decompression and data analysis from a vehicle performance point of view was done by UMTRI.

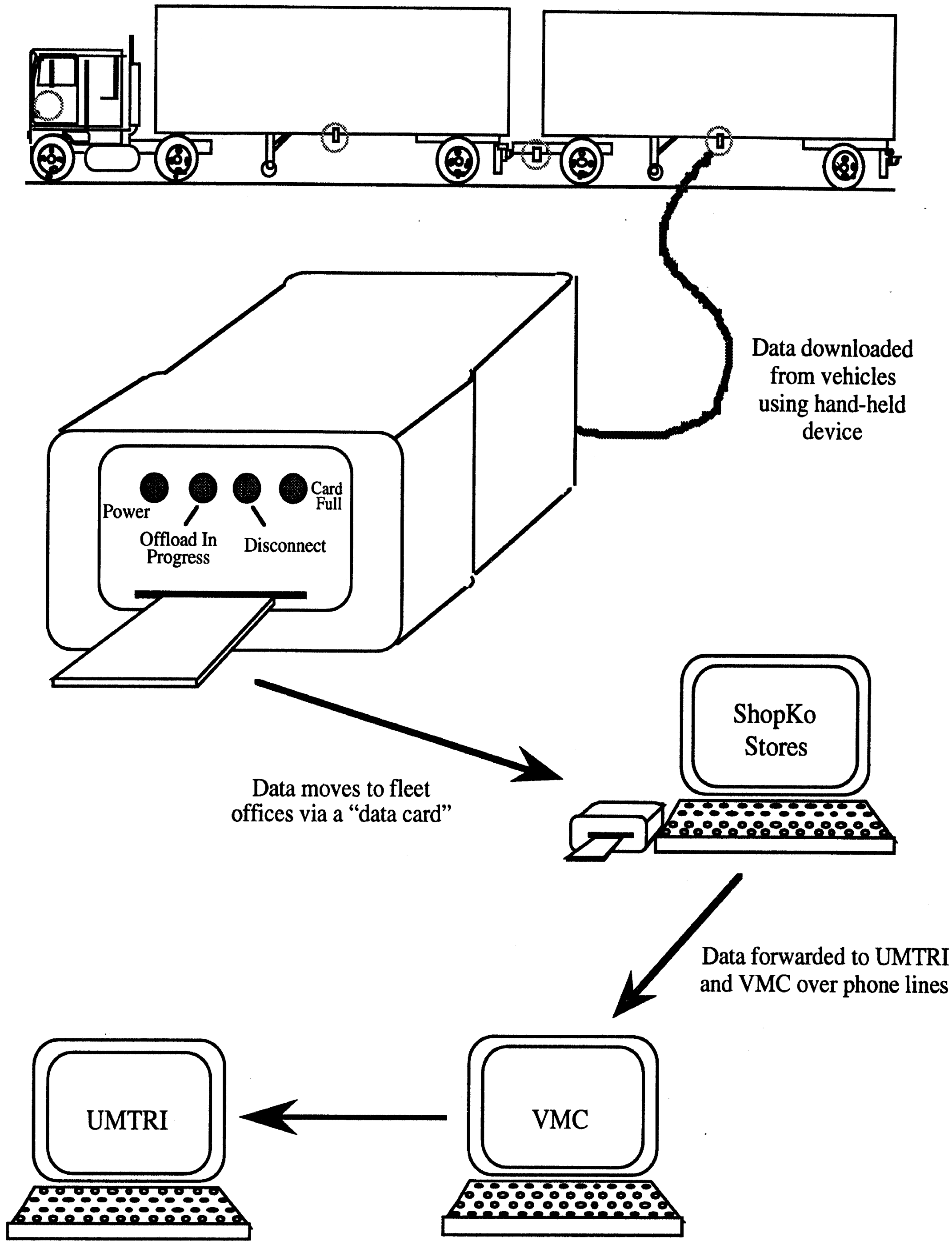


Figure B-2. A schematic view of the electronic data collection system

The specific procedures for data downloading were tailored to fit the needs of each fleet. For three of the fleets, instrument data collection was the responsibility of the driver. At the other two fleets, data were downloaded by maintenance supervisory personnel.

In some fleet operations, the vehicles were often broken down on the road. Trailers that began the trip could be left at a store and not return to the distribution center for some time. Other trailers previously dropped off could be picked up and brought home on the trip. To avoid delays in receiving data, minimize the logistical problems in data reduction, and to keep data records segregated by configuration and loading, whenever a driver made a substantial change to the configuration or loading of his vehicle, he was to download the data from the vehicle. Data were to be downloaded from each unit of the entire vehicle when it returned to the fleet distribution center.

The hand-held device was used to read data from the data loggers on board each unit of the LCV and to write the data to a memory card. The operators were given an adequate supply of cards and were trained in the use of the system. After all data were downloaded from the data logger to the memory cards, the data were erased from the logger memory, making it ready for the next trip. Similarly, when office personnel inserted the memory cards into the communications computer the data were transferred to the computer and the card erased for future use.

Maintenance of the system hardware and the continuous assurance of data quality was the responsibility of VMC corporation who was the supplier of the system software and hardware.

Special Synchronous Data Loggers For Continuous Recording Of Lateral Acceleration

Another element of the overall instrumentation system was a special set of instrumentation and data loggers constructed by UMTRI. This system was capable of continuous, synchronous recording of the lateral acceleration of the tractor and each trailer, respectively, along with the forward speed of the vehicle. The purpose of this system was to obtain the data needed to describe the *coherence functions* between the tractor lateral acceleration and that of each trailer, respectively. These coherence functions, along with the lateral acceleration PSD data gathered by the standard loggers, were used to calculate rearward amplifications functions in the frequency domain.

Four sets of instruments and loggers were constructed. Three of the four consisted of only a lateral accelerometer and the means for continuous data storage (at 12.5 hz). The fourth unit had the same capability plus a global positioning system used to obtain vehicle speed. (Self containment and ease of installation was a high priority in this system. Use of GPS for vehicle velocity met these requirements very nicely and provided more than adequate accuracy for the purpose.) When in use, these units were installed on the tractor (GPS unit) and up to three trailers of an LCV. Data recording was initiated synchronously in the four units prior to the start of the trip and gathered continuously. These units were operated by UMTRI's field representative who rode with the vehicle on the entire trip. A limited number of trips were taken with the system, but a minimum of one trip for each configuration and dolly style used by each of the five fleets were made.

Performance Data Processing

VMC was responsible for reviewing all data files received on a daily basis to ensure the integrity of the data and flag any faulty performance of either the instrumentation system or the ABS. VMC was to notify UMTRI of any potential problems identified in this process. VMC was to retain the data only for those purposes and was not to retain the data for the long term.

UMTRI was responsible for the technical analysis of the data files in terms of vehicle performance.

The first stage in data processing was to reorganize the data files by vehicle trip. When the data files were received by UMTRI, they were identified by a corresponding unit number and various dates and time stamps within the data. With this information and the Driver Trip Reports, the data files were grouped into sets that recreated all the units that were coupled together in an LCV for a particular trip. An example of the problem is illustrated in figure B-3. The figure illustrates the units of an LCV on a trip out from and back to the distribution center. The vehicle began as a fully loaded triple leaving the distribution center. When it arrived in the region of the stores it services, the driver broke apart the LCV for delivery of the individual trailers to three stores. In this period the vehicle operated as a single and a double. The loaded trailers were left at the stores and local empty trailers were collected. During this process the position of a particular trailer in the vehicle occasionally changed. The vehicle then returned to the distribution center with a different set of trailers. Sorting out the individual unit data files received after such a trip, in order to organize the data into a whole-vehicle picture was a major effort in the data analysis process.

Sorting of data files as described here was guided by time stamps. Each data file had a number of time/date stamps. Power-up and downloading times were used to superimpose files in a gross sense. The time of each brake application, determined by the brake light circuit coming on, was noted in the file. This provided high-density, intrafile time information. Brake-on time patterns could be used to clearly identify units connected in a vehicle and to closely align related events in different units. Each brake application stamp also included brake-light-circuit voltage. The assumption of progressively lower voltages moving rearward in the train were used to establish unit order. The written driver trip report was also an aid in this sorting process.

The manner of final manipulation of the data was generally very straightforward and, in most cases, is apparent from volume 1 of this report. Exceptions to this are:

- processing of brake-light-circuit voltage during braking with ABS activity

- determination of the number of *cycles* during ABS activity
- calculation of rearward amplification

Specifics of the data manipulation in these areas are described below.

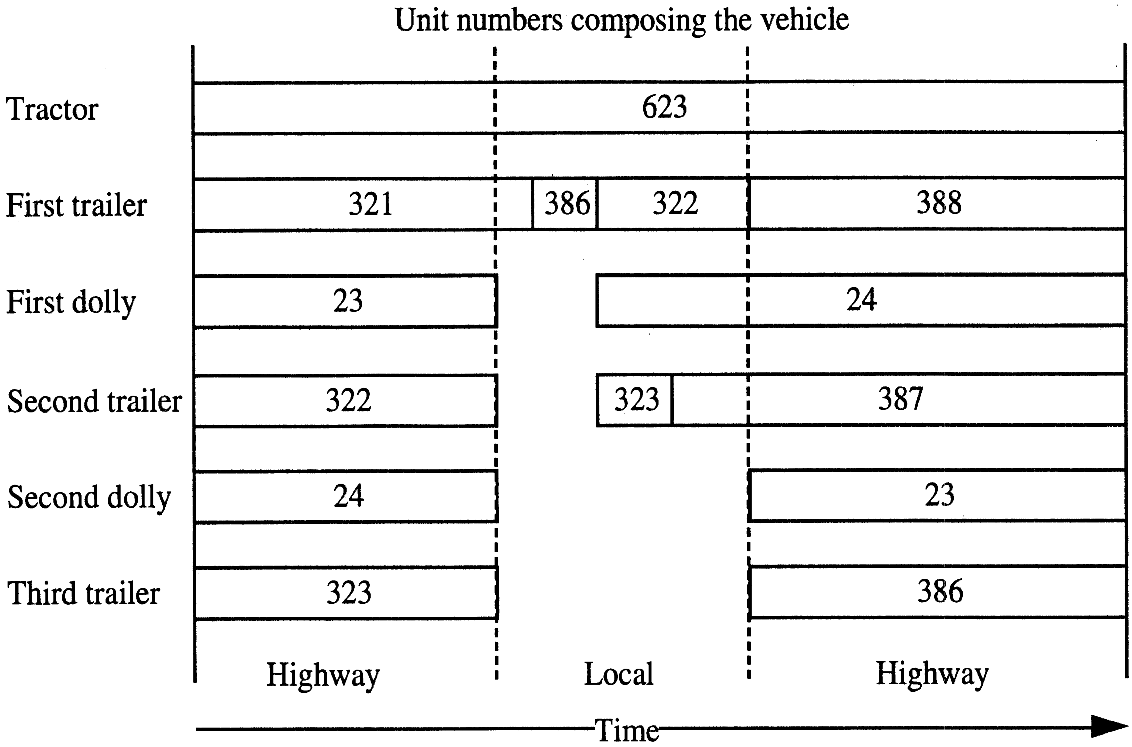


Figure B-3. A hypothetical example of the changing composition of a vehicle during one trip

Procedure for determining the brake-light-circuit voltage during braking with ABS activity

The instrumentation system on each vehicle unit recorded brake-light-circuit voltage continually during braking whenever there was significant ABS activity on that unit. These continuous recordings of brake-light-circuit voltage were analyzed to determine the percentage of time that this voltage (which is the ABS supply voltage) fell below three specific voltage thresholds.

The figure B-4 shows the time history data of an ABS event taken from a dolly with a single modulator ABS. Time, two wheel-speeds, brake-light-circuit voltage and the modulator-control signal are shown.

	TIME	S1	S2	BRK	I1
DATA	3600	10.0	11.0	12.36	0
DATA	3620	12.0	12.0	12.49	0
DATA	3640	10.0	10.7	12.55	0
DATA	3660	6.3	10.3	12.42	0
DATA	3680	5.0	8.0	12.23	10
DATA	3700	11.0	6.7	12.17	10
DATA	3720	12.0	15.0	12.17	10
DATA	3740	13.7	12.7	12.17	10
DATA	3760	11.0	11.7	12.10	10
DATA	3780	11.3	9.3	12.36	10
DATA	3800	11.7	10.7	12.04	10
DATA	3820	11.3	10.0	12.10	10
DATA	3840	11.0	10.3	12.17	10

Key:
DATA = Keyword
Time = 50 Hz Sampling
S1, S2 = Wheel Speeds
BRK = Brake Light Circuit Voltage
I1 = Modulator Activity; 0 = Off, 10 = On

Figure B-4. Example of time history recording including brake-light-circuit voltage and ABS modulator activity switch

Whenever there was modulator activity (I1=10), the corresponding brake-light-circuit voltage was compared to each threshold value and a count of the voltage values below each of the three thresholds was accumulated. If there were two modulators on a unit a separate count of the time below each threshold was made for single- and double-modulator activity. The time below each threshold was derived by multiplying these counts for each threshold by the data sampling period (0.02 sec). These times were then compared with the total time of modulator activity.

Procedure for determining the number of cycles during ABS activity

The occurrence of an ABS response *cycle* was determined by analyzing the wheel speed, treadle pressure, and chamber-pressure time-history data, during periods of modulator activity. A *cycle* was assumed to exist if a wheel experienced 20 percent or more longitudinal slip (where longitudinal slip is defined as one minus the ratio of tangential wheel speed at the tire/road interface to vehicle speed). However, because some of the cycles appeared to be insignificant (like hitting a pothole in the road), existence of the ABS cycle had to be confirmed by a significant change in the brake chamber pressure for that wheel. Like longitudinal slip (where the wheel speed is compared to the vehicle speed), the brake chamber pressure was compared to the service line pressure. If the change in the difference between the service line and brake chamber pressure exceeded a rate of change of 50 psi per second for two or more consecutive time steps (of 0.02 sec.), then the event was considered to be a legitimate ABS response cycle.

Procedure for determining rearward amplification

The term *rearward amplification* refers to the lateral acceleration gain exhibited between the tractor and the trailers of a combination vehicle. This gain is known to be sensitive to the frequency content of the maneuver in which the accelerations are observed. Thus, maneuver frequency is always a consideration in the evaluation of rearward amplification. Further, the most comprehensive approach to characterizing rearward amplification of a combination vehicle is to determine the full lateral acceleration gain function in the frequency domain through spectral analysis techniques. That, indeed, was the approach taken in this study.

The gain of any linear system in the frequency domain can be expressed in the following form:

$$G(\omega) = [PSD_o(\omega) / PSD_i(\omega)]^{1/2} * COH_{oi}(\omega) \qquad \text{(B-1)}$$

where

G	is the gain of the system
PSD_i	is the power spectral density of an input to the system (having adequate power throughout the frequency range of interest)
PSD_o	is the power spectral density of the output from the system
COH_{oi}	is the coherence function between the system output and input
ω	is frequency

For those not familiar with the language of the frequency domain and of spectral analysis techniques, *power spectral density* (PSD) is a means for condensing a long, continuous data signal (like the continuous measurement of the lateral acceleration of a tractor or a trailer) and characterizing it according to the amount of signal strength that it has at different frequencies. PSDs can be determined for individual signals, one at a time.

The *coherence function* is a means of examining two different continuous data signals and describing the extent to which one is related to the other; this is also done as a function of frequency. If one signal is purely the results of the other at a particular frequency, then the coherence at that frequency is one. If, on the other hand, the two signals have nothing to do with each other at a given frequency, then the coherence at that frequency is zero. Coherence functions can be determined only by the *simultaneous* analysis of the two signals of interest.

For example, consider a singer, singing into a microphone and the resulting reproduction of the singer's voice at the speakers. If the sound of the singers voice is one signal, and the sound produced by the speaker is the other, these two signals will have very high coherence (nearly one) at most frequencies covered by the singers voice. However, if the speaker is also producing a background hiss that results from a cheap audio amplifier system, then the coherence of the two signals will be much lower than one at the frequency of the hiss because so much of the output at this frequency is unrelated to the input.

The gain of this audio system can be determined (at those frequencies at which the singer provides sufficient power) by measuring the PSD of each signal, and dividing the *power* of the speaker sound by the *power* of the singer's voice and multiplying by the coherence of two signals at each frequency of interest. At most frequencies being sung, the gain would be virtually equal to the ratio of the power of the two signals at the frequency since the coherence at that frequency is one. At the frequency of the hiss, however, the extra power in the output signal makes the ratio of the two signals actually bigger than the true gain, but the lower value of the coherence at this frequency "corrects" the result to be equal to the true gain at this frequency.

In this study, rearward amplification was the gain of interest. The lateral acceleration of the tractor is the input signal, and the lateral acceleration of the trailer is the output signal. The data loggers installed on each tractor and each trailer continuously determine the PSD of the lateral acceleration of their respective unit. However, the loggers did not actually record lateral acceleration continuously, nor did they communicate with loggers on other units. Thus, the PSD functions needed to calculate rearward amplification were obtained by the loggers, the coherence function was not.[2]

Instead, the coherence functions for the vehicles of the study were determined through the separate measurements made using the special loggers built by UMTRI. As noted above, these loggers were capable of continuous and simultaneous recording of lateral acceleration of the tractor and trailers of a vehicle. Also as noted above, these loggers were used to measure the lateral acceleration time histories of at least one trip of each configuration of vehicle used by each participating fleet. These data were used to obtain a coherence function that was assumed to be characteristic of that type of vehicle. The extremely long time histories that were recorded (many hours of travel) and the fact that processing was done after-the-fact, allowed the use of sophisticated data analysis algorithms and the subsequent calculation of a continual coherence function from d.c. to well out beyond 1 hz. The coherence values used in the final calculation were the values taken from these continuous functions at the center-frequencies of the eight PSD frequency bins. (See the specifications at the end of this appendix.)

Calculation of rearward amplification was the finally accomplished on a trip-by-trip basis according to the following formula process.

In the following, the symbols i, j, and k are indices as follows:

- i — varies from 0 to 3 and represents the vehicle unit starting with the tractor and proceeding through up to three trailers
- j — varies from 1 to 7 and represents the seven frequency ranges of the PSD data collected by the data loggers (see logger specifications)
- k — varies from 5 to 7 and represents the three highest of the seven velocity ranges of the data loggers (above 45 mph, see logger specifications)

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2 This was not an oversight. The expense of an instrument system that could determine cohernece function was not feasible in terms of either the purchase cost to the project or the cost of burden to daily operations of the participating fleets.

The first step in processing was to normalize the PSD data from a unit by the power of the lowest frequency. That is:

$$P'(i,j,k) = P(i,j,k) / P(i,1,k) \quad \text{(B-2)}$$

where P is the logged power value and P' is the *normalized* power. The logged power value is in fact the *integral* of the filtered accelerometer signal typically *integrated over hours*. As for any long-term integration, absolute accuracy can only be achieved if the base signal is extremely accurate. Accelerometers of sufficient accuracy to allow absolute comparison (of these measures) across units was not economically or practically feasible. However, it is basic in spectral analysis process, that at sufficiently low frequency, the gain of the system is unity. Thus, in this case, the gain of the lowest frequency available is assumed to be one, and the problem of absolute accuracy is avoided by normalizing the data of each unit by the value of its own lowest frequency data.

Rearward amplification was then calculated according to the following:

$$RA(i,j,k) = [\, P'(i,j,k) / P'(0,j,k) \,]^{1/2} * COH(i,j,k) \quad \text{(B-3)}$$

where COH is the appropriate value of coherence derived from the simultaneous data processing described above.

The validity of this approach to the measurement of rearward amplification is worth questioning due to the unconventional elements of (1) the separate determination of coherence and (2) the assumption of a rearward amplification of unity for all trailers at the lowest frequency which is implied by the normalization of the PSD data. As evidence of the validity of the approach, we cite (1) the broad agreement in form of the results presented in this report and its appendices to the many findings on rearward amplification presented in the literature, and (2) the following specific comparison of results herein with previous work.

UMTRI has recently conducted work on behalf of the International Standards Organization (ISO) in its effort to develop standard test procedures for the measurement of rearward amplification in the test-track environment.[23,25] Of interest here is the result of computer modeling work which simulated the testing of a fully loaded, western double using an A-dolly and traveling at a speed of 62 mph. The work included the simulation of a pseudo-random steering test. The steering time history used for the simulation work was taken from data recorded in actual pseudo-random testing conducted by Volvo Heavy Truck at their test facilities in Sweden. The lateral acceleration gain of the second trailer of the simulated western double appears as the solid line plotted in figure B-5. Rearward amplification results for the second trailer of loaded western doubles and triples using A-dollies and traveling in the 55–66 mph speed range appear in the figure in the form of data points. The comparison is good, particularly for the western double. The shape of the two curves for western doubles is very similar and the two results show peak rearward amplifications occurring at virtually the same frequencies.

Note that for the LCV study data, lateral acceleration gain is identically 1.0 at the lowest frequency of 0.25 hz. This is a direct result of the decision to normalize the power data according to the value at this frequency. For the purpose of this discussion on validity, it is of interest to alter the process of normalization to force this value not to 1.0, but to 1.35, under the assumption that this is the correct value at this frequency as indicated by the simulation results. Figure B-6 compares the simulation results with the LCV study data which would result from this altered normalization. Under this assumption, the comparison between simulation results and the western double results from the LCV study are even more striking.

Finally on this subject, we note that the data reduction process which normalizes according to an independently established gain in the lowest frequency (1.35, in this case) may be more rationally defensible then the process actually used in this work (normalizing to 1). The former method might have been pursued by conducting reference simulations for each of the individual variations of the broad classes of vehicle configuration, loading condition, dolly type, velocity, etc. The rearward amplification value at 0.25 hz found for each trailer in each vehicle in each condition could have then been used as the normalizing reference for that group of units in the LCV study. We did not pursue this method for the obvious reason that it would add a great deal of complication without substantially changing the qualities of the findings. We point out however, that results from this method would show even greater differences (absolutely and proportionately) between the rearward amplification of vehicles using A-dollies and vehicles using C-dollies than are reported herein. This is so because (1) the reference values would generally be greater than one, and (2) the reference values for normalizing A-dolly data would be larger than the corresponding reference values for normalizing C-dolly data.

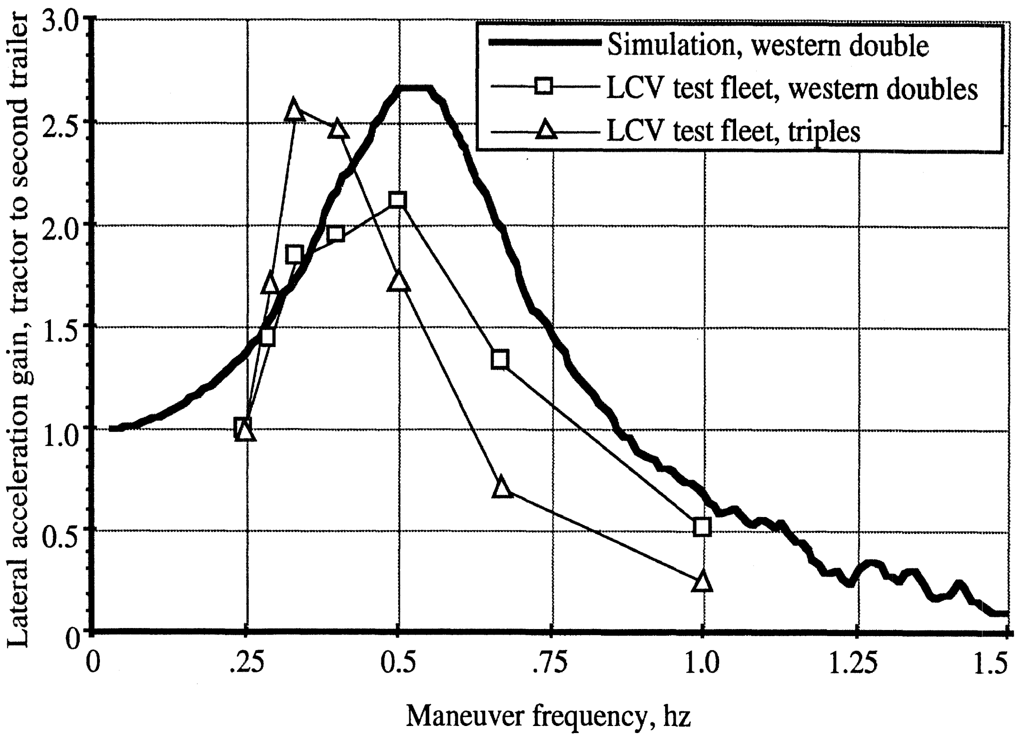


Figure B-5. Comparison of rearward amplification of the second trailer of short-trailer combinations as determined in the LCV field study and by vehicle simulation (assuming a reference gain of 1.0 for the field test data)

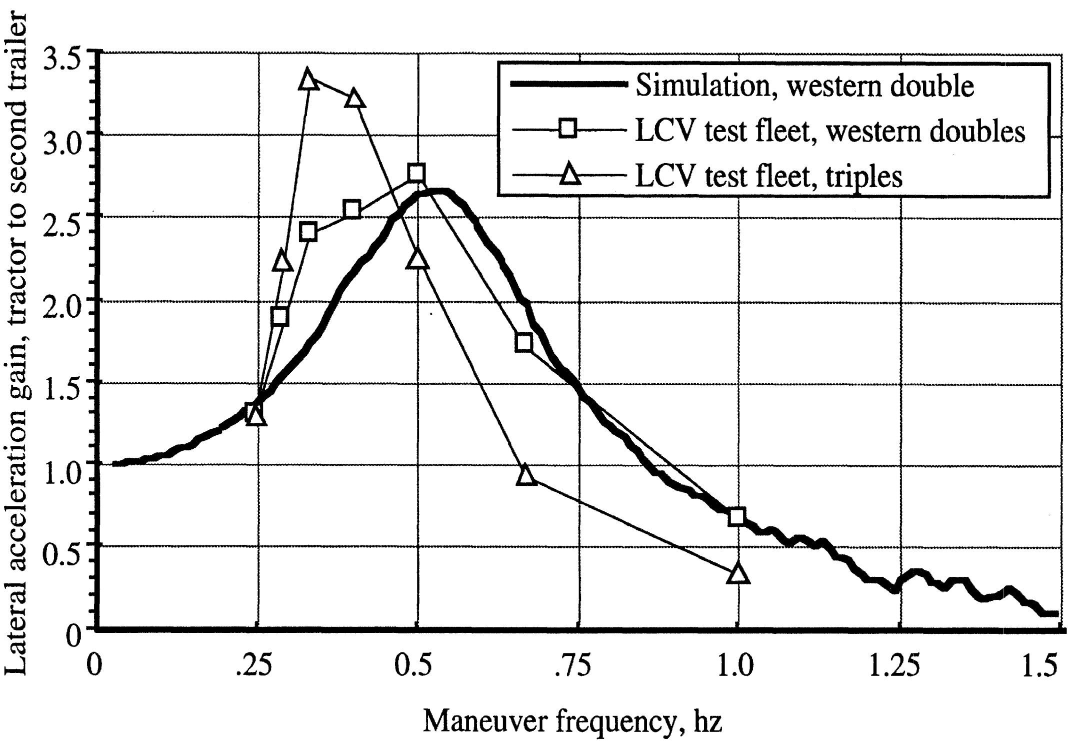


Figure B-6. Comparison of rearward amplification of the second trailer of short-trailer combinations as determined in the LCV field study and by vehicle simulation (assuming a reference gain of 1.35 for the field test data)

ELECTRONIC DATA LOGGER AND INSTRUMENTATION SPECIFICATION

REVISION HISTORY

Second submittal:

Item	Revision
6.1.	Changed number of wheel speed channels from four to six. Changed speed sensor threshold voltage from 250 mv to 750 mv.
6.7.	Deleted extraneous word "indicate".
8.1.1.3.3.10.	Added acceleration resolution bin.
8.1.1.3.3.11.	Added acceleration resolution bin.
8.1.1.6.1.	Added reference to non-event condition. Deleted reference to brake light signal state.
8.2.1.2.	Changed pre-event logging rate from ten to four Hz.
8.2.1.4.	Changed post event duration from one to three seconds. Changed post-event logging rate from ten to four Hz.
8.2.2.2.1.	Changed normal logger sample rate from 10 to 100 Hz.
8.2.2.7.	Added one second time constraint to the low speed termination condition.
8.2.8.2.	Deleted low acceleration termination condition from lateral acceleration event definition.

Implementation Version One

Item	Revision
8.1.1.2.3.	Rounded all fractional pressure range values up to the nearest psi.
8.1.1.4.3.	Revised acceleration ranges to be equal to those in 8.1.1.3.3.

Implementation Version Two

Item	Revision
8.2.1.2.	Increased pre-event sample rate from four to ten Hz.
8.2.1.4.	Increased post-event sample rate from four to ten Hz.
8.3.2.	Added description of brake light voltage exception criteria.

Implementation Version Three (Rev C)

Item	Revision
8.1.1.6	Extensively re-rewritten to reflect PSD board band pass frequencies, and software in lieu of hardware squaring.
6.9	Paragraph added to define the PSD board.

1.0 **OVERVIEW**

1.1. Data recorder supplier requirements.

1.1.1. The data recorder supplier shall furnish all materials, equipment, personnel, and facilities to design, build, and provide field service for data recorder systems.

1.1.2. The data recorder supplier shall provide instruction and guidance as necessary to enable service providers to install the data acquisition equipment on project vehicles.

1.1.3. The data recorder supplier shall provide documentation describing the construction, installation, and use of the data recorders.

1.1.4. The data recorder system shall include these components:
1.1.4.1. Sensors.
1.1.4.2. Cable to provide power and to connect system components.
1.1.4.3. Signal conditioning capability, as necessary.
1.1.4.4. Microprocessor capability sufficient to comply with the data acquisition, storage, and transfer requirements as detailed in this document.
1.1.4.5. All software necessary to accomplish these tasks:
1.1.4.5.1. Data acquisition (Ref 8.0.).
1.1.4.5.2. Data extraction (Ref 5.0.).
1.1.4.5.3. Display of data (Ref 9.0.).

2.0 PHYSICAL REQUIREMENTS FOR THE DATA RECORDER SYSTEM

2.1. The data recorder is required to withstand the levels of shock and vibration typically encountered in tractors, trailers, and dollies during normal on-highway service.

2.2. The data recorder shall operate for a minimum of two years without any scheduled maintenance.

2.3. The data recorder is required to function reliably over a temperature range of -20° - 140° F.

2.4. The data recorder is required to function reliably in humidity up to 99 percent.

2.5. The data recorder must be shielded against radiated emissions. Both the recorder enclosure and the various cables that attach to the recorder shall be shielded against radiated emissions. Additionally, the recorder shall not serve as a source of radiated emissions.

2.6. The data recorder enclosure and all its peripheral hardware must be sufficiently protected against moisture such that these components can be installed on the outside of a vehicle. Components installed on the outside of a vehicle shall be in an enclosure with an environmental integrity equivalent to the NEMA 4 standard.

2.7. If known in advance, data recorder components which will be installed inside a vehicle may be supplied in an enclosure with an environmental integrity equivalent to the NEMA 12 standard..

3.0. ELECTRICAL REQUIREMENTS FOR THE DATA RECORDER SYSTEM

3.1. The data recorder must perform all normal functions with supply voltages from 11 to 14 volts DC.

3.2. The data recorder is required to withstand supply voltage fluctuations of 7.2 to 16 volts DC without damage or loss of data.

3.3. The data recorder is required to retain data for 30 days during periods when vehicle power is not available.

4.0. MEMORY REQUIREMENTS FOR THE DATA RECORDER

4.1. The data recorder shall have 256 kilobytes of battery-backed RAM available for storage of data.

4.2. The data stored in recorder memory must be accessible by an MS-DOS computer via an RS-232 port.

5.0 DATA TRANSFER REQUIREMENTS FOR THE DATA RECORDER

5.1. The data logger must be capable of transferring 256 kilobytes of stored data to an MS-DOS computer in six minutes or less.

5.2. The data transfer procedure must be sufficiently simple such that a person who is "computer illiterate" can accomplish the transfer.

5.3. Upon completion of a successful offload, the memory of the data logger shall be reset to a state in which all registers and counters (except those which contain configuration and identification information) are reset to a default state.

6.0. INPUT CAPABILITIES FOR THE DATA RECORDER SYSTEMS

6.1. Six wheel speed pulse channels (frequencies in the range of 15 Hz to 1.2 KHz with a resolution of one mph with an accuracy of plus or minus one mph when speed sensor output voltage is in excess of 750 mv.

6.2. Five pressure channels with range from 0 to 150 psi with a resolution of plus or minus one psi. These pressure channels shall be optionally used for the measurement of other 0-5V DC analog data.

6.3. Two accelerometer channels with a resolution of 1 ft/sec≤ and an accuracy of plus or minus 0.5 ft/sec≤.

6.3.1. On tractor data recorder systems, one accelerometer shall be used for lateral acceleration (Ref 8.1.1.4.) and one accelerometer shall be used for longitudinal acceleration (Ref 8.1.1.3.).

6.3.2. On trailer data recorder systems, it shall not be necessary to provide a channel for longitudinal acceleration.

6.3.3. On dolly logger systems, it shall not be necessary to provide any accelerometer channels.

6.4. Four antilock solenoid activity channels which will indicate the Boolean state of modulator solenoid current.

6.5. One ABS warning lamp channel will indicate the Boolean state of a vehicle's warning lamp.

6.6. Data recorder power will be used to record the level of vehicle power as well as to determine the Boolean state of the vehicle's switched power.

6.7. One analog channel will be used to record the level of brake light voltage.

6.8. On dolly recorder systems, one pressure channel will be used to record the Boolean state of steering input (Ref 6.2.).

6.9 A PSD board will be supplied that will accept the lateral accelerometer output as an input, and provide seven channels of output as described in paragraph 8.1.1.6.

7.0 INTERNAL DATA TO BE PROVIDED BY THE DATA RECORDER SYSTEM

7.1. Real time clock information which provides the time and date of the occurrence of a data item, relative to the start of a file, with resolution to one second.

7.2. Vehicle identification.

7.3. Data recorder diagnostic status.

8.0. RECORDED INFORMATION TO BE PROVIDED BY THE DATA RECORDERS

8.1. HISTOGRAMS

8.1.1. The logger shall record histograms using the following bin structures as appropriate:

8.1.1.1. Various histograms are two-dimensional, with one independent variable being vehicle speed. In such an occasion, the histogram shall use the following speed bin ranges:

	Speed is greater than or equal to	and less than
8.1.1.1.1.	0 mph	5 mph
8.1.1.1.2.	5 mph	15 mph
8.1.1.1.3.	15 mph	25 mph
8.1.1.1.4.	25 mph	35 mph
8.1.1.1.5.	35 mph	45 mph
8.1.1.1.6.	45 mph	55 mph
8.1.1.1.7.	55 mph	65 mph
8.1.1.1.8.	65 mph	Unbounded

8.1.1.2. **Brake pressure histogram (tractors only).**

8.1.1.2.1. Recorded while switched power is available, vehicle speed is in excess of the Vehicle Speed Low Trip Point, and the brake light signal is high.

8.1.1.2.2. Counter incremented at 10 Hz.

8.1.1.2.3. Bin structure is eight arrays of 12 four-byte counters (384 bytes). Incrementation of a counter occurs as a function of vehicle speed (Ref 8.1.1.1.) and pressure. Pressure resolution is achieved using the following bins:

	Treadle pressure is greater than or equal to	and less than
8.1.1.2.3.1.	0.0 psi	3.0 psi
8.1.1.2.3.2.	3.0 psi	5.0 psi
8.1.1.2.3.3.	5.0 psi	8.0 psi
8.1.1.2.3.4.	8.0 psi	10.0 psi
8.1.1.2.3.5.	10.0 psi	13.0 psi
8.1.1.2.3.6.	13.0 psi	15.0 psi
8.1.1.2.3.7.	15.0 psi	18.0 psi
8.1.1.2.3.8.	18.0 psi	20.0 psi
8.1.1.2.3.9.	20.0 psi	25 .0 psi
8.1.1.2.3.10.	25.0 psi	35.0 psi
8.1.1.2.3.11.	35.0 psi	50.0 psi
8.1.1.2.3.12.	50.0 psi	Unbounded

8.1.1.3. **Longitudinal acceleration histogram (tractors only).**

8.1.1.3.1. Recorded continuously while switched power is available, vehicle speed is in excess of the Vehicle Speed Low Trip Point, and the brake light signal is high.

8.1.1.3.2. Counter incremented at 10 Hz.

8.1.1.3.3. Bin structure is eight arrays of 12 four-byte counters (384 bytes). Incrementation of a counter occurs as a function of vehicle speed (Ref 8.1.1.1.) and acceleration. Acceleration resolution is achieved using the following bins:

	Deceleration is greater than or equal to	and less than
8.1.1.3.3.1.	0 ft/sec^2	1 ft/sec^2
8.1.1.3.3.2.	1 ft/sec^2	2 ft/sec^2
8.1.1.3.3.3.	2 ft/sec^2	3 ft/sec^2
8.1.1.3.3.4.	3 ft/sec^2	4 ft/sec^2
8.1.1.3.3.5.	4 ft/sec^2	5 ft/sec^2
8.1.1.3.3.6.	5 ft/sec^2	6 ft/sec^2
8.1.1.3.3.7.	6 ft/sec^2	7 ft/sec^2
8.1.1.3.3.8.	7 ft/sec^2	8 ft/sec^2
8.1.1.3.3.9.	8 ft/sec^2	11 ft/sec^2
8.1.1.3.3.10.	11 ft/sec^2	13 ft/sec^2

8.1.1.3.3.11.	13 ft/sec^2	15 ft/sec^2
8.1.1.3.3.12.	15 ft/sec^2	Unbounded

8.1.1.4. **Lateral acceleration while brake light signal low histogram (tractors and trailers). (Type 0).**

8.1.1.4.1. Recorded continuously while switched power is available, vehicle speed is in excess of the Vehicle Speed Low Trip Point, and the brake light signal is low.

8.1.1.4.2. Counter incremented at 10 Hz.

8.1.1.4.3. Bin structure is eight arrays of 12 four-byte counters (384 bytes). Incrementation of a counter occurs as a function of vehicle speed (Ref 8.1.1.1.) and the absolute value of lateral acceleration. Acceleration resolution is achieved using the following bins:

	Absolute value of acceleration is greater than or equal to	and less than
8.1.1.4.3.1.	0 ft/sec^2	1 ft/sec^2
8.1.1.4.3.2.	1 ft/sec^2	2 ft/sec^2
8.1.1.4.3.3.	2 ft/sec^2	3 ft/sec^2
8.1.1.4.3.4.	3 ft/sec^2	4 ft/sec^2
8.1.1.4.3.5.	4 ft/sec^2	5 ft/sec^2
8.1.1.4.3.6.	5 ft/sec^2	6 ft/sec^2
8.1.1.4.3.7.	6 ft/sec^2	7 ft/sec^2
8.1.1.4.3.8.	7 ft/sec^2	8 ft/sec^2
8.1.1.4.3.9.	8 ft/sec^2	11 ft/sec^2
8.1.1.4.3.10.	11 ft/sec^2	13 ft/sec^2
8.1.1.4.3.11.	13 ft/sec^2	15 ft/sec^2
8.1.1.4.3.12.	15 ft/sec^2	Unbounded

8.1.1.5. **Lateral acceleration while brake light signal high histogram (tractors and trailers). (Type 1).**

8.1.1.5.1. Recorded continuously while switched power is available, vehicle speed is in excess of the Vehicle Speed Low Trip Point, and the brake light signal is high.

8.1.1.5.2. Counter incremented at 10 Hz.

8.1.1.5.3. Bin structure is eight arrays of 12 four-byte counters (384 bytes). Incrementation of a counter occurs as a function of vehicle speed (Ref 8.1.1.1.) and lateral acceleration. Acceleration resolution is achieved using the following bins:

	Absolute value of acceleration is greater than or equal to	and less than
8.1.1.5.3.1.	0 ft/sec^2	1 ft/sec^2
8.1.1.5.3.2.	1 ft/sec^2	2 ft/sec^2
8.1.1.5.3.3.	2 ft/sec^2	3 ft/sec^2
8.1.1.5.3.4.	3 ft/sec^2	4 ft/sec^2
8.1.1.5.3.5.	4 ft/sec^2	5 ft/sec^2

8.1.1.5.3.6.	5 ft/sec^2	6 ft/sec^2
8.1.1.5.3.7.	6 ft/sec^2	7 ft/sec^2
8.1.1.5.3.8.	7 ft/sec^2	8 ft/sec^2
8.1.1.5.3.9.	8 ft/sec^2	11 ft/sec^2
8.1.1.5.3.10.	11 ft/sec^2	13 ft/sec^2
8.1.1.5.3.11.	13 ft/sec^2	15 ft/sec^2
8.1.1.5.3.12.	15 ft/sec^2	Unbounded

8.1.1.6. **Lateral Acceleration Power Spectral Density**

8.1.1.6.1. PSD is recorded continuously after a settling period of 2 minutes have elapsed and switched power is available, vehicle speed is in excess of the Vehicle Speed Low Trip Point, and the logger is not in an event condition (Ref 8.2).

8.1.1.6.2. Counter incremented at 10 Hz.

8.1.1.6.3. Bin structure is a three dimensional array of three-byte counters:

- Σ Eight speed bins, reference 8.1.1.1,
- Σ Seven PSD Bins as described below,
- Σ Amplitude, 132 bins as described below.

This array will require 22,176 bytes. Incrementation of a counter occurs as a function of vehicle speed (Ref 8.1.1.1.) and PSD board output. A separate bin is provided for each speed increment, each PSD channel, and each PSD signal level. The PSD signal level is:

PSD_Sig = PSD_A/D_Count - Comp_Null

where the PSD_Sig is the PSD signal level, PSD_A/D_Count is the Analog to Digital converter count for the PSD channel, and Comp_Null is the computed offset or null for the PSD channel. The PSD board will filter the lateral acceleration signal with the low pass and high pass frequencies as defined below, using 4th order roll off for both the high pass and low pass, using a Butterworth implementation with a damping ratio of 0.7:

	High Pass break point	Low Pass break point
8.1.1.6.3.1.	1.115 Hz	0.990 Hz
8.1.1.6.3.2.	0.990 Hz	0.865 Hz
8.1.1.6.3.3.	0.865 Hz	0.740 Hz
8.1.1.6.3.4.	0.740 Hz	0.616 Hz
8.1.1.6.3.5.	0.615 Hz	0.490 Hz
8.1.1.6.3.6.	0.490 Hz	0.365 Hz
8.1.1.6.3.7.	0.365 Hz	0.240 Hz

8.1.1.6.4. The bins are counters. There is a separate bin for each speed range, PSD channel and output level. Each 100 milliseconds (except for the settling time or during a lateral event) one bin for each PSD channel will be incremented. The bin incremented will depend upon the vehicle speed and the output level. Each bin will have the count of occurrences of 0.1 second time intervals that the speed and output level were in the ranges that particular bin represents. The accumulated PSD for each channel can then be computed by the following equation:

$$PSD_c = 0\Sigma Bin0 + 1\Sigma Bin_{c1} + 4\Sigma Bin_{c2} + 9\Sigma Bin_{c3} + 16\Sigma Bin_{c4} \ldots\ldots + 17{,}161\Sigma Bin_{c131}$$

where c is the PSD channel number, and the Bin subscript number represents the signal level bin for that channel.

8.1.1.6.5 The Null for each channel will be computed by using a recursive filter that increments the long present value for the null by the equivalent of one count, i.e.:

$$Null_{cn} = x/(2^n) + Null_{cn-1}(1-1/2^n)$$

where x is 0 if the signal level is zero, +1 if the signal level >0 and -1 if the signal level <0. The Bin_{132} will be considered overrange, and will not be included in the PSD sum. If there are a few counts in this bin, it can be assumed that there was a event that created an "out of range" condition. If this bin is full of counts, a filter failure for this channel can be assumed.

8.1.1.7. **Solenoid pulse count histogram (tractors, trailers, and dollies),**

8.1.1.7.1. Recorded continuously while switched power is available and vehicle speed is in excess of the Vehicle Speed Low Trip Point.

8.1.1.7.2. Counter incremented at 10 Hz.

8.1.1.7.3. Bin structure is six four-byte counters (24 bytes). Incrementation of a counter occurs when a solenoid state transitions from on to off (trailing edge triggered).

8.2. **EVENTS**

8.2.1. An event will be recorded in logger memory with the following format:

8.2.1.1. EVENT START exception.

8.2.1.2. Pre-event data. This shall be comprised of a record of all active sensor readings for the three seconds which preceded the event condition, recorded at 10 Hz.

8.2.1.3. Event data. This shall be comprised of all active sensors readings, recorded at 50 Hz.

8.2.1.4. Post-event data. This shall be comprised of all active sensor readings for the three seconds which followed the event condition, recorded at 10 Hz.

8.2.1.5. EVENT END exception.

8.2.1.6. An INTO EVENT exception will be recorded in the event table. This exception will be comprised of a time stamp followed by a bit map of the event conditions which initiated the event.

8.2.1.7. An OUT OF EVENT exception will be recorded in the event table. This exception will be comprised of a time stamp followed by the OR'ed result of every event initiation condition which occurred during the event.

8.2.2. Event initiation and termination shall be accomplished by testing the state of the following conditions:

8.2.2.1. Vehicle Speed > Vehicle Speed High Trip Point ($Speedv > Speed_{HTP}$)

8.2.2.1.1. Vehicle Speed is defined as the highest functional wheel speed taken during a sample period.

8.2.2.1.2. The vehicle speed high trip point is currently set at 8 mph.

8.2.2.2. Solenoid Activity Density > Solenoid Activity Density Trip Point ($ActDens_{Sol} > ActDens_{TP}$)

8.2.2.2.1. When a sample of all sensors is taken at a rate of approximately 100 Hz, the logger shall determine at each sample period if there was any solenoid activity. This shall effectively be determined by OR'ing together the activity status of all functional current sensors. The logger shall maintain a queue of the last ten such status bytes. The solenoid activity density is determined by counting the number of samples periods over the last ten sample periods (last 100 ms) which had solenoid activity.

8.2.2.2.2. The solenoid activity density trip point is currently set at 20 percent. This implies that the solenoid activity density must be at least 30 percent to set this flag.

8.2.2.2.3. The solenoid activity density trip point shall be field programmable.

8.2.2.3. Brake Light Voltage > Brake Light Voltage Trip Point ($Voltage_{brake} > Voltage_{brakeTP}$)

8.2.2.3.1. The brake light voltage trip point shall, by default, be set at 6 volts.

8.2.2.3.2. The brake light voltage trip point shall be field programmable.

8.2.2.4. Wheel Lock Duration (Wheel Lock)

8.2.2.4.1. A wheel is deemed to be in a lock state when the speed of a wheel drops below 50 percent of vehicle speed for more than 100 milliseconds.

8.2.2.5. Lateral Acceleration > Lateral Accel Trip Point For Accel Trip Point Period ($Accel_{lat} > Accel_{latTP}$)

8.2.2.5.1. The lateral acceleration trip point will, by default, be set at $|8|$ ft/sec^2. The "left" and "right" trip points shall be field programmable.

8.2.2.5.2. The lateral acceleration trip point period will, by default, be set at 0.3 sec, This parameter shall be field programmable.

8.2.2.6. Solenoids inactive for a period of time exceeding the post-event time ($Inactive_{sol}$).

8.2.2.7. Vehicle Speed < Low Trip Point ($Speed_v < Speed_{LTP}$) for one second.

8.2.2.7.1. The vehicle speed low trip point is currently set at 3 mph.

8.2.2.8. Event Time Out (Time Out_{Event})

8.2.2.8.1. The event time out is currently set at 5 seconds. If any event termination condition has not been encountered within the specified period after an event initiation condition has been encountered, then this flag shall be set to TRUE in order to terminate the event.

8.2.3. When the logger is in a non-event state and an event initiation condition is detected, the logger shall write the items mentioned in 8.2.1.1, 8.2.1.2., and 8.2.1.6. to logger memory.

8.2.3.1. The event initiation condition shall be maintained by the logger for the duration of the event.

8.2.3.2. While recording event data to memory, the logger shall continue to test data for event termination conditions or new event initiation conditions. If a new event initiation condition is satisfied before an event termination condition is encountered, the following actions shall occur:

8.2.3.2.1. The event time-out clock shall be reset to zero.

8.2.3.2.2. The logger shall OR the new event initiation condition with all previous event initiation conditions which have occurred since the last event termination.

8.2.3.2.3. The logger shall use the most recent event initiation condition to test for initiation-condition-specific event termination conditions.

8.2.4. While in an event condition, the logger shall perform these tasks:

8.2.4.1. Sample data at 50 Hz and write the data from all active sensors to logger memory.

8.2.4.2. Test data for event termination conditions or new event initiation conditions. If a new event initiation condition is satisfied before an event termination condition is encountered, the following actions shall occur:

8.2.4.2.1. The event time-out clock shall be reset to zero.

8.2.4.2.2. The logger shall OR the new event initiation condition with all previous event initiation conditions which have occurred since the last event termination.

8.2.4.2.3. The logger shall use the most recent event initiation condition to test for initiation-condition-specific event termination conditions.

8.2.4.2.4. Record POWER DOWN exceptions as necessary.

8.2.5. When the logger is in an event state and appropriate event termination condition is encountered, the logger shall write the items mentioned in 8.2.1.4, 8.2.1.5., and 8.2.1.7. to logger memory.

8.2.6. **Solenoid Event Definition**

8.2.6.1. Initiation:

	Condition	State
8.2.6.1.1.	($Speedv > Speed_{HTP}$)	True
8.2.6.1.2.	($ActDens_{Sol} > ActDens_{TP}$)	True
8.2.6.1.3.	($Voltage_{brake} > Voltage_{brakeTP}$)	True
8.2.6.1.4.	Wheel Lock	Don't Care
8.2.6.1.5.	($Accel_{lat} > Accel_{latTP}$)	Don't Care

8.2.6.1.6.	(Inactive$_{sol}$)	Don't Care
8.2.6.1.7.	(Speed$_V$ < Speed$_{LTP}$)	Don't Care
8.2.6.1.8.	(Time Out$_{Event}$)	Don't Care

8.2.6.2. Solenoid Inactivity Termination

	Condition	State
8.2.6.2.1.	(Speedv > Speed$_{HTP}$)	Don't Care
8.2.6.2.2.	(ActDens$_{Sol}$ > ActDens$_{TP}$)	Don't Care
8.2.6.2.3.	(Voltage$_{brake}$ > Voltage$_{brakeTP}$)	Don't Care
8.2.6.2.4.	Wheel Lock	Don't Care
8.2.6.2.5.	(Accel$_{lat}$ > Accel$_{latTP}$)	Don't Care
8.2.6.2.6.	(Inactive$_{sol}$)	True
8.2.6.2.7.	(Speed$_V$ < Speed$_{LTP}$)	Don't Care
8.2.6.2.8.	(Time Out$_{Event}$)	Don't Care

8.2.6.3. Time Out Termination

	Condition	State
8.2.6.3.1.	(Speedv > Speed$_{HTP}$)	Don't Care
8.2.6.3.2.	(ActDens$_{Sol}$ > ActDens$_{TP}$)	Don't Care
8.2.6.3.3.	(Voltage$_{brake}$ > Voltage$_{brakeTP}$)	Don't Care
8.2.6.3.4.	Wheel Lock	Don't Care
8.2.6.3.5.	(Accel$_{lat}$ > Accel$_{latTP}$)	Don't Care
8.2.6.3.6.	(Inactive$_{sol}$)	Don't Care
8.2.6.3.7.	(Speed$_V$ < Speed$_{LTP}$)	Don't Care
8.2.6.3.8.	(Time Out$_{Event}$)	True

8.2.6.4. Low Speed Termination

	Condition	State
8.2.6.4.1.	(Speedv > Speed$_{HTP}$)	Don't Care
8.2.6.4.2.	(ActDens$_{Sol}$ > ActDens$_{TP}$)	Don't Care
8.2.6.4.3.	(Voltage$_{brake}$ > Voltage$_{brakeTP}$)	Don't Care
8.2.6.4.4.	Wheel Lock	Don't Care
8.2.6.4.5.	(Accel$_{lat}$ > Accel$_{latTP}$)	Don't Care
8.2.6.4.6.	(Inactive$_{sol}$)	Don't Care
8.2.6.4.7.	(Speed$_V$ < Speed$_{LTP}$)	True
8.2.6.4.8.	(Time Out$_{Event}$)	Don't Care

8.2.7. **Wheel Lock Event Definition**

8.2.7.1. Initiation:

	Condition	State
8.2.7.1.1.	(Speed$_V$ > Speed$_{HTP}$)	True
8.2.7.1.2.	(ActDens$_{Sol}$ > ActDens$_{TP}$)	Don't Care

8.2.7.1.3.	($Voltage_{brake} > Voltage_{brakeTP}$)	True
8.2.7.1.4.	Wheel Lock	True
8.2.7.1.5.	($Accel_{lat} > Accel_{latTP}$)	Don't Care
8.2.7.1.6.	($Inactive_{sol}$)	Don't Care
8.2.7.1.7.	($Speed_{V} < Speed_{LTP}$)	Don't Care
8.2.7.1.8.	($Time\ Out_{Event}$)	Don't Care

8.2.7.2. Unlock Termination:

	Condition	State
8.2.7.2.1.	($Speed_{V} > Speed_{HTP}$)	Don't Care
8.2.7.2.2.	($ActDens_{Sol} > ActDens_{TP}$)	Don't Care
8.2.7.2.3.	($Voltage_{brake} > Voltage_{brakeTP}$)	Don't Care
8.2.7.2.4.	Wheel Lock	False
8.2.7.2.5.	($Accel_{lat} > Accel_{latTP}$)	Don't Care
8.2.7.2.6.	($Inactive_{sol}$)	Don't Care
8.2.7.2.7.	($Speed_{V} < Speed_{LTP}$)	Don't Care
8.2.7.2.8.	($Time\ Out_{Event}$)	Don't Care

8.2.7.3. Time Out Termination:

	Condition	State
8.2.7.3.1.	($Speed_{V} > Speed_{HTP}$)	Don't Care
8.2.7.3.2.	($ActDens_{Sol} > ActDens_{TP}$)	Don't Care
8.2.7.3.3.	($Voltage_{brake} > Voltage_{brakeTP}$)	Don't Care
8.2.7.3.4.	Wheel Lock	Don't Care
8.2.7.3.5.	($Accel_{lat} > Accel_{latTP}$)	Don't Care
8.2.7.3.6.	($Inactive_{sol}$)	Don't Care
8.2.7.3.7.	($Speed_{V} < Speed_{LTP}$)	Don't Care
8.2.7.3.8.	($Time\ Out_{Event}$)	True

8.2.7.4 Low Speed Termination

	Condition	State
8.2.7.4.1.	($Speedv > Speed_{HTP}$)	Don't Care
8.2.7.4.2.	($ActDens_{Sol} > ActDens_{TP}$)	Don't Care
8.2.7.4.3.	($Voltage_{brake} > Voltage_{brakeTP}$)	Don't Care
8.2.7.4.4.	Wheel Lock	Don't Care
8.2.7.4.5.	($Accel_{lat} > Accel_{latTP}$)	Don't Care
8.2.7.4.6.	($Inactive_{sol}$)	Don't Care
8.2.7.4.7.	($Speed_{V} < Speed_{LTP}$)	True
8.2.7.4.8.	($Time\ Out_{Event}$)	Don't Care

8.2.8. **Lateral Acceleration Event Definition**

8.2.8.1. Initiation

	Condition	State
8.2.8.1.1.	($Speed_V > Speed_{HTP}$)	True
8.2.8.1.2.	($ActDens_{Sol} > ActDens_{TP}$)	Don't Care
8.2.8.1.3.	($Voltage_{brake} > Voltage_{brakeTP}$)	Don't Care
8.2.8.1.4.	Wheel Lock	Don't Care
8.2.8.1.5.	($Accel_{lat} > Accel_{latTP}$)	True
8.2.8.1.6.	($Inactive_{sol}$)	Don't Care
8.2.8.1.7.	($Speed_V < Speed_{LTP}$)	Don't Care
8.2.8.1.8.	($Time\ Out_{Event}$)	Don't Care

8.2.8.2. Low Acceleration Termination: Deleted (Second Submittal)

8.2.8.3. Time Out Termination:

	Condition	State
8.2.8.3.1.	($Speed_V > Speed_{HTP}$)	Don't Care
8.2.8.3.2.	($ActDens_{Sol} > ActDens_{TP}$)	Don't Care
8.2.8.3.3.	($Voltage_{brake} > Voltage_{brakeTP}$)	Don't Care
8.2.8.3.4.	Wheel Lock	Don't Care
8.2.8.3.5.	($Accel_{lat} > Accel_{latTP}$)	Don't Care
8.2.8.3.6.	($Inactive_{sol}$)	Don't Care
8.2.8.3.7.	($Speed_V < Speed_{LTP}$)	Don't Care
8.2.8.3.8.	($Time\ Out_{Event}$)	True

8.2.8.4 Low Speed Termination

	Condition	State
8.2.8.4.1.	($Speedv > Speed_{HTP}$)	Don't Care
8.2.8.4.2.	($ActDens_{Sol} > ActDens_{TP}$)	Don't Care
8.2.8.4.3.	($Voltage_{brake} > Voltage_{brakeTP}$)	Don't Care
8.2.8.4.4.	Wheel Lock	Don't Care
8.2.8.4.5.	($Accel_{lat} > Accel_{latTP}$)	Don't Care
8.2.8.4.6.	($Inactive_{sol}$)	Don't Care
8.2.8.4.7.	($Speed_V < Speed_{LTP}$)	True
8.2.8.4.8.	($Time\ Out_{Event}$)	Don't Care

8.3. EXCEPTIONS

8.3.1. The logger shall record self-diagnostics exceptions in memory. Additionally, exceptions shall be recorded in logger memory when the following events occur:

	EVENT	TIME STAMP	ADDITIONAL INFORMATION
8.3.1.1.	POWER ON	YES	NONE
8.3.1.2.	POWER OFF	YES	NONE
8.3.1.3.	THIS OFFLOAD	YES	NONE

8.3.1.4.	LAST OFFLOAD	YES	NONE
8.3.1.5.	BRAKE LIGHT ON	YES	BRAKE LIGHT VOLTAGE LEVEL
8.3.1.6.	EVENT START	YES	NONE
8.3.1.7.	EVENT END	YES	NONE
8.3.1.8.	WARN ON	YES	WHEELS SPEEDS, ECU POWER LEVEL
8.3.1.9.	WARN OFF	YES	NONE
8.3.1.10.	CAPTURE START	YES	NONE
8.3.1.11.	CAPTURE END	YES	NONE
8.3.1.12.	INTO EVENT	YES	EVENT INITIATION CONDITION
8.3.1.13.	OUT OF EVENT	YES	OR'ed SUM OF ALL EVENT INITIATION CONDITIONS WHICH OCCURRED DURING THE EVENT.

8.3.2. The brake light voltage level referenced in 8.3.1.5. shall be recorded 20 milliseconds after the brake light voltage trip point has been exceeded.

8.4 CAPTURED DATA

8.4.1. The logger normally logs data when triggered by an event condition. It shall be possible to log data upon demand by the user (via an RS-232 link). This data is defined as "captured data".

8.4.2. Captured data shall be logged at 100 Hz. Data will continue to be logged until one of the following conditions occur:

8.4.2.1. The operator notifies the logger to stop capturing data (via an RS-232 link).

8.4.2.2. The logger memory is exhausted.

8.4.3. A CAPTURE START exception shall be written to logger memory when the START CAPTURE command is received.

8.4.4. Captured data shall include a sample from every active sensor.

8.4.5. A CAPTURE END exception shall be written to logger memory when the END CAPTURE command is received.

8.5. EVENT TABLE

8.5.1. The event table is a list of event start and end time and conditions. It appears in a data file immediately after the THIS OFFLOAD exception.

8.5.2. The event list shall consist of a series of matched sequential pairs of INTO EVENT and OUT OF EVENT exceptions. A matched pair shall appear for every event which occurs in the file.

8.6. MAINTAINED PARAMETERS

8.6.1. Distance traveled between consecutive offloads.

9.0. DATA RECORDER OUTPUT

9.1. Data extracted from recorder memory will consist of all data stored in available memory since the last data extraction.

9.2. A report on data collected shall be capable of providing the following items:

9.2.1. Vehicle identification information (Ref 7.2.).

9.2.2. A sequential list of the time and date of each exception (Ref 8.3.).

9.2.3. A sequential list of the time, date, and duration of each event (Ref 8.2.).

9.2.4. A sequential history of data recorded during braking events (Ref 8.2.1.3.).

9.2.5. A summary of all histograms recorded (Ref 8.1.).

9.2.6. A summary of all maintained parameters (Ref 8.6.).

9.2.7. A sensor diagnostic report (Ref 8.3.1.).

APPENDIX C

FLEET PERSONNEL OPINIONS AND COMMENTS

This appendix contains additional information on the reactions and opinions of fleet personnel to the C-dolly and ABS. This information includes:

Average Age And Experience Of The Fleet Personnel

Table C-1 below summarizes the average age and years of experience with heavy-trucks of each group involved in the study. The average age of the participants at the start of the study was forty-two years. The average length of heavy-truck experience was nineteen years.

The table also shows the number of survey responses for each evaluation period. The large number of responses to the first survey was due to the fact that all potential participants were asked to complete an evaluation at the start of the study. In subsequent survey periods, only drivers who had some experience with the test units were asked to complete the forms. The number of participants in the fourth survey period is low due to a strike of drivers and loading-dock clerks at one of the fleets.

Table C-1. The number of survey participants and their average age and experience

	Average (years)		*Total Number of Participants for each Evaluation Period*				
Group	*Age*	*Experience*	*1*	*2*	*3*	*4*	*5*
Drivers	44	21	49	28	31	20	38
Managers	45	22	14	16	14	8	15
Mechanics	36	14	29	25	21	16	20
All Personnel	42	19	92	69	66	44	73

Driver Opinion Form

Name	Company	Date

Please answer the following questions by circling the appropriate number that best represents your opinion. The numbers represent a scale defined by the smaller text written above the numbers 1, 4, and 7. (Comments can be written on the back.)

1) How familiar are you with Anti-lock Braking Systems (ABS)?

not familiar			somewhat familiar			very familiar
1	2	3	4	5	6	7

2) How would you rate the reliability of ABS?

not reliable			average reliability			very reliable
1	2	3	4	5	6	7

3) What is your opinion regarding ABS on tractors?

strongly opposed			no opinion			strongly favor
1	2	3	4	5	6	7

4) What is your opinion regarding ABS on trailers?

strongly opposed			no opinion			strongly favor
1	2	3	4	5	6	7

5) What is your opinion regarding ABS on dollies?

strongly opposed			no opinion			strongly favor
1	2	3	4	5	6	7

6) Have you ever been in an emergency situation where ABS helped you avoid or reduce the severity of an accident?

never			a few times			many times
1	2	3	4	5	6	7

7) How would you rate the importance of having ABS on the tractor you drive?

not important			does not matter			very important
1	2	3	4	5	6	7

8) Do you feel ABS on the entire vehicle (tractor, trailers, dolly(s)) changes your job?

makes it easier			no change			makes it harder
1	2	3	4	5	6	7

9) How familiar are you with double draw-bar C-dollies?

not familiar			somewhat familiar			very familiar
1	2	3	4	5	6	7

10) How would you rate the reliability of the C-dolly?

not reliable			average reliability			very reliable
1	2	3	4	5	6	7

11) Judging from your experience with A- and C-dollies, is one more difficult to use?

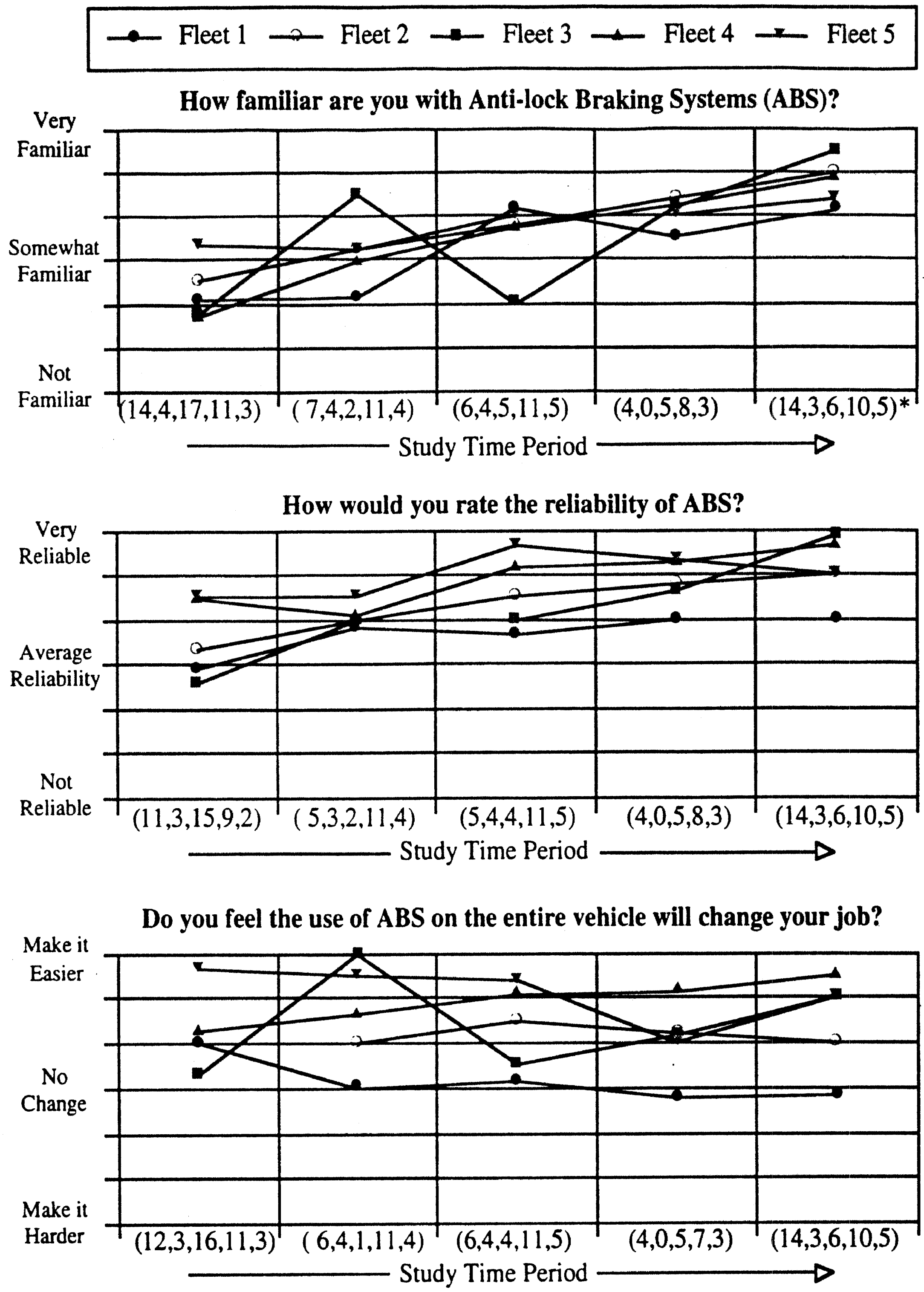
A-Dolly more difficult			both are the same			C-Dolly more difficult
1	2	3	4	5	6	7

12) Does the use of the C-dolly change your job?

makes it easier			no change			makes it harder
1	2	3	4	5	6	7

13) What is your opinion of using C-dollies in double and triple combinations?

strongly opposed			no opinion			strongly favor
1	2	3	4	5	6	7



*Number of replies for each evaluation period.

Figure C-1. Reaction of drivers to ABS for each fleet in the LCV study

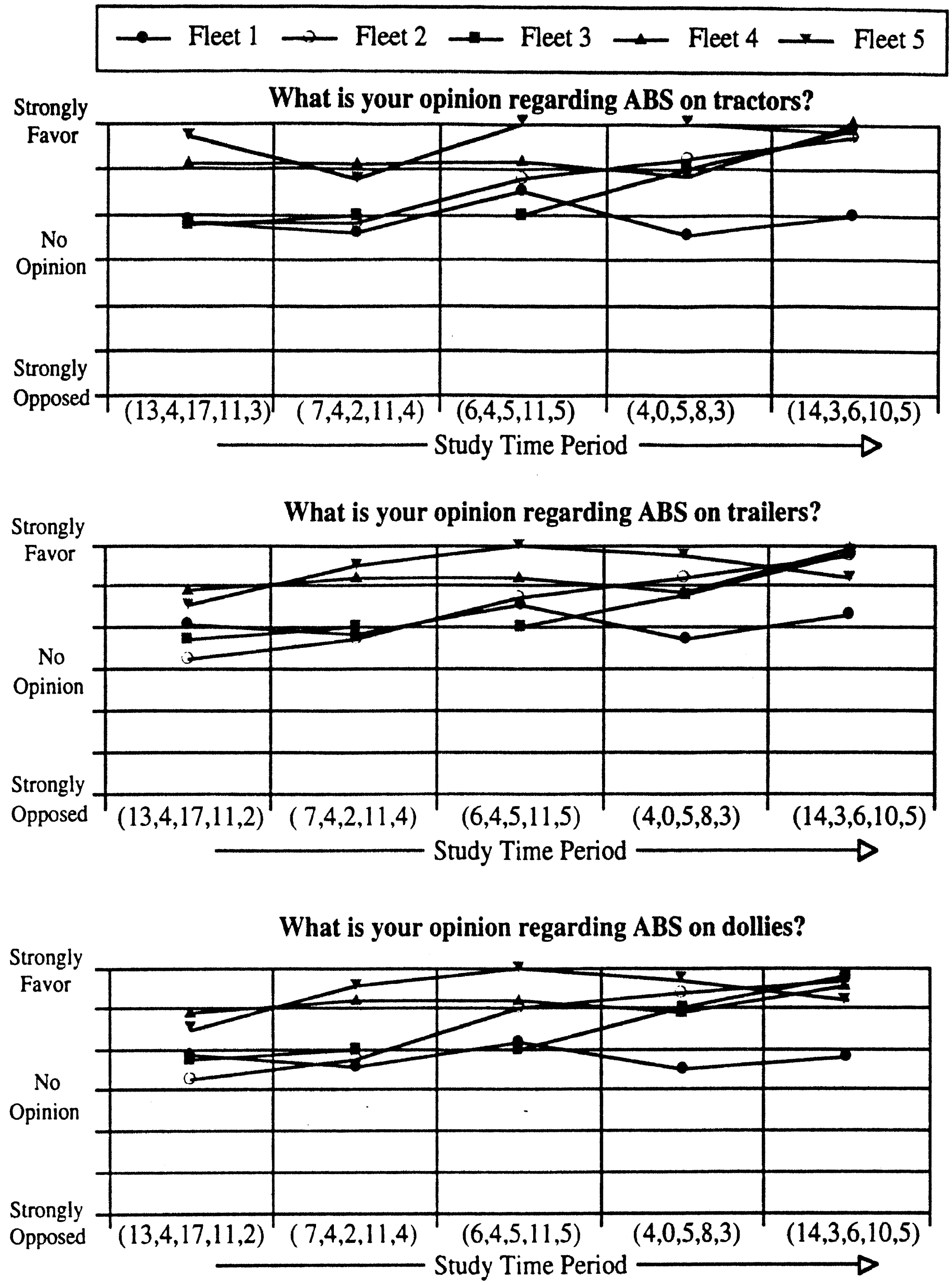


Figure C-1 (continued). Reaction of drivers to ABS for each fleet in the LCV study

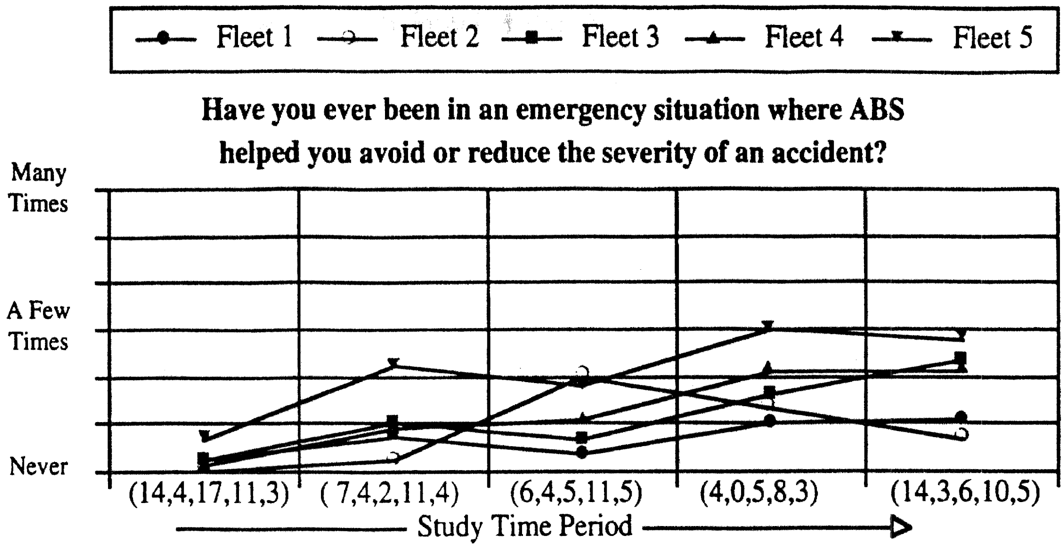
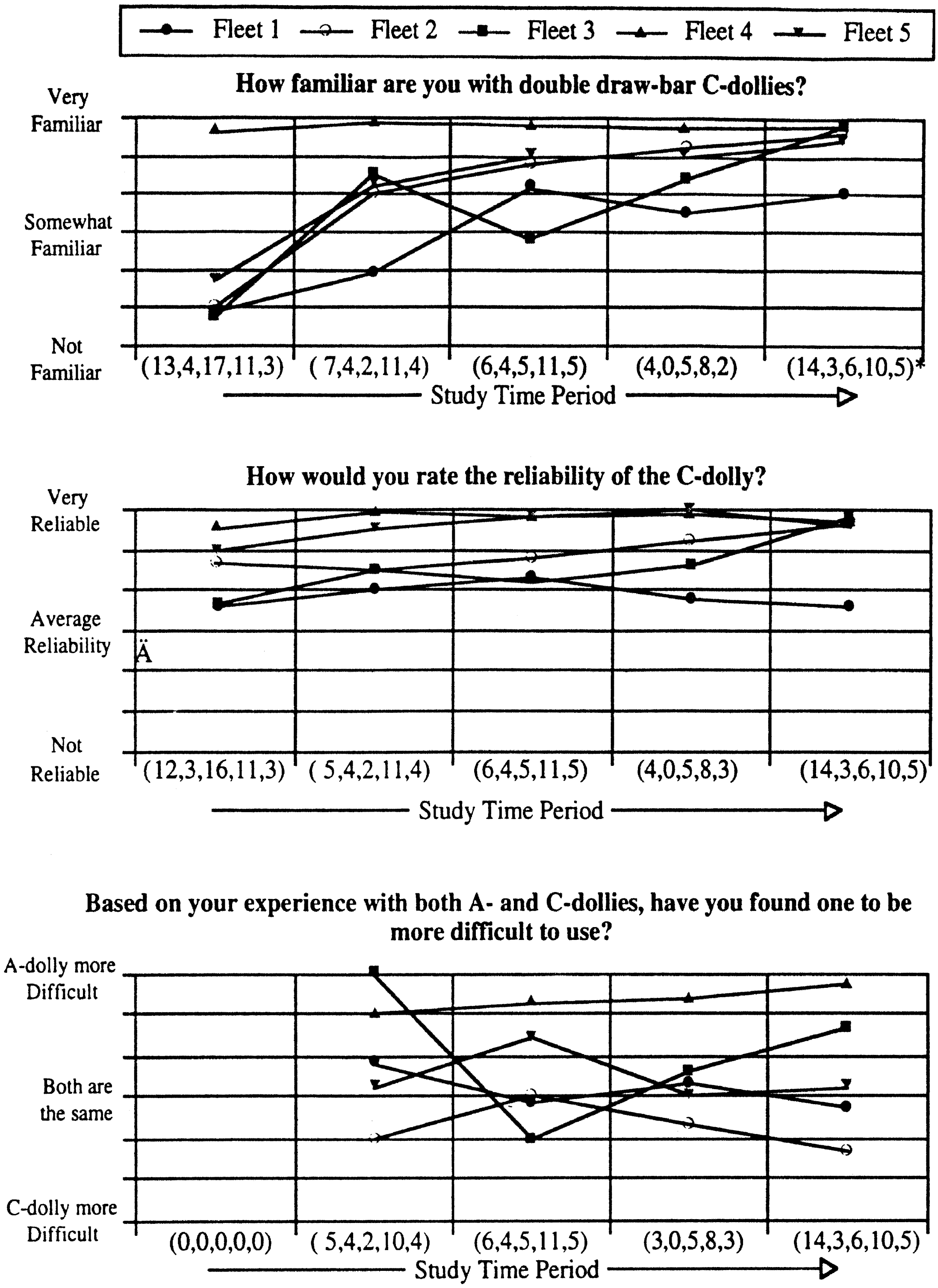


Figure C-1 (continued). Reaction of drivers to ABS for each fleet in the LCV study



*Number of replies for each evaluation period.

Figure C-2. Reaction of drivers to C-dolly for each fleet in the LCV study

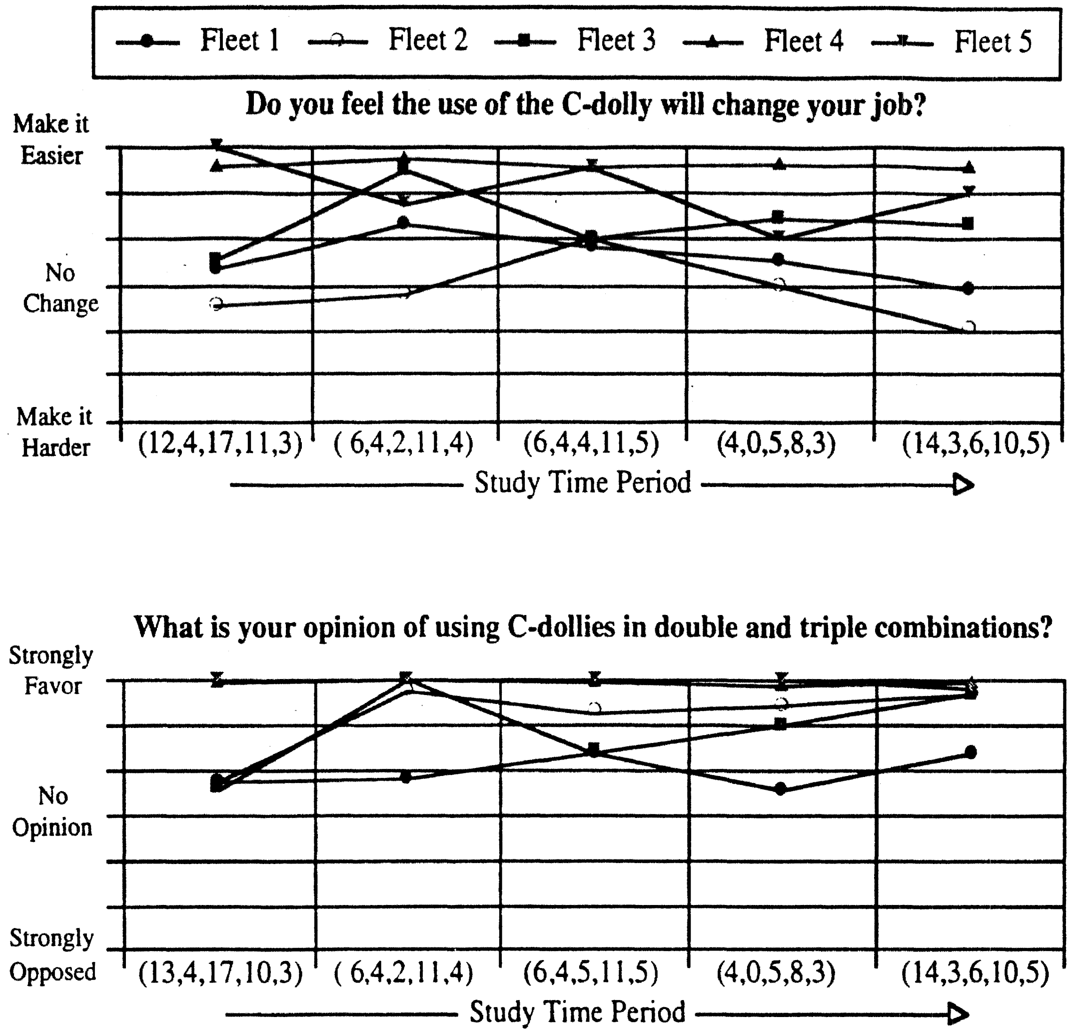
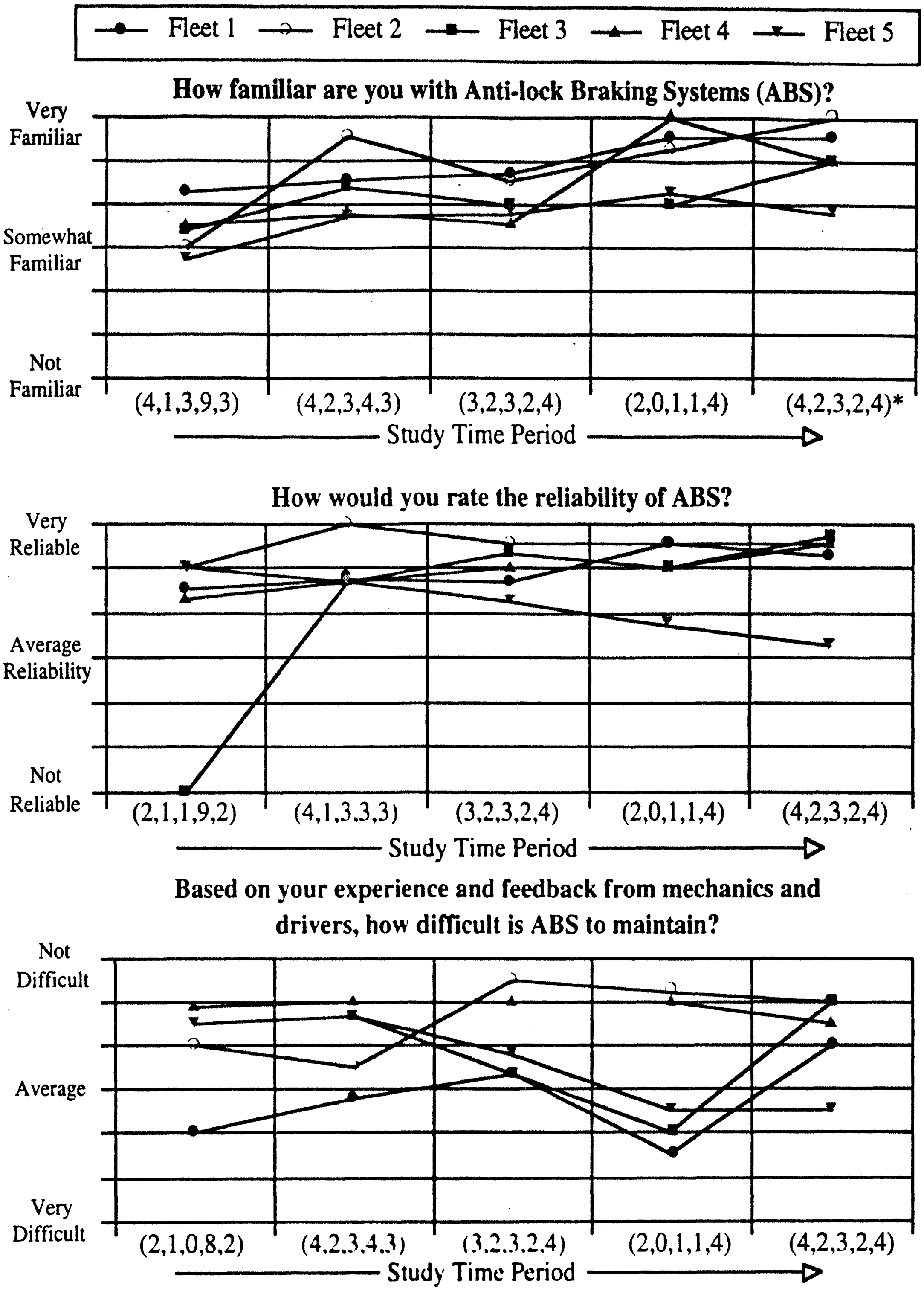


Figure C-2 (continued). Reaction of drivers to C-dolly for each fleet in the LCV study



*Number of replies for each evaluation period.

Figure C-3. Reaction of managers to ABS for each fleet in the LCV study

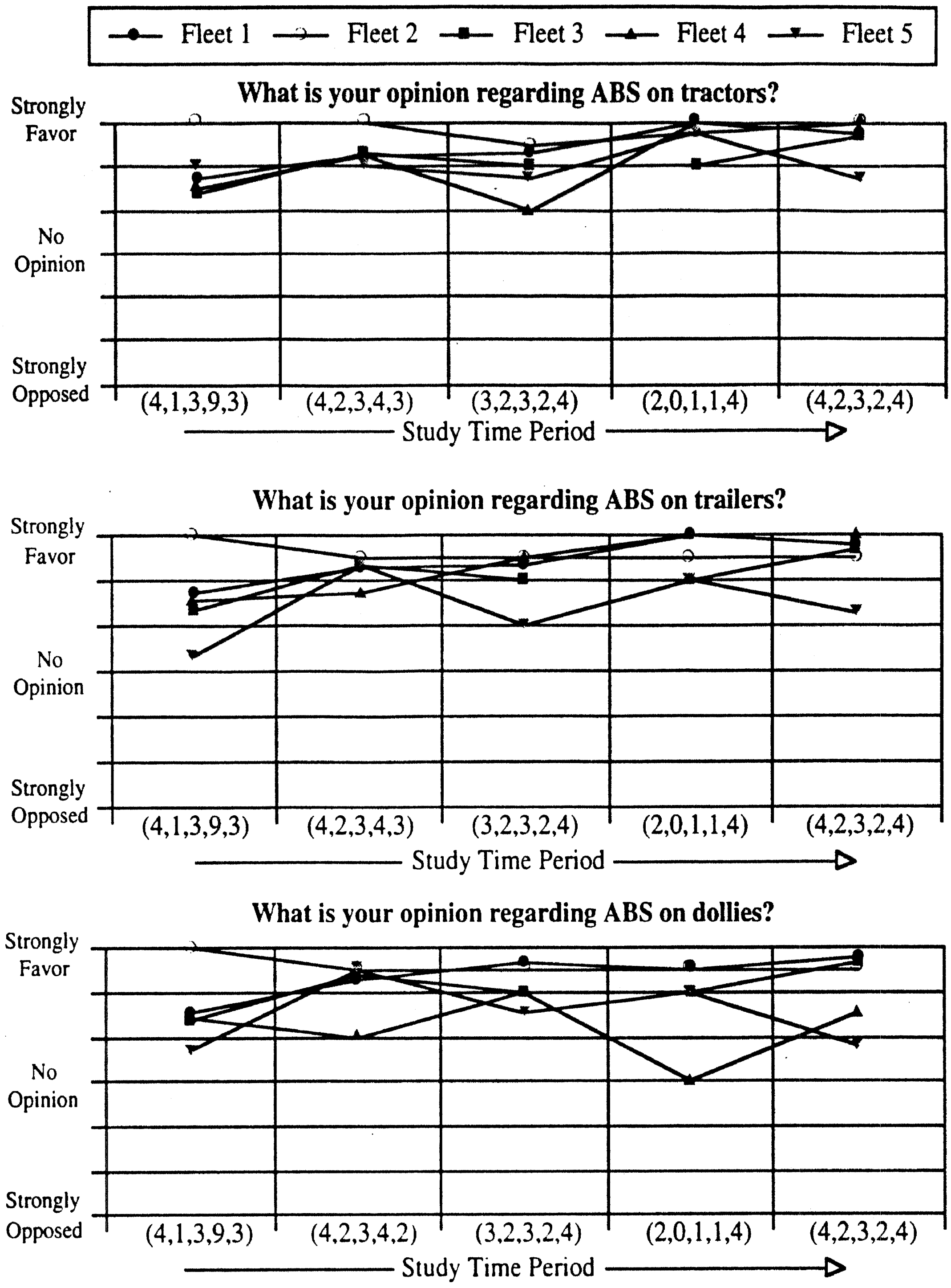


Figure C-3 (continued). Reaction of managers to ABS for each fleet in the LCV study

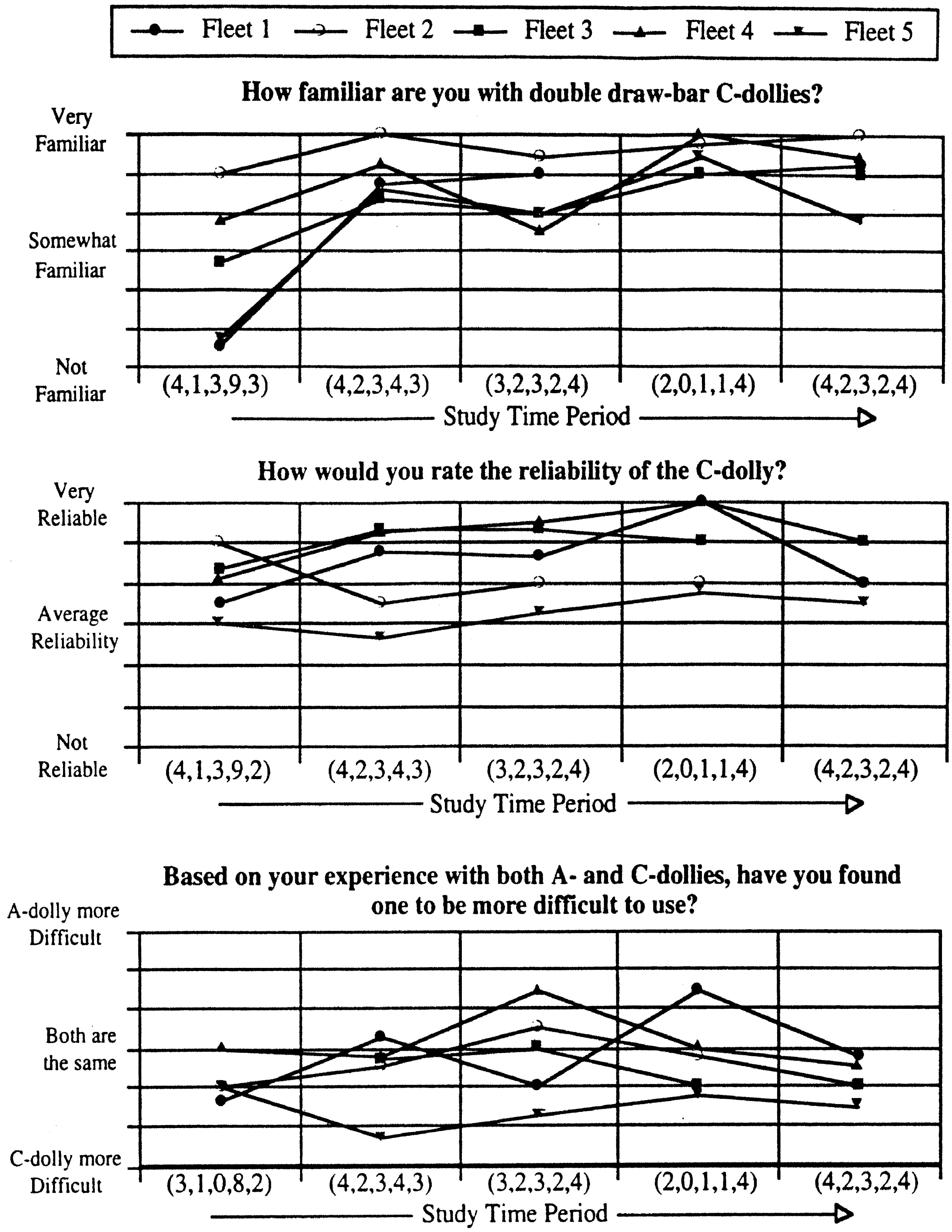


Figure C-4. Reaction of managers to the C-dolly for each fleet in the LCV study

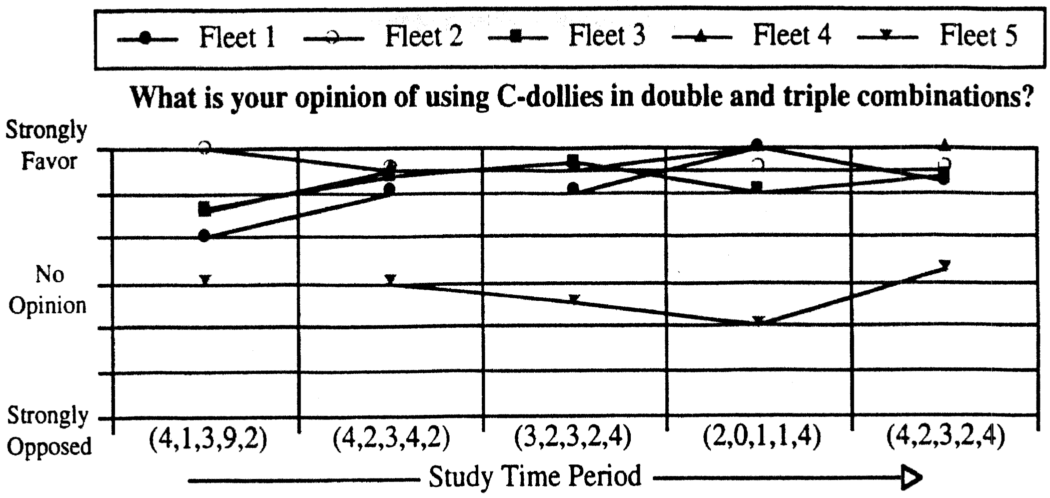
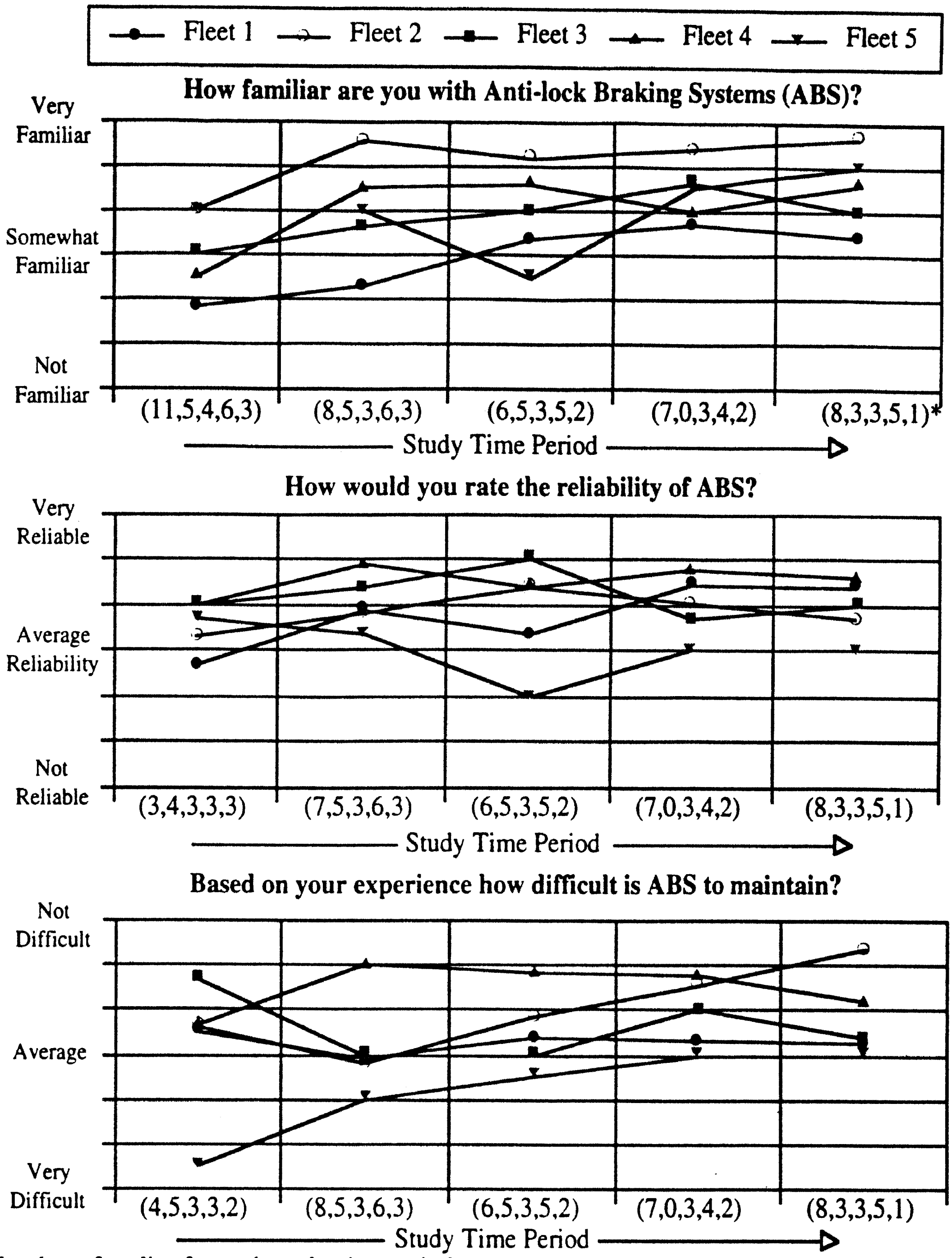


Figure C-4 (continued). Reaction of managers to the C-dolly for each fleet in the LCV study



*Number of replies for each evaluation period.

Figure C-5. Reaction of mechanics to ABS for each fleet in the LCV study

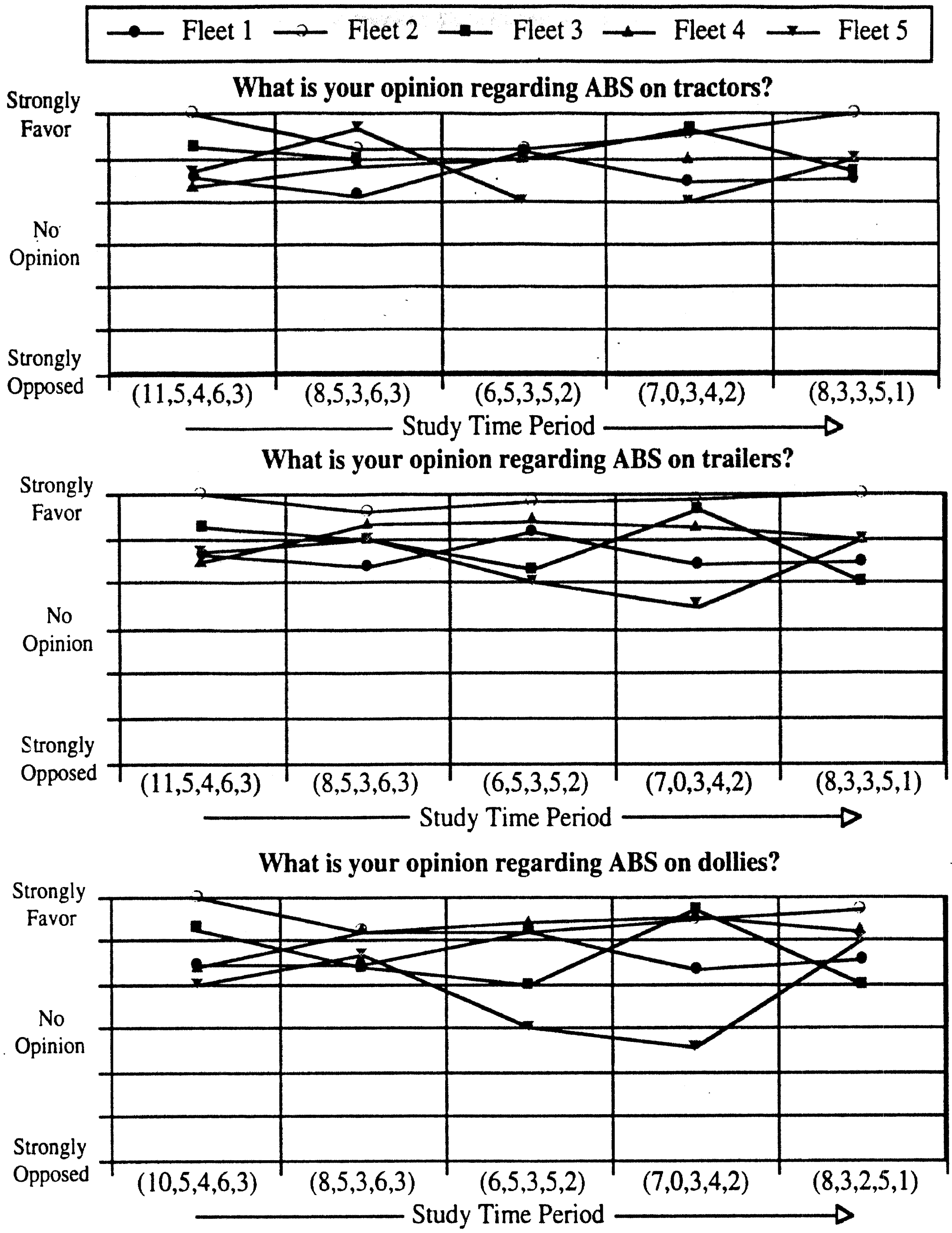


Figure C-5 (continued). Reaction of mechanics to ABS for each fleet in the LCV study

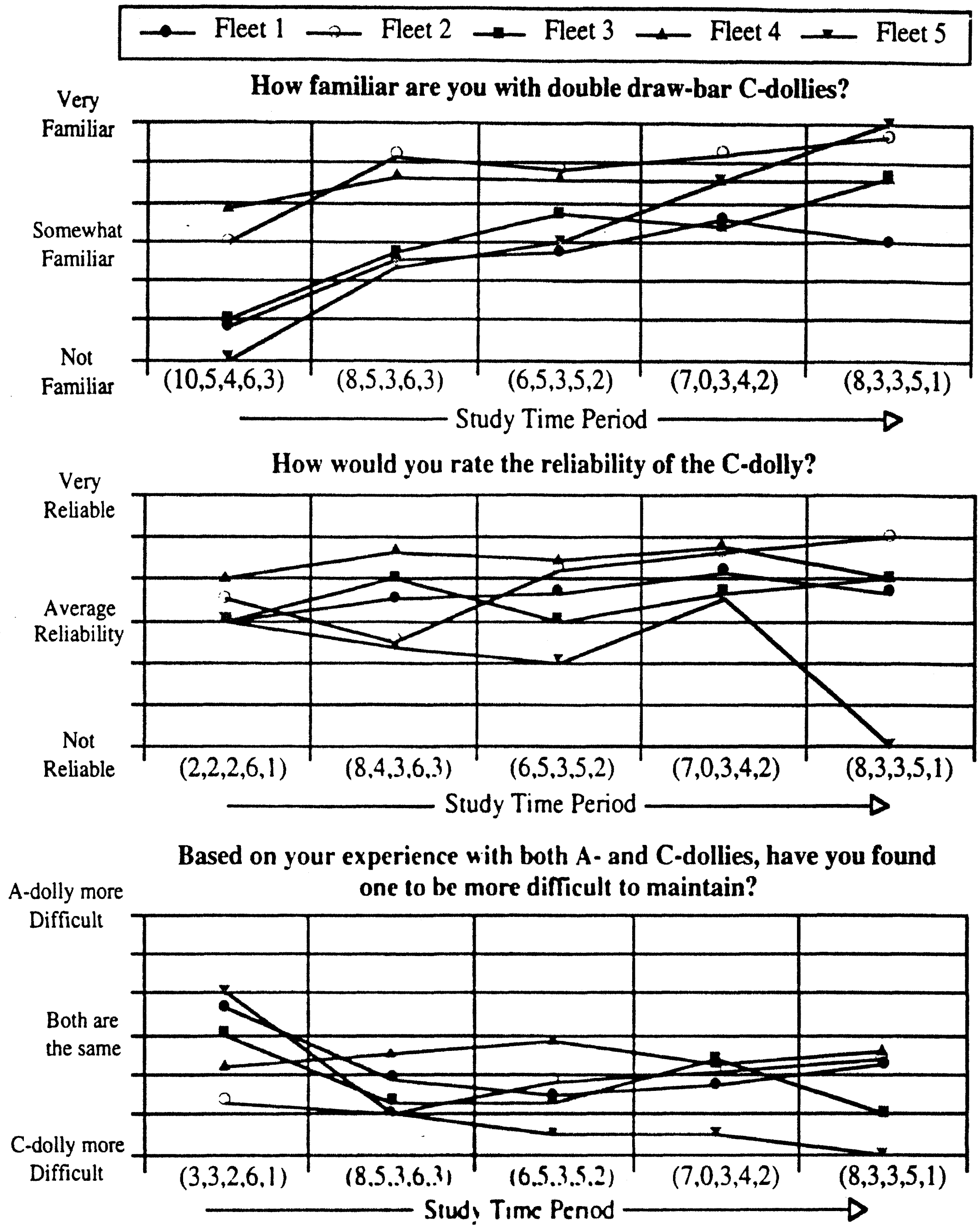


Figure C-6. Reaction of mechanics to the C-dolly for each fleet in the LCV study

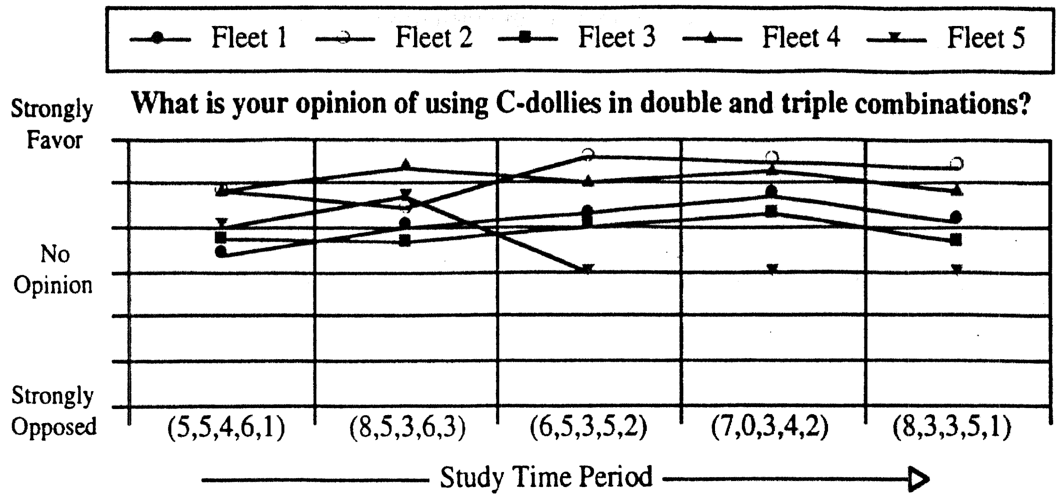


Figure C-6 (continued). Reaction of mechanics to the C-dolly for each fleet in the LCV study

Fleet Personnel Comments On The C-dolly And ABS From The Opinion Surveys

Survey 1

Positive comments on ABS and C-dollies

8/21/93, Driver -"I haven't had too much experience with ABS because up until 2 weeks ago I wasn't assigned a tractor that had it. I am very glad to have ABS and if they've been out for several years I am disappointed that we didn't have them right from the beginning.
On C-dollies, I've been using the C-dolly for three years. I pull nothing but triples and the C-dolly has at least saved me once from loosing the back trailer in a curve. I think they are the safest thing to have for triples operation. I would hate to have to go without them."

11/16/93, Driver -"ABS: Should be a comfort knowing that on brake applications trailers will stay straighter and not lock-up. C-dolly: It should have less sway, less shoulder rocking, and 100% better stability."

Positive comments on ABS

1/14/94, Driver -"I owned a '77 Kenworth with the old style ABS system that worked very well! I really noticed a difference in the winter driving conditions and I'm sure the ABS kept me from losing it in Salem one time when I had to make an emergency stop on an icy highway. "

Positive comments on C-dollies

8/21/93, Driver -"After learning how the C-Dolly works, its the best way to go! Back trailers are a lot more stable in wind, on rutted roads, etc."

8/21/93, Driver -"C-dolly Saves!"

8/21/93, Driver -"In my opinion the C-dolly is the best thing made for safety of pulling combinations."

8/21/93, Driver -"Wouldn't want to haul triple combos or Rocky sets up 95 without C-dollies."

9/12/93, Manager -"From what I have seen of the C-dolly, [it] seems to have a lot of the right qualities."

9/12/93, Manager -"As a driver I operated C-dollies in a 60 day test in the late 1980's. I was and am favorably impressed with the operation of C-dollies for safety and ease of operation."

10/27/93, Driver -"I have yet to drive with C-dollies in bad weather, if they handle then like they do now I would say that they should become mandatory on all combo's, especially triples!!! Backing and Hooking is much quicker once you get the drift of it all and a whole lot safer. No longer necessary to lift or push the dolly around."

12/8/93, Driver -"Very good to back sets. Very good in high winds."

Neutral or mixed comments

9/11/93, Driver -"We will see!"

9/12/93, Manager -"Don't have very much knowledge on ABS or C-dollies. Know a lot more today in theory than in the past."

11/21/93, Driver -"We will see how they [C-dollies] operate after running in snow conditions on my run."

11/21/93, Driver -"Don't know enough about ABS or C-dolly to make an opinion yet."

Negative comments on C-dollies

10/28/93, Mechanic -"C-dollies look like they are more of a hassle for drivers and more things can go wrong with them with all the extra parts on them."

12/15/93, Driver -"Long runs - OK; for our operation, I feel it [C-dolly] will just create a lot of extra work time and effort."

12/16/93, Driver -"I am very familiar with the old double tongue dolly. I haven't tried the new style. I didn't have any reason to apply the brakes hard so I really can't critique the ABS system."

1/19/94, Driver -"Time will tell."

Survey 2

Positive comments on ABS and C-dollies

1/22/94, Driver -"Strongly agree that both [ABS and C-dolly] should be part of a [trucking] operation."

1/25/94, Driver -"I strongly believe that C-dollies should be mandatory for all triple trailer operation. As goes for doubles they are more stable on rough and cambered roads. They [trailers] don't sway all over in rutted road ways. Doesn't take any longer to hook C-dollies up as it does A-dollies. The only disadvantage I see is moving them around at the store or in yard, because the off set is so much greater. But they can be moved with a little common sense. Best thing I've seen in 28 years of pulling doubles and triples!!! I'll take them every trip. Also, like ABS braking system, nice and smooth."

1/30/94, Driver -"I believe the ABS brakes, when used on tractors, trailers, and dolly together as a unit, gives the driver a much greater braking ability in a much shorter distance.
The C-dollies are much more stable, especially with triples, pulls a lot straighter and much more stable."

2/1/94, Driver -"I have never been in a "near" accident with ABS and yet I feel much more comfortable pulling equipment with ABS systems -- especially when "bob-tail" or pulling empty trailers. The C-dollies are much (very much) an improvement in trackability in long combinations (triples). They also eliminate sway almost completely. I feel safer in snow or ice when pulling a set with a C-dolly than with an A-dolly. I would hope that, in the near future, these C-dollies will become universal converter gear used with all doubles and triple combinations."

2/2/94, Driver -"ABS brakes are the way to go.
All doubles should have C-dollies, they are safer and the most efficient way to go."

2/23/94, Mechanic -"From what I've seen the brakes [ABS] work well and seem to be reliable. We have not seen many problems with the ABS.
The C-dolly - I've heard from most drivers [that] they like it better than a regular dolly. The trailers change lanes better and without the whipping you get from a regular dolly. From a service point of view, the C-dolly is not much harder than the A-dolly. As a mechanic and shop foreman I am impressed with the operation of both ABS and the C-dolly."

2/23/94, Mechanic -"The C-dolly is definitely the way to go. There is more to take care of and maintain but they don't have any major problems that I have seen. The drivers also appreciate the advantages of the C-dolly. The ABS also are a great advantage. I haven't heard any complaints by the drivers and I haven't noticed much mechanically wrong with the system."

Positive comments on ABS

1/22/94, Driver -"Only tested ABS once on trailer. Was impressed with action."

1/22/94, Driver -"Anything that makes my job safer I'm all for it. I had used ABS back in the late 70's and this ABS is a major improvement over the old. I enjoy testing it and would like to help to make it mandatory on all heavy vehicles on the highway today."

1/22/94, Manager -"[Fleet] is purchasing only ABS Tractors. ABS is not as necessary on C-dollies if it's leading trailer has ABS."

1/28/94, Manager -"Braking and stability of doubles and triples combinations are greatly improved with ABS."

2/1/94, Mechanic -"I feel that ABS is a plus to all fleets operating LCV's."

2/23/94, Mechanic -"Rockwell ABS is real simple to install and maintain, as well as finding fault codes."

Positive comments on C-dollies

1/22/94, Driver -"C-dolly operation is much safer than A-dolly."

1/31/94, Manager -"The feedback I have heard from the drivers that have been using them [is that] they are very good. The drivers all feel they take the sway out of the road and make the whole ride safer and more comfortable."

2/1/94, Driver -"I think A-dollies should be outlawed!"

2/2/94, Manager -"The drivers seem to be learning how to hook and unhook the C-dollies much better and are beginning to like them very much."

2/10/94, Hostler -"They take some getting used to as far as hooking goes, but after that they are a good idea."

2/15/94, Hostler -"Speaking from a hostlers position, [C-dollies] are easier to back (ABS trailer with C-dolly attached) than a trailer with an A-dolly attached. My only experience with ABS has been in the yard hooking doubles and triples."

Neutral or mixed comments

1/22/94, Driver -"The only reason I feel the ABS is more work at this time is the extra we are doing for this test."

1/31/94, Manager -"My experience comes from driver comments and watching hostlers hooking equipment in our Portland yard."

1/31/94, Manager -"Only thing I have to go by is hear-say."

2/8/94, Hostler -"Let me pull a set and I'll tell you more."

2/9/94, Hostler -"I have no idea how reliable they are. I have just put together a couple of dollies and trailers while hostling."

2/10/94, Hostler -"I've only been working with C-dollies for two weeks. I'm not sure how they really work yet."

2/16/94, Mechanic -"The ABS is still new. I am curious to see how they are after some age and wear and tear."

2/23/94, Driver -"They [C-dollies] are great for backing and keeping trailers in line on ice but breaking up is a pain. Has to be just so for locking handle to stay down."

2/23/94, Mechanic -"So far no complaints!"

Negative comments on ABS

2/10/94, Mechanic -"Make some changes to mounting of ABS box and tail lights -- they're too exposed and will be damaged when stacking!"

Negative comments on C-dollies

1/28/94, Mechanic -"The C-dolly hitches require training in addition to regular single hitches. They can easily frustrate an unfamiliar driver."

1/29/94, Manager -"C-Dollies hard to hook up and seem to get damaged during hook/unhook more than A-dollies. Drivers and yard hostlers say it takes twice as long to hook triples with C-dollies."

2/1/94, Mechanic -"May still be room for improvement on C-dolly "down the road.""

2/1/94, Mechanic -"The C-dolly pintle hooks stink. The day they hook up and release without 3 or 4 attempts, then we will see."

2/8/94, Hostler - "I have hooked C-dollies three times and each time it has taken a minimum of 45 minutes and on one occasion I changed to an A-dolly because pintle hook would not latch and stay latched! I think the release mechanism is extremely hard to pull in order to release tongues. They are extremely heavy and difficult to maneuver by hand. My overall view of the C-dolly is very poor!"

2/9/94, Mechanic -"Drawbar eyes have broken - support leg and braces have broken - release/latch jaws are a pain and hard on back to reach across to unlatch."

2/10/94, Mechanic -"C-dollies need to go through a slight change. Concept of idea is good but some mechanical aspects were over-looked. Needs to be more user friendly for a fleet operation like us."

Survey 3

Positive comments on ABS and C-dollies

6/1/94, Driver -"Would like to see it [C-dolly] mandatory for all triples! The stability and handling is 100% better than A-dollies. No whipping or rocking, all around safer handling. ABS brake system are 100% more efficient than standard air brake systems. Smoother—more responsive and better combined braking over all."

6/1/94, Driver -"C-dollies work real good with three trailers. ABS is probably the coming thing in transportation. More testing should be done in winter driving."

6/1/94, Driver -"Both features [ABS and C-dolly] are a huge contribution toward safety in operation on highways. No whipping at highway speed and simple hooking because a C-dolly can be backed easily when hooked behind one or two trailers. The ABS delivers maximum braking ability to double and triple operation with obvious safety consequences. Attaching to C-dollies is sometimes not as quick an operation, but is safer than manhandling done with "A" dollies. Fewer comp. claims and injury losses should occur using "C" dolly techniques."

6/1/94, Driver -"It was a joy to drive the all ABS systems between Portland and Boise—the "C" dollies were terrific and the ABS brakes were a nice change from individual axles "locking-up" in demand situations."

6/1/94, Driver -"I have found the C-dolly to be the greatest safety feature that could be imagined. I firmly believe that C-dollies should be a mandatory requirement for double or triple trailer operations. I always feel confident I'll be able to control my equipment even under extreme conditions when my truck and trailers are equipped with an ABS equipped C-dolly. C-dollies equipped with ABS keep your trailers in a straight line on slick surfaces even under hard braking situations."

6/1/94, Manager -"Both types of equipment will improve the safety and handling of doubles and triples."

6/1/94, Mechanic -"This stuff is still working great; everybody should be using it."

6/4/94, Driver -"I feel very comfortable driving on a two lane or four-lane highway with the ABS brakes on my tractor. It's not that I drive faster or take chances because of the brakes but when I have to use my brakes it's a nice or more even stop. Even though when I run I don't have the ABS on the dolly or trailers. The C-dolly is the only way to pull combinations. Hopefully soon all trucks, trailers and dollies will have ABS."

9/14/94, Driver -"The ABS system seems to work very good in the few times I have had to really use it. The C-dolly equipment is great. I have never driven anything that handled that good in my life!"

Positive comments on ABS

6/1/94, Driver -"Only tested ABS once on trailer. Was impressed with action."

6/1/94, Driver -"Anything that makes my job safer I'm all for it. I had used ABS back in the late 70's and this ABS is a major improvement over the old.
I enjoy testing it and would like to help to make it mandatory on all heavy vehicles on the highway today."

6/1/94, Mechanic -"We do not see enough of the equipment now because of no problems so the ABS must be doing a real good job."

6/1/94, Mechanic -"I feel that ABS is a plus to all fleets operating LCV's."

Positive comments on C-dollies

6/1/94, Driver -"I have not run into any problems to use and see the difference in an emergency. I do like the way we can back up with this set using the C-dolly."

6/1/94, Driver -"Turns corners better (sharp—like stinger steering). Easier to back set."

6/1/94, Driver -"I feel the C-dolly should be law to pull triples and doubles. [LCVs] would be a lot safer. I have had several compliments pulling doubles and triples down the road on how straight they are pulling! (No Wiggle!)"

6/1/94, Mechanic -"I think that everyone should use the C-dolly. It isn't much more to maintain and it is a lot safer for everyone on the road."

6/1/94, Mechanic -"It's [C-dolly] the way to go!"

7/21/94, Driver -"Like C-dollies!"

Neutral or mixed comments

6/1/94, Driver -"The C-dollies could use a little more play around the hooks. This would make them easier to unhook. Other than that I really like them."

6/1/94, Mechanic -"Haven't worked on enough to have an opinion."

6/1/94, Mechanic -"So far no complaints!"

6/1/94, Mechanic -"The ABS seems to be going well. If it wasn't for the hooking and moving around they [C-dollies] would be better."

6/1/94, Mechanic -"Is still too early to tell—have talked with a few drivers that like the system!"

6/28/94, Driver -"Liked the way they pulled down the road. First trip with C-dolly made job a little slow because of hook-up but can see no real change in job or time with more trips."

7/14/94, Driver -"Good idea but hitch system needs improving."

8/13/94, Driver -"I did not have enough time or weather conditions to form an opinion good or bad on one versus the other. I do think the C-dolly has obvious advantages, but without the proper conditions one can not make an informed opinion."

Negative comments on C-dollies

6/1/94, Manager -"The C-dolly hitching set-up can be difficult to unlatch."

6/1/94, Mechanic -"Pintle hooks are hard to use."

6/1/94, Mechanic -"C-dolly hitches still hard to unlock; C-dollies not suited for this company's type of work."

6/1/94, Mechanic -"Relocate all tail lights and ABS control box. Also need better wiring methods on light cord and junction box."

Survey 4

Positive comments on ABS and C-dollies

10/27/94, Driver -"Any attempts at trying a "panic stop" when using the C-dollies with the test trailers while I was Boise bid driver were very positive.
Use of a bobtail tractor with ABS is much more easily maneuverable when in a braking situation. I appreciate the use of ABS equipment I've had the opportunity to use as a driver here at [Fleet]."

10/27/94, Mechanic -"I think ABS on all units of any combination along with C-dollies in doubles or triples is the safest rig on the road."

10/29/94, Driver -"I like having ABS. It makes my job safer and the safer it is, the more I like it. I could say the same for C-dollies. I hope I never have to look for a different driving job cause they probably won't have C-dollies and ABS."

11/4/94, Driver -"I do like ABS brakes on all wheels. It greatly reduces the stopping distance. I have nothing but good things to say about ABS. C-dollies are a major step in combination vehicle safety."

Positive comments on ABS

11/7/94, Mechanic -"I feel that ABS is a plus to all fleets operating LCV's."

Positive comments on C-dollies

11/17/94, Driver -"A-dolly should be outlawed!"

Neutral or mixed comments

10/31/94, Manager -"C-dollies seem to be more stable but harder to maintain and more difficult to use."

Negative comments on C-dollies

11/2/94, Manager -"C-dollies need hitches changed to easier ones to operate."

11/3/94, Mechanic -"Pintle hooks are hard to use."

Survey 5

Positive comments on ABS and C-dollies

4/10/95, Mechanic -"From what I have seen I am impressed with both."

4/12/95, Driver -"We only have ABS on one drive axle on tractor. When applying brakes, drive axle will lock up causing the tractor to slide. If the power divider is locked in it causing both axles to lock up and then you really slide & could cause a jack-knife. The same thing could happen with a combination that ABS on trailers & not on tractor. I also wonder what would happen in a panic stop situation where ABS was on one trailer & not on the others.
If I had my choice, I would want ABS on all vehicles & if it was a double or triple combination then I would want to have C-dollies."

4/18/95, Mechanic -"Equipment wise, from a mechanical view, ABS has proven to be very effective and reliable. Very few problems were encountered. From an operational view, ABS & C-dollies require more education & training. Operators accept them for the most part, but as with anything new there is always some resistance. I personally liked all the equipment involved and after a delayed start-up period, I think our part of the test went really well!"

4/18/95, Mechanic -"The test equipment was very reliable. I don't think we encountered any more problems with the test equipment than other equipment in the fleet. The majority of the problems I ran into were with the information gathering equipment and getting the drivers to fill out the forms properly."

Positive comments on ABS

3/21/95, Mechanic -"Drivers pleased with braking capability"

4/18/95, Manager -"It appears that ABS is NO more difficult to maintain than non-ABS equipment"

4/19/95, Mechanic -"It gave me great insight into ABS equipment and its importance to the trucking industry"

Positive comments on C-dollies

4/18/95, Driver -"C-dollies should be mandatory."

4/21/95, Driver -"A-dollies should be outlawed!"

Neutral or mixed comments

3/21/95, Manager -"None"

3/21/95, Mechanic -"None."

4/4/95, Manager -"None"

4/10/95, Manager -"The data recording equipment left much to be desired. This put a big burden on our drivers. I think that we did an excellent job for all the electronic problems we had."

4/18/95, Manager -"Just insuring continuing education of unfamiliar drivers with new equipment"

4/20/95, Driver -"The only problem I have or see with the C-dollies is trying to hook them to front of trailer. The same person doing it all the time won't have much of a problem but somebody new each time will. The A-dollies are a lot easier to move around. As for the whole ABS system, it's probably a good thing for the transportation industry in the long run. I enjoyed taking part in the test. Thanks."

Negative comments on ABS and C-dollies

4/18/95, Mechanic -"ECU Box needs to be placed other than in front of tires, too much water & spray shorts out (on trailers). C-dollies have eye wear & 36" steering diaphragms are too big, need smaller. Brakes wear fast on 35 ft trailers. Tires wear fast on C-dolly, not just tow problem."

Negative comments on C-dollies

4/18/95, Driver -"C-dollies are difficult to use & makes it harder because of hitch releases"

4/18/95, Mechanic -"Very hard on tires (C-dollies & 35 ft.) Hitches need improvements"

4/19/95, Mechanic -"The C-dollies seem to have been rough on tires & the hitches could use some release improvements."

4/22/95, Manager -"I have a concern with tire wear on the C-dolly"

Comments On The C-Dolly And ABS From The Driver Trip Form

The comments below were logged by drivers on their Driver Trip Forms. Drivers were asked to complete a DTF for every trip. (An example copy of the Driver Trip Form can be found in appendix A). These comments are arranged into events associated with braking and events associated with maneuvering. In general the comments are followed by a description of the general weather conditions and LCV load.

Braking comments

Sudden Braking - "Trucks in middle of road on hill and curve. Road surface was solid ice. I was able to stop and pull off out of the way with very little trouble. C-dolly Problem - Had tongue on driver's side come loose when leaving the yard. After precheck and locking both handles, tongue popped out of lock. I relocked it and had no more problems. I think it is very important to tell all drivers to double check mechanism and make sure they are locked." Conditions: 12:30 AM, Climate - Freezing Rain, Road -Wet, Load - Full.

"While descending 6% grade at approx. 33 mph, I had a sudden stop for a red light. The road was wet and it was raining. The truck had 4 pallets in the front trailer and the rear trailer was empty. The truck stopped in a straight line and the rear trailer and dolly tracked straight with no wheel lock-ups. " Conditions: 8:38 AM, Climate - Rain, Road - Wet, Load - mixed.

Braking Event - "Stopped fast for red light. 40 footer loaded, pup empty. Pup rear tires locked for a split second, slid to left. Immediately released and stopped in a straight line. " Conditions: 6% downgrade, going approx. 30 mph.

"Large deer ran out in front from ditch. Foggy conditions made it impossible to see her until point of imminent impact. I braked hard and turned to the right without running off the road and missed the deer. I was surprised at the handling quality and how easy it straightened back out. The hard braking without skidding was just enough to miss her. If I had hit this deer, it would have caused extensive damage and possibly caused me to wreck. Very impressive!" Conditions: Time - 3:00AM; Climate - fog, snow,windy; Road - wet: Load - full.

"A car stopped abruptly in front of me in a dust storm. I served and applied brakes to avoid a collision - successfully. " Conditions: 3:00 AM, Climate - windy, Road - dry, Load - full.

"Avoided a deer. " (driver reported that stated that everything worked fine and he stopped in a straight line with no problem. He liked the handling of the C-dolly and ABS.)

"Hard braking at RR tracks without warning lights." Time - 3:15 AM, Climate - clear, Road - dry, Load - full.

Aggressive braking - "A car stopped at green light; realized it was green and accelerated" - aggressive brake at slow speed; approx. 25 mph - Time - 6:55AM, Climate - clear, Road - dry, Load - mixed.

"ABS - Absolutely Great!! Good control of brakes. Comes on easy. Works well under short 5 mph drops in speed. C-dolly should be mandatory for triples!! Excellent!"

"C-dolly would not release from front trailer until I pulled up and back. These dollies sure are temperamental about releasing from front trailer hitches. Other than that, I was very impressed with the handling characteristics, and the ABS seemed to work well, too. I hope I get to run this system again sometime."

"Sudden stop due to sudden traffic light change at odometer 463857." Conditions: 8:20 AM, raining, road wet, empty loading.

"Following about 100 ft. behind a four wheeler southbound on Hwy 395 at milepost 67 in a (severe) dust storm when I saw brake lights and then was able to see traffic at a stop in front of us (because of an accident in the nb lane).The four wheeler locked up his brakes and steered off the roadway to avoid stopped vehicles. Est. speed at time of emergency was 40-50 mph. Even though trailers were virtually empty, everything came to a smooth, straight stop with about 80 ft. to spare."

"Via Coeur d'Alene - At 10:00 AM, had to set down real hard to avoid accident. Everything worked fine."

Braking incident - "A vehicle spun out sideways in front of me and I had to come to a very sudden stop to avoid. Everything stayed in line and seemed to handle well. " Time - 2:10AM, Climate - snow/ice, Road - ice, Load - full (68500 GCW).

"Sudden traffic light change; had to stop very quickly" - Time - 12:25 PM, Climate - rain, Road - wet, Load - full.

"At approximately 8:40 am on a clear day with dry roads and a full load, the driver reported he had a very aggressive braking incident at about 15 mph. According to written comments by the driver a "car with no direction lamp on, stopped and turned in front of me." The driver made a panic stop about 10 feet short of the car in his path. The driver believes that the ABS on all units worked correctly and he credits it for making the difference between a near miss and an accident."

Sudden stop - "Light turned red at intersection, had to stop quickly. " Conditions: Time - 7:00PM, Weather - clear, Road - dry, Load - empty.

"Ran on about one mile of slightly slick roads. Temp. was 22 degrees in the canyon area about 10 miles north of New Meadows on 95. Road runs along the side of the river and moisture came from the river and the road was what we drivers call greasy. Didn't have to put on brakes, but I had a surge of confidence that if I did I wouldn't slide out of control. Can't wait for snow to get here so I can really try these babies out."

"Six head of deer ran out into roadway. I had to come to a complete stop in order to miss all of the deer. I don't think that I could have stopped in time or without skidding tires or jackknifing with regular brakes." Conditions: Time - 10:30 AM, Weather - clear, Road Condition - dry, Load Condition - full.

"I was driving in heavy traffic at 50 mph headed into Reno. The traffic ahead of me came to an abrupt stop which forced me to severely brake. An empty truck in front of me locked brakes and swerved to avoid hitting traffic. I was able to brake to an appropriate speed without wheel lock and swerving." Conditions: 5:45 PM, climate - clear, road - dry, load - full.

"Had to apply brakes hard to avoid a dog that crossed the road in front of me. Set stayed straight and stopped well." Conditions: 11:30 AM, climate - clear, road - dry, load - full.

"Coming down hill north of Grangeville, ID, on US 95 S, had a car pull out in front of me. Hit the brakes pretty hard 3 times; on solid ice. The combination stayed in line in spite of stab braking procedure. " Conditions: 9:30 AM, Climate: Snow/Ice & Windy, Road: Ice, Load: Empty.

"Accident at junction west of [city]. Struck car ... after it ran a stop sign." See Accident Report for details.

"Came up on pickup making left hand turn coming down Winchester Grade. No oncoming traffic, just took too long to turn. I may have overreacted to the situation." Conditions: 4:10 PM, windy and raining, road wet, full load.

"Had to apply brakes hard to avoid a car that pulled out in front of me. Everything seemed to work properly."

Sudden stop or aggressive braking; "Following a car that made a sudden left hand turn." Time - 2:00 PM,Climate - clear, Road - dry, Load Condition - empty.

"Straight truck pulled out in front of me on I-84 in Boise." Time - 3:12 PM, Climate - clear, Road - dry, Load - full.

"Sudden stop because of merging traffic, jam up downtown Reno." Conditions: 4:42 PM, Climate - clear, Road - dry, Load - full.

"On US 95N, going downhill - car, apparently lost, stopped right in front of me." Time 3:26 PM, Climate - clear & windy, Road - dry, Load - full.

"Had to stop quickly, came up on stopped traffic turning left while rounding curve on US 95N." Time - 5:09PM. Climate - clear, Road - dry, Load - full.

Sudden stop - "Came up behind tanker truck with no rear lights stopped at RR tracks on US 95N near Weiser, ID."

Sudden stop - "In middle of curve - truck turning right with half sticking out in the road and with on-coming traffic." Time - 5:58 PM, Climate - clear, Road - dry, Load - full.

"Sudden stop; caught by stop light." Time - 9:30 AM, Climate - clear, Road - dry, Load - full.

Sudden stop or aggressive braking - "Car in front of me hit the shoulder and stopped." Time - 5:59 AM, Climate - clear, Road - dry, Load - full.

Sudden stop or aggressive braking - "A car making slow turn to right; had to slow and go around." Time - 11:44 AM, Climate - clear, Road - dry, Load - full.

Sudden stop or aggressive braking: (1)"US 95N, car pulled out in front of me." Time - 1:12 PM, Climate - windy, starting to snow, Road - snow/wet, Load - full. (2) "Car passing me on double yellow line met oncoming traffic." Time - 4:25 PM, Climate - snow, Road - wet, Load - full.

Sudden stop or aggressive braking - "A car slid off road in front of me." Time - 11:50 AM, Climate - fog & snow/ice, Road - snow, Load - empty.

"Forest Service truck stopped suddenly in front of me to help person slid off road. Combination stayed in line." Conditions: Time -11:21 AM, Climate - snow/ice, Road - snow covered, Load - full, Other - had chains on.

"Coming down Winchester grade, I came around a curve and a rock slide came across two lanes. I got on the brakes hard and went to the right into a wide spot along the road. I had no problems with any sliding or locking up. Tractor, dolly and trailers handle good!" Time - 1:40 PM, Climate - rain, snow/ice and windy, Road - wet, Load - full.

"Car made sudden left turn in front of me. Trailers stayed straight." Time - 11:26 AM, Climate - Snow/Ice, Road - Snow, Load - Full.

"Coming around curve and met vehicle over in my lane." Time - 8:30 PM, Climate - clear, Road - dry, Load - full.

"Coming into Boise on Interstate - cars merging from right off Meridian interchange mixed it up with cars in front of me - I got on the brakes - truck combination stayed straight." Time -12:07 PM, Climate - clear, Road - dry, Load - empty.

"Chains used once for 100 miles. Snow was rough and rutted. Trailers pulled very well, back box didn't flop around and try to pull the rest of the set out of line (like with A dollies). ABS brakes seem to work real well under these conditions; never slid a wheel under braking and was able to stop without sliding."

"Via Umatilla. This set of triples had 30000# on the front two boxes and light load on the third. With this combination, routine braking almost always locks up the back box, causing smoke and dust."

"A wide load (1/2 house) drove into the path of my truck with traffic in the left lane that wouldn't move, so I had to make a sudden stop - from 55 mph to 10 mph."

"Heavy braking to avoid three deer - unsuccessfully! Evasive maneuver to avoid merging traffic and 14' wide mobile homes."

"Pickup towing a car moved into my lane as I was getting ready to pass, had to get on the brakes fairly good (hard). Everything stayed straight and handled OK." Conditions: 4:30 AM, Climate - clear, Road - dry, Load - full.

"Had to change lanes and get on the brakes hard to avoid a slow car. I was very impressed with the ABS system; it works like a dream." Conditions: Time - 11:00 AM, Climate - clear, Road - dry, Load - mixed.

"I was blinded by lights in a construction zone and drove off the pavement edge, which resulted in surprise steering to correct. I reacted with power braking based on past A-dolly experience, (but) I do not believe it was necessary with the C-dollies."

"Lost sight of the road in a corner during extremely heavy fog. Applied brakes hard and turned to avoid going off shoulder. Stopped. Speed at the time was less than 10 mph." Conditions: Time 1:45 AM, Climate - fog, Road - wet, Load - full.

Maneuvering Comments

"Swerved slightly and braked for deer crossing roadway." Time - 11:15 PM, Climate - clear, Road - dry, Load - full.

"Surprise maneuvering/steering to avoid an obstacle or vehicle" - Time - 11:00 AM, Climate - clear, Road - dry, Load - empty. No other details provided. Driver reported that trailers stayed straight behind the tractor; he was pleasantly surprised.

"Vehicle had a more violent whipping action while attempting to move in or out of highway ruts."

"I sure do like this set-up; nothing bad to say. Good trip."

"The C-dolly made for the most stable combination of trailers that I have ever pulled. I was highly impressed with the way the trailers handled. It also made it very easy to maneuver when backing into a dock. "

"This is the best thing that's happened to the transportation industry. There should be a law that all trucking companies have this system."

"Seemed to handle well even in ruts with lots of water in them. Super C- dolly seems to make the unit a lot more stable."

"Set seemed to handle good in heavy snow and slippery conditions."

"Rig does not handle very well when hooked up like this - 27' + A-dolly + 27' + C-dolly + 27'. When near trailer sways, it actually sways middle and back trailer, which in turn sway front trailer and tractor pretty bad."

"The tracking is much better and almost all the trailer sway is gone."

"When triples are hooked up with C-dolly up front and A-dolly as the rear dolly, the whole unit is easier to control; much smoother set-up."

"Triples pull real nice and handle well loaded or empty with two C-dollies."

"With 27' in front and 35' in back, combination handles good until you get on grooved road, then it handles terrible."

"My third trailer was to be left at Springfield. I was able, because of the Super C- dollies, to back all three trailers into the dock and disconnect as usual, leaving the dolly under the trailer. I have been able to save a considerable amount of time using the Super C-dolly."

"On this trip, I went from Spokane to Coeur d'Alene (about 30 miles) with the 35' trailer empty as my lead box and my 27' trailer loaded. Even with this situation, my whole unit was very stable."

"With A-dolly up front and C-dolly as the 2nd dolly, the whole unit sways some; not as bad as 2 A-dollies, but when it sways, it moves the tractor a lot more. I think it moves the tractor more because as the sway occurs it's moving the two back trailers as one - the tail wagging the dog, so to speak, but the tail is bigger than the dog."

"With C-dolly as #1 dolly and A-dolly as #2, the whole unit is much more stable than with A-dolly #1 and C-dolly #2."

"The equipment handles very good - triples track very straight, back trailer doesn't flip back and forth. C-Dolly Problem: Each time I have used C dollies I have had some trouble releasing latches."

"Handled very good in the wind."

"During high crosswinds, lock steering wheels on dollies on straight highways; makes tandem axle trailers very stable - same as B Train sets."

"I keep marking winds in the bottom of the Columbia River Gorge as normal, when in fact they are very strong. These triples handle so good that you don't notice the strong winds."

"This set - empty, in high winds - handled very well. No noticeable sway; great."

"I had forgotten how great these C-dollies are; had a straight trip!"

"Very good trip. Great not to have the back trailer whipping back and forth in construction zones and on rutted highways."

"After using a C-dolly for so long, going back to the A-dolly is like going from the space shuttle to a horse and buggy. It takes longer to do my work; more hooking and unhooking, switching trailers around. Going down the road there is a considerably more rear trailer sway. Also, I believe that when the rear trailer sways and moves the dolly, it also allows the front trailer to move more. The C-dolly provides stability to both front and rear trailers."

"I'll sure be glad to get back to C-dollies, hopefully next week."

"Triples handled very well with C dollies, almost like it wasn't even three trailers."

"Car pulled out in front of truck west of Nampa on Hwy. 55."

"Vehicle in front made sudden left hand turn in upper Salmon Canyon US 95 S."

"Steered to avoid merging traffic trying to avoid an accident in Boise." Time - 1:24 PM, Climate - clear, Road - dry, Load - empty.

Surprise maneuvering/steering to avoid an obstacle or vehicle - "A car pulled out in front of me from shoulder of road while coming down Winchester Grade." Time - 2:53 PM, Climate - clear, Road - dry, Load - full.

"Surprise maneuvering/steering to avoid an obstacle or vehicle - trying to avoid a box in the middle of the road on US 95S." Time 11:00 AM, Climate - clear, Road - dry, Load - empty.

"Caught by a strong side wind gust" - Time - 7:55 AM, Climate - clear, Road - dry, Load - empty.

"Coming down Winchester grade, I came around a curve and a rock slide came across two lanes. I got on the brakes hard and went to the right into a wide spot along the road. I had no problems with any sliding or locking up. Tractor, dolly and trailers handle good!" Time - 1:40 PM, Climate - rain, snow/ice and windy, Road - wet, Load - full.

"Noticed difference between A-dollies and C-dollies in the first mile of freeway driving. C-dollies pull straight as a pin - can't get them to sway without really trying. The C-dolly cornering at road speed is much improved over A-dollies. First impression - They're a pleasure to pull."

APPENDIX D

EQUIPMENT LIST AND ABS CONFIGURATIONS

The table below shows a list of all the equpment involved in the study. It also shows the ABS manufacturer, ABS configuration, and suspension type for each piece of equipment. Figure D-1 shows the ABS configurations for the semi-trailers and dollies used in this study.

Table D-1. Equipment list and ABS manufacturers and configurations

Albertsons	Tractors	Description	ABS Manufacturer	Config.	Susp. Type
	01-526	1993 Kenworth 6 X 4	Rockwell/WABCO	4S/4M	Air
	01-527	1993 Kenworth 6 X 4	Rockwell/WABCO	4S/4M	Air
	01-528	1993 Kenworth 6 X 4	Rockwell/WABCO	4S/4M	Air
Albertsons	Trailers	Description	ABS Manufacturer	Config.	Susp. Type
	13-737	1988 Utility 40' Tandem Axle Van	Allied Signal/Bendix	2S/1M	Steel
	13-738	1988 Utility 40' Tandem Axle Van	Allied Signal/Bendix	2S/1M	Steel
	13-739	1988 Utility 40' Tandem Axle Van	Allied Signal/Bendix	2S/1M	Steel
	13-753	1988 Utility 24' Tandem Axle Van	Allied Signal/Bendix	2S/1M	Steel
	13-754	1988 Utility 24' Tandem Axle Van	Allied Signal/Bendix	2S/1M	Steel
	13-755	1988 Utility 24' Tandem Axle Van	Allied Signal/Bendix	2S/1M	Steel
Albertsons	C-Dollies	Description	ABS Manufacturer	Config.	Susp. Type
	15-068	1993 Independent Trailer Super C	Allied Signal/Bendix	2S/1M	Steel
	15-069	1993 Independent Trailer Super C	Allied Signal/Bendix	2S/1M	Steel
	15-070	1993 Independent Trailer Super C	Allied Signal/Bendix	2S/1M	Steel
Fred Meyer	Tractors	Description	ABS Manufacturer	Config.	Susp. Type
	40310	1993 Freightliner 6 X 4	Rockwell/WABCO	4S/4M	Steel
	40311	1993 Freightliner 6 X 4	Rockwell/WABCO	4S/4M	Steel
	40312	1993 Freightliner 6 X 4	Rockwell/WABCO	4S/4M	Steel
Fred Meyer	Trailers	Description	ABS Manufacturer	Config.	Susp. Type
	51220	1990 27' Wabash Single Axle Van	Allied Signal/Bendix	2S/1M	Steel
	51221	1990 27' Wabash Single Axle Van	Allied Signal/Bendix	2S/1M	Steel
	52209	1990 31' Wabash Single Axle Van	Allied Signal/Bendix	2S/1M	Steel
	61146	1990 27' Comet Single Axle Reefer	Allied Signal/Bendix	2S/1M	Steel
	61147	1990 27' Comet Single Axle Reefer	Allied Signal/Bendix	2S/1M	Steel
	62162	1990 31' Comet Single Axle Reefer	Allied Signal/Bendix	2S/1M	Steel
	62163	1990 31' Comet Single Axle Reefer	Allied Signal/Bendix	2S/1M	Steel
	51219	1990 27' Wabash Single Axle Van	Midland-Grau	2S/2M	Steel

Table D-1 (continued). Equipment list and ABS manufacturers and configurations

	52220	1990 31' Wabash Single Axle Van	Midland-Grau	2S/2M	Steel
	61148	1990 27' Comet Single Axle Reefer	Midland-Grau	2S/2M	Steel
	62164	1990 31' Comet Single Axle Reefer	Midland-Grau	2S/2M	Steel
Fred Meyer	C-Dollies	Description	ABS Manufacturer	Config.	Susp. Type
	18284	1993 Independent Trailer Super C	Midland-Grau	2S/1M	Steel
	18285	1993 Independent Trailer Super C	Midland-Grau	2S/1M	Steel
	18286	1993 Independent Trailer Super C	Allied Signal/Bendix	2S/1M	Steel
	18287	1993 Independent Trailer Super C	Allied Signal/Bendix	2S/1M	Steel
	18288	1993 Independent Trailer Super C	Allied Signal/Bendix	2S/1M	Steel
	18289	1993 Independent Trailer Super C	Allied Signal/Bendix	2S/1M	Steel
Payless	Tractors	Description	ABS Manufacturer	Config.	Susp. Type
	133264	1991 Freightliner 6 X 4	Rockwell/WABCO	4S/4M	Steel
	133265	1991 Freightliner 6 X 4	Rockwell/WABCO	4S/4M	Steel
Payless	Trailers	Description	ABS Manufacturer	Config.	Susp. Type
	235513	1987 Alloy Frp 35' Tandem Axle Van	Midland-Grau	4S/2M	Steel
	235519	1987 Alloy Frp 35' Tandem Axle Van	Midland-Grau	4S/2M	Steel
	127351	1987 Alloy 27' Single Axle Van	Midland-Grau	2S/1M	Steel
	127352	1987 Alloy 27' Single Axle Van	Midland-Grau	2S/1M	Steel
	127353	1987 Alloy 27' Single Axle Van	Midland-Grau	2S/1M	Steel
	127354	1987 Alloy 27' Single Axle Van	Midland-Grau	2S/1M	Steel
	127355	1987 Alloy 27' Single Axle Van	Midland-Grau	2S/1M	Steel
	127356	1987 Alloy 27' Single Axle Van	Midland-Grau	2S/1M	Steel
	127357	1987 Alloy 27' Single Axle Van	Midland-Grau	2S/1M	Steel
	127358	1987 Alloy 27' Single Axle Van	Midland-Grau	2S/1M	Steel
Payless	C-Dollies	Description	ABS Manufacturer	Config.	Susp. Type
	910887	1993 Independent Trailer Super C	Midland-Grau	2S/1M	Steel
	910888	1993 Independent Trailer Super C	Midland-Grau	2S/1M	Steel
	910889	1993 Independent Trailer Super C	Midland-Grau	2S/1M	Steel
	910890	1993 Independent Trailer Super C	Midland-Grau	2S/1M	Steel
ShopKo	Tractors	Description	ABS Manufacturer	Config.	Susp. Type
	127	1992 Peterbilt Model 362 6 X 4	Rockwell/WABCO	4S/4M	Air
	128	1992 Peterbilt Model 362 6 X 4	Rockwell/WABCO	4S/4M	Air
	130	1993 Peterbilt Model 362 6 X 4	Rockwell/WABCO	4S/4M	Air
	131	1993 Peterbilt Model 362 6 X 4	Rockwell/WABCO	4S/4M	Air
	132	1993 Peterbilt Model 362 6 X 4	Rockwell/WABCO	4S/4M	Air
	133	1993 Peterbilt Model 362 6 X 4	Rockwell/WABCO	4S/4M	Air
	134	1993 Peterbilt Model 362 6 X 4	Rockwell/WABCO	4S/4M	Air
ShopKo	Trailers	Description	ABS Manufacturer	Config.	Susp. Type
	19	1991 Great Dane 44' Tandem Axle Van	Rockwell/WABCO	4S/2M	Air
	20	1991 Great Dane 44' Tandem Axle Van	Rockwell/WABCO	4S/2M	Air

Table D-1 (continued). Equipment list and ABS manufacturers and configurations

	21	1991 Great Dane 44' Tandem Axle Van	Rockwell/WABCO	4S/2M	Air
	22	1991 Great Dane 44' Tandem Axle Van	Rockwell/WABCO	4S/2M	Air
	23	1991 Great Dane 44' Tandem Axle Van	Rockwell/WABCO	4S/2M	Air
	24	1991 Great Dane 44' Tandem Axle Van	Rockwell/WABCO	4S/2M	Air
	25	1993 Great Dane 44' Tandem Axle Van (New)	Rockwell/WABCO	4S/2M	Air
	26	1993 Great Dane 44' Tandem Axle Van (New)	Rockwell/WABCO	4S/2M	Air
	27	1993 Great Dane 44' Tandem Axle Van (New)	Rockwell/WABCO	4S/2M	Air
	834	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	835	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	836	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	837	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	838	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	839	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	840	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	841	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	842	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	843	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	844	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	845	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	846	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	847	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	848	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	849	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	850	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	851	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	852	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	853	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	854	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	855	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	856	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	857	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	858	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	859	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	860	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
	861	1992 Great Dane 28' Single Axle Van	Rockwell/WABCO	2S/2M	Air
ShopKo	C-Dollies	Description	ABS Manufacturer	Config.	Susp. Type
	C12	1991 Independent Trailer Super C Retrofit	Rockwell/WABCO	2S/1M	Steel
	C13	1991 Independent Trailer Super C Retrofit	Rockwell/WABCO	2S/1M	Steel
	C14	1992 Independent Trailer Super C Retrofit	Rockwell/WABCO	2S/1M	Steel
	C15	1992 Independent Trailer Super C Retrofit	Rockwell/WABCO	2S/1M	Steel

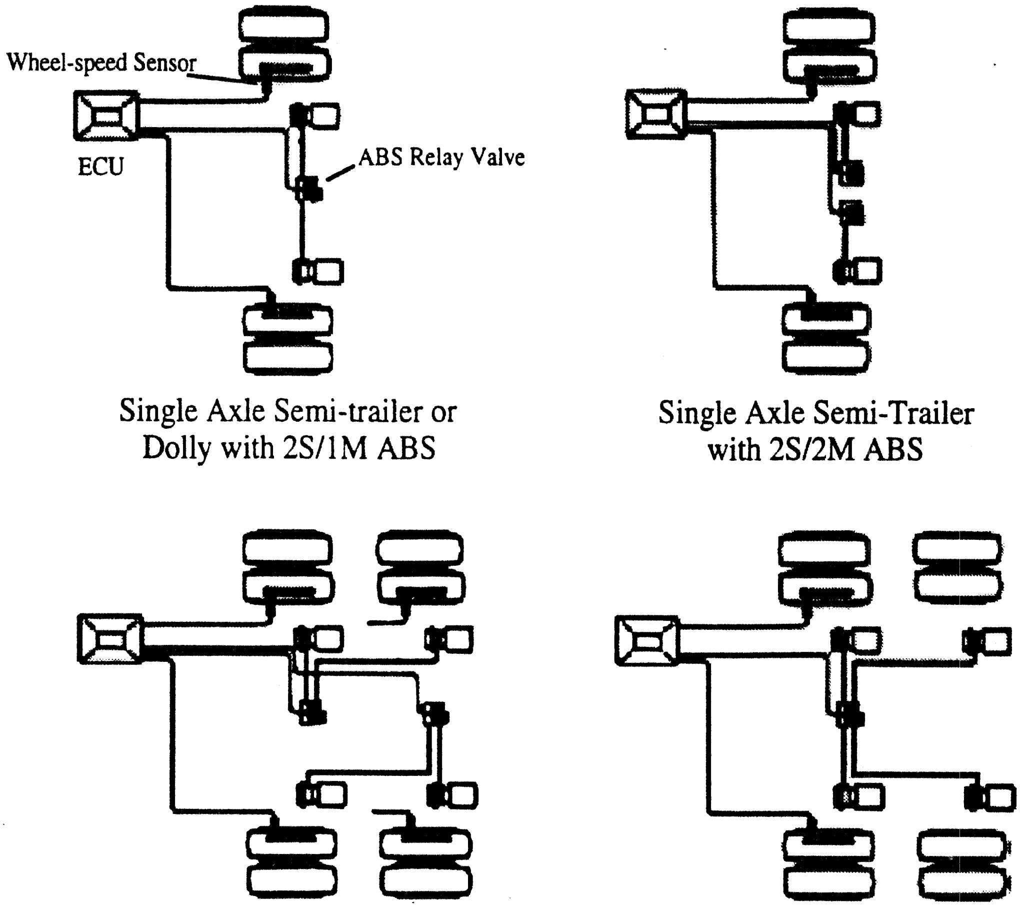
Table D-1 (continued). Equipment list and ABS manufacturers and configurations

	C16	1992 Independent Trailer Super C Retrofit	Rockwell/WABCO	2S/1M	Steel
	C17	1992 Independent Trailer Super C Retrofit	Rockwell/WABCO	2S/1M	Steel
	C18	1993 Independent Trailer Super C	Rockwell/WABCO	2S/1M	Steel
	C19	1993 Independent Trailer Super C	Rockwell/WABCO	2S/1M	Steel
	C20	1993 Independent Trailer Super C	Rockwell/WABCO	2S/1M	Steel
Silver Eagle	Tractors	Description	ABS Manufacturer	Config.	Susp. Type
	2733	1993 Freightliner 4 X 2	Rockwell/WABCO	4S/4M	Steel
	2735	1993 Freightliner 4 X 2	Rockwell/WABCO	4S/4M	Steel
Silver Eagle	Trailers	Description	ABS Manufacturer	Config.	Susp. Type
	8825	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8826	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8827	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8828	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8829	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8830	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8831	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8832	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8833	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8834	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8835	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8836	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8837	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8838	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8839	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8840	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8841	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8842	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8843	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8844	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8845	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
	8846	1990 Strick 28' Single Axle Van	Rockwell/WABCO	2S/2M	Steel
Silver Eagle	C-Dollies	Description	ABS Manufacturer	Config.	Susp. Type
	9800	1993 Independent Trailer Super C	Rockwell/WABCO	2S/1M	Steel
	9801	1993 Independent Trailer Super C	Rockwell/WABCO	2S/1M	Steel
	9802	1993 Independent Trailer Super C	Rockwell/WABCO	2S/1M	Steel
	9803	1993 Independent Trailer Super C	Rockwell/WABCO	2S/1M	Steel
	9804	1993 Independent Trailer Super C	Rockwell/WABCO	2S/1M	Steel
	9805	1993 Independent Trailer Super C	Rockwell/WABCO	2S/1M	Steel

Table D-1 (continued). Equipment list and ABS manufacturers and configurations

Semi-trailer and dolly ABS configurations used in the LCV field study

ABS configurations:
2S/1M = two wheel-speed sensors and one modulator relay valve
2S/2M = two wheel-speed sensors and two modulator relay valves
4S/2M = four wheel-speed sensors and two modulator relay valves



Single Axle Semi-trailer or Dolly with 2S/1M ABS

Single Axle Semi-Trailer with 2S/2M ABS

Tandem Axle Semi-Trailer with 4S/2M ABS

Tandem Axle Semi-Trailer with 2S/1M ABS

Figure D-1. Semi-trailer and dolly ABS configurations used in this study

APPENDIX E

C-DOLLY OPERATION AND SUPPLIER COMMENTS

Observations And Suppliers Comments Concerning The ITR Pintle Hitches

One aspect of the bell-mouth pintle hitch supplied by ITR that seemed to confuse some drivers was the existence of a neutral position in the operation of the releasing/locking handle.

This existence of this neutral position seemed to cause problems during the coupling and uncoupling process. In some cases, there were complaints of hitches coming unlatched even though they appeared to be locked. According to ITR, this was due to improper positioning of the hitch handle, most likely in the neutral position. ITR claims that "it is mechanically impossible for the hitch to come open if it is properly locked."

Another problem occurred when a driver or hostler attempted to couple the unit with the hitch handle in the neutral position. According to ITR this results in internal damage to certain set screws which in turn makes the hitch more difficult to operate properly. Disassembly and examination of hitches by ITR following problem reports revealed damaged or sheared set screws in six cases.

In response to these complaints and problems ITR had the following comments:

- Improvements in the hitch design are being made to make the hitches more reliable and user friendly. These include minor internal angle modifications, new foundry and machining tolerances, machining some surfaces that were previously ground, defining manufacturing and assembly procedures, and establishing quality control procedures for foundry/heat treat.
- Since the conclusion of the study, an operating placard placed near the bell hitches has virtually eliminated all coupling problems in other fleets.
- ITR changed thirteen hitches during the study and in some cases they did this instead of rebuilding the hitches. This was primarily done to avoid any delays in the study and to keep the fleets as content as possible. Many of the hitches, which were removed, however, were repaired and reused in the study, so the full replacement cost for hitches exaggerates the actual costs.
- Inspection of the hitches at one fleet showed that they were not being properly maintained and lubricated. This probably aggravated the hitching problems experienced by this fleet.

Operation, Maintenance, And Parts Manual Of The ITR C-dolly and Hitches

The following material is taken from manuals supplied by ITR.

MANUAL USE

This manual provides the necessary information for the safe operation, adjustments, alignments, scheduled maintenance, troubleshooting and parts ordering information, along with illustrated parts breakdowns of the various components, of the I.T.R.'S manufactured *Super C* converter dolly.

The manual is organized as follows:

Chapter 1 contains the manual use instructions, updating procedures, model number definition, description and operational safety precautions associated with the *Super C* converter dolly.

Chapter 2 contains brief descriptions of the controls and indicators and the procedures for the safe hitching and operation of the *Super C* converter dolly.

Chapter 3 contains the required scheduled maintenance necessary for the proper upkeep of the *Super C* converter dolly.

Chapter 4 contains the adjustment and alignment procedures which may be necessary to perform during the operational life of the *Super C* converter dolly.

Chapter 5 contains simple troubleshooting procedures which may be used to identify problems which may arise with the *Super C* converter dolly.

Chapter 6 contains parts ordering information and illustrated parts breakdowns of the *Super C* converter dolly.

Pages, figures and tables in this manual are numbered with a decimal format to accommodate the various options which may develop in the manufacture of the *Super C* converter dolly. This provides for the easy insertion of additional pages without the need to renumber the pages in the remainder of the chapter. New pages can be inserted between existing pages. For example, if pages 1.1.1 and 1.2.1 are existing pages and a new page, 1.1.2, is developed, page 1.1.2 would be inserted between pages 1.1.1 and 1.2.1. When inserting a revised page, dispose of the existing page and insert the new revision of that page in its place.

DESCRIPTION

Unlike most conventional dollies, *Super C*'s single-pivot, double drawbar design allows drivers to back up double trailers, without disconnecting, for faster, more efficient loading/unloading, and easier parking and maneuvering in tight quarters. Locking controls for the self-steering axle can be conveniently activated from the cab.

The self-steering axle offers a combination of high strength, excellent stability and improved maneuverability. Compared to A-type dollies, *Super C* offers 38% less off-tracking for significantly easier handling coming out of tight corners or congested areas. Superior lateral stability eliminates serpentining, which cuts down unnecessary tire wear and stress to trailer structural components. Patented "flexing" frame, engineered for long life, compensates for uneven surfaces.

DESCRIPTION - continued

Super C's double drawbar design provides improved roll stability and added protection against "jack-knifing". Eliminating serpentining promotes a smoother ride. There is no need for constant oversteering thereby reducing driver fatigue and the potential for accidents and injury. In many cases, this results in lower insurance costs.

Due to the patented full-flex frame, *Super C* weighs 25-30% less than other drawbar-type dollies for a significant increase in load-carrying capacity. Equipped with optional slider fifth wheel, *Super C* can be readily set up for load-and-dump-thru applications.

SPECIFICATIONS

STANDARD EQUIPMENT

The following equipment is standard equipment of the *Super C* converter dolly.

Frame:

1. Formed T-1 steel channel designed to flex for high loads.
2. Front flex plate fabricated of T-1 steel plate.
3. Rear crossmember formed from steel channel.
4. Coupler eyes cast of alloy steel.
5. Standard length of 73" (center of axle to center of eye).

Suspension:

1. Three-leaf low arch springs.

Fifth Wheel:

1. Customer can specify any brand fifth wheel.
2. 49" overall standard mounting height (depending upon tires).

Axle:

1. Self-steering type.
2. 71-1/2" track width.
3. 20,000 pounds capacity.
4. 5" round beam axle.
5. 16-1/2" x 7" brakes.

SPECIFICATIONS - continued

STANDARD EQUIPMENT - continued

Axle - continued

6. Steel construction, 10 stud, inboard mount hubs.

7. Cast steel brake drums.

8. Axle also features oil seals, air dampened steering, and air piston on tie rod for steering lock-up.

All parts are primed and finish painted with automotive polyurethane acrylic enamel fleet white.

OPTIONAL EQUIPMENT

The following equipment is optional equipment which must be specified at time of purchase.

Tires and Wheels:

1. Customer can specify any brand, standard style and size.

Axle:

1. 77-1/2" track width.

2. Aluminum hubs.

3. Centrifugally cast hubs.

4. Springless parking brake with quick-release valve.

5. Also available are tandem axles, outboard drum assemblies, eight-stud hubs and automatic slack adjusters.

Fifth Wheel Slider Assembly:

1. Fifth wheel assembly attached to mounting slider assembly with spring set, air released locking device (utilizes top flange of dolly frame for slider support surface.

2. 30" slider length.

3. Sliding fifth wheel mounting with 3/8" thick slider pad UHMW low friction, non-lube material.

4. Adjustable lock position, 3/4" increments located under mount between frame rails.

Other options available for the *Super C* converter dolly are mud flaps, lights, hubometer, customer choice of fleet colors, electric solenoid operated valves, cab mounted controls and emergency brake chamber with Hostler valve release.

MODEL NUMBER EXPLANATION

The model number is a short explicit code of the dolly's significant characteristics. This number is stamped on the dolly nameplate. The following briefly explains the dolly model number by number position

1 2 3 - 4

Position 1: The letter C will always appear in this position for "C"-Dolly.

Position 2: One of the following letters will appear in this position.
F - Fixed Fifth Wheel (Standard)
S - Slider Fifth Wheel (Optional)

Position 3: One of the following letters will appear in this position to identify the dolly's track width.
71 - 71-1/2" Track Width (Standard)
77 - 77-1/2" Track Width (Optional)

Position 4: One or both of the following letters will appear in this position to identify any special options. This position may also be left blank.
T - Tandem Axle Model
L - Low Hitch Model

A typical model number would be CF71-L

VEHICLE IDENTIFICATION NUMBER (VIN) EXPLANATION

The VIN is a required Department of Transportation (DOT), National Highway Traffic Safety Administration (NHTSA) 17 digit code generated per instructions in Code of Federal Regulations (CFR) Volume 49, Part 565. This number will be stamped on the dolly nameplate and frame. The following briefly explains the VIN by position.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Positions 1, 2 and 3: World Manufacturer Identifier (WMI); the number 1J9, assigned by the Society of Automotive Engineers (SAE) to I.T.R. will appear here.

Position 4: Type of Vehicle; the letter D (Dolly, Converter) will appear here.

Position 5: Series/Body Type
F - Fixed Fifth Wheel
S - Slider Fifth Wheel

Positions 6 and 7: Length (inches) from centerline of eye to centerline of axle.

Position 8: Number of Axles

Position 9: Check Digit (per CFR 49, Part 565)

Position 10: Model Year (per CFR 49, Part 565)

VEHICLE IDENTIFICATION NUMBER (VIN) EXPLANATION - continued

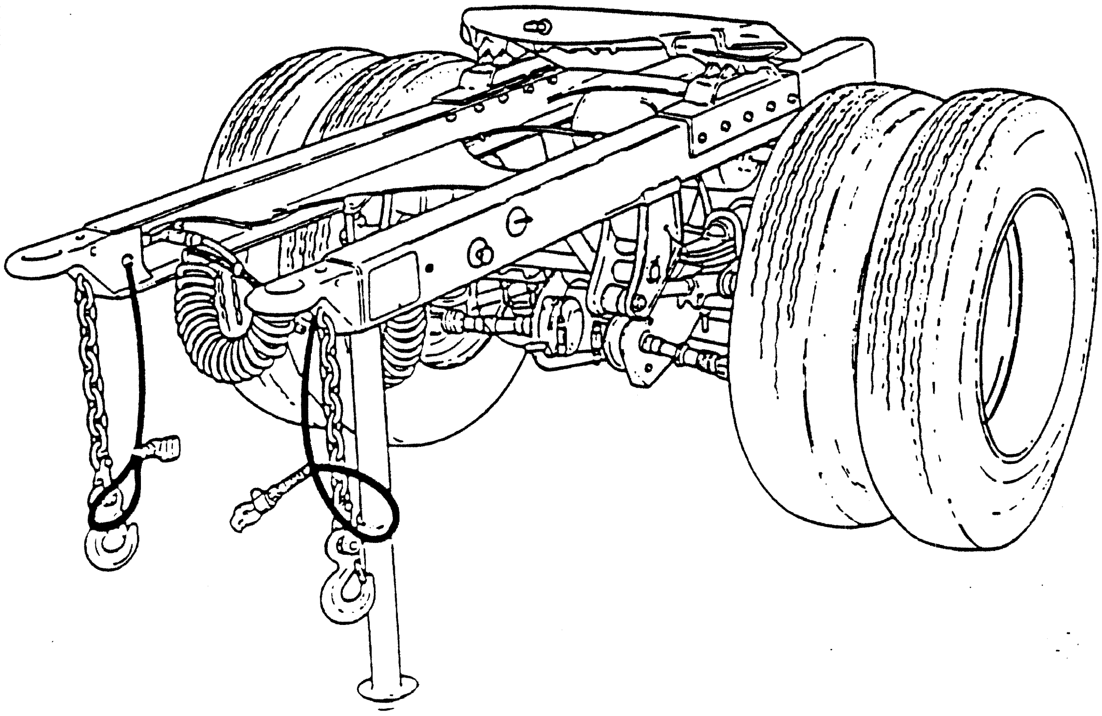
Position 11: Manufacturing Plant Location
R - Iron River, MI
O - Ontanogon, MI
M - Marquette, MI
K - Kingsford, MI
H - Rhinelander, WI
Y-Yakima, WA
Positions 12, 13, 14, 15, 16 and 17: Sequential Production Number

A typical VIN number would be 484DF7313KR000101.

SAFETY PRECAUTIONS

Following is a list of safety precautions associated with the operation and maintenance of the *Super C* converter dolly.

1. Always ensure dolly is hitched properly and safety chains are attached before operating the dolly.
2. Always ensure landing gear is at the proper height for hitching, unhitching or travel.
3. Before operating dolly, ensure fifth wheel is locked to king pin.
4. Ensure air hoses are properly connected before performing operations.
5. Special precautionary measures are essential to prevent applying air pressure to pneumatic system when performing maintenance or servicing the pneumatic system.
6. Use cleaning solvents in a well ventilated area to prevent inhalation of fumes.
7. Ensure pneumatic system is completely drained of air pressure before performing maintenance to pneumatic system



INTRODUCTION.

The following pages contain a description of the controls, the preoperational inspection procedures and operating procedures associated with the *Super C* converter dolly. These procedures shall be followed when operating the *Super C* converter dolly.

DESCRIPTION OF CONTROLS

The *Super C* converter dolly contains several controls which are essential to the operation of the *Super C* converter dolly. The controls and a short description of their function are as follows. See figure 2.1 for the physical location of these controls.

<u>Bell Mouth Hitch Handles</u> - The bell mouth hitch handles are located on the bell mouth hitch, which is mounted to the rear of the lead trailer. The bell mouth hitch is actually not part of the *Super C* converter dolly, but are mentioned in this manual for operational purposes.

<u>Jack Leg Handle</u> - The jack leg handle, located at the front of the left frame member, is used for raising and lowering the landing gear for hitching and unhitching procedures.

<u>Fifth Wheel Release Handle</u> - The fifth wheel release handle, located on the fifth wheel, is used for releasing the fifth wheel locking mechanism from the kingpin of the rear trailer. This handle is used only for unhitching procedures. The locking mechanism is automatic when hitching.

<u>Axle Lock Valve</u> - The axle lock valve, located on the left frame member, is used for locking and unlocking the self-steering axle locking mechanism. The axle locking mechanism is locked for travel and unlocked for hitching and unhitching procedures.

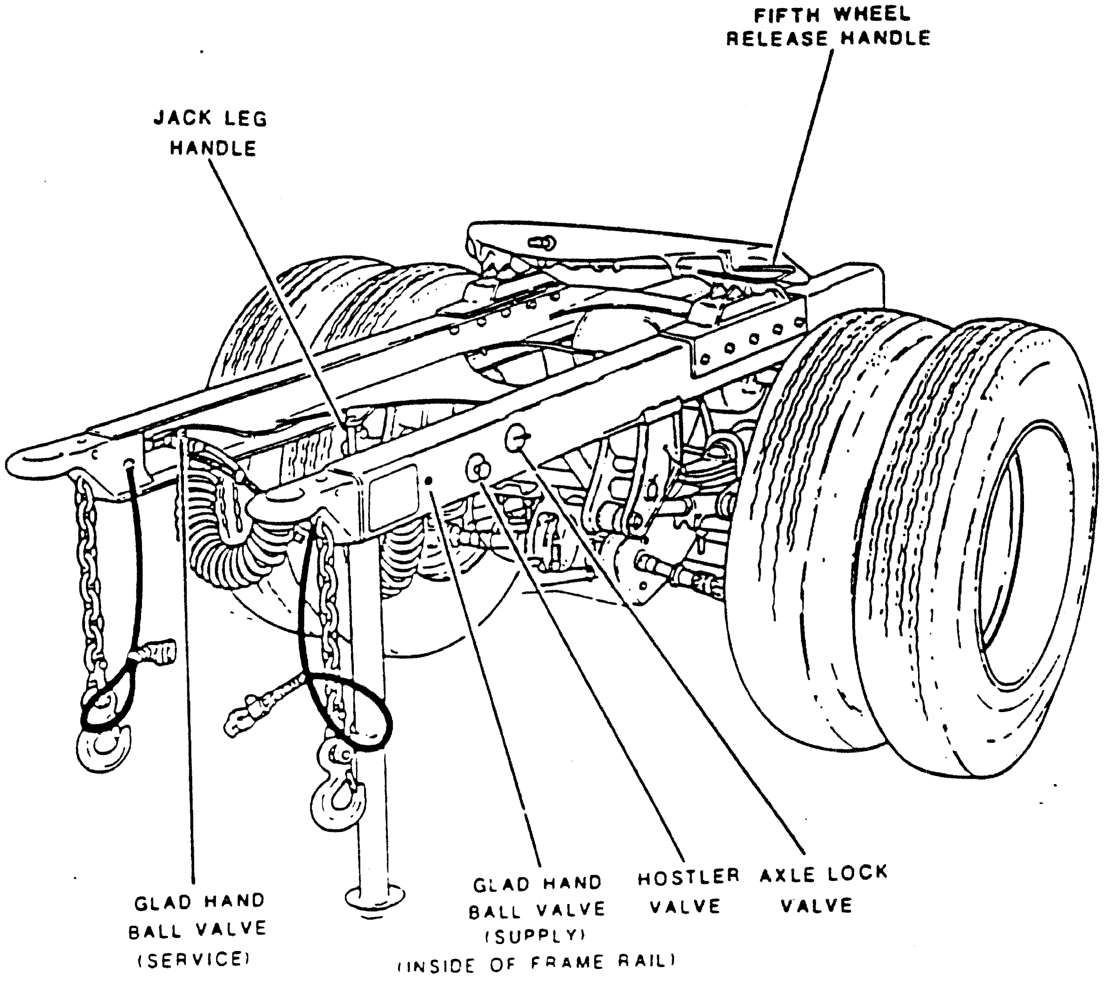
<u>Hostler Valve (Optional)</u> - The Hostler valve, located on the left frame member, is used for releasing the emergency brakes on models equipped with this option.

<u>Glad Hand Ball Valves</u> - The glad hand ball valves, located on the service and supply glad hands at the front and at each side of the dolly, are used for opening and closing the air supply through the glad hand assembly. These valves are open when the glad hands are connected to a rear trailer and closed when disconnecting the glad hands from the rear trailer.

PREOPERATIONAL INSPECTION PROCEDURES.

Before hitching to the *Super C* converter dolly, ensure that the following inspection procedures have been performed.

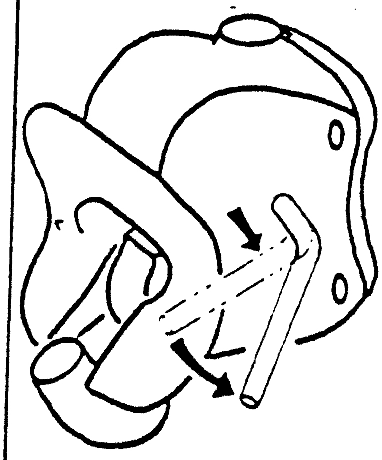
1. Inspect frame for any cracks, deformation or any other damage which may cause hazardous operation of the *Super C* converter dolly.
2. Ensure that tires are at the correct operating pressure.
3. Inspect wheel hubs for correct lubricant level (sight gauge is provided on wheel hub cap).
4. Ensure that safety chains, electrical wires and pneumatic lines are clear of *Super C* converter dolly drawbar eyes for hitching.
5. Ensure that jack leg is lowered to the proper level for hitching (drawbar eyes shall line up with bell mouth hitch of lead trailer).


FIFTH WHEEL
RELEASE HANDLE
JACK LEG
HANDLE
GLAD HAND
BALL VALVE
(SERVICE)
GLAD HAND
BALL VALVE
(SUPPLY)
(INSIDE OF FRAME RAIL)
HOSTLER
VALVE
AXLE LOCK
VALVE

HITCHING PROCEDURES.

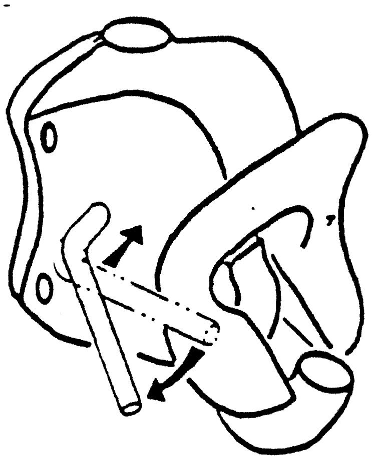
The following procedures shall be followed when hitching the *Super C* converter dolly to the lead trailer.

1. Open the bell mouth hitches on the rear of the lead trailer in accordance with the following steps and referring to figure 2.2.



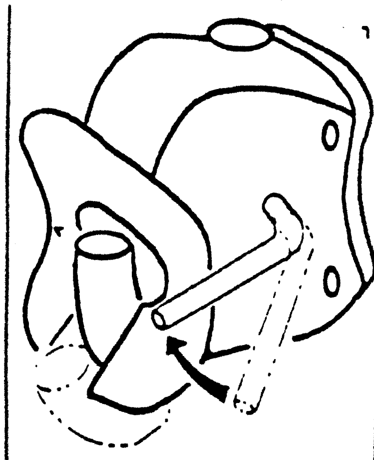
LEFT SIDE HITCH

IMPORTANT: The Handle must be slid to the extreme right before rotating down "Counterclockwise to be in ready position for hitching.



RIGHT SIDE HITCH

IMPORTANT: The handle must be slid to the extreme right before rotating down "Clockwise" to be in ready position for hitching.



LOCKED POSITION

IMPORTANT: The handle must be aligned with arrow on hitch face to be in fully locked position.

2. Hitch the *Super C* converter dolly to the lead trailer by backing the trailer into the *Super C* converter dolly. The hitches will automatically lock.

3. Perform the following procedures to prepare the *Super C* converter dolly for hitching to the rear trailer.

   a. Ensure that both drawbar eyes are locked in bell mouth hitches. Should ONE of these hitches fail to lock, steering to the right or left as you pull away should guarantee the hitch to lock. If neither hitch locked, repeat the hitching procedure.

   b. Raise the *Super C* converter dolly jack, on which the dolly was resting, to a locked, out-of-the-way position.

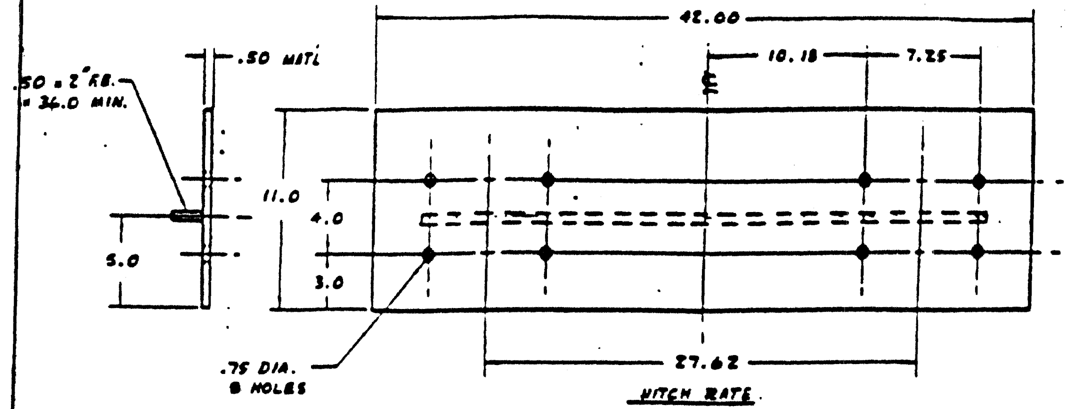
   c. Connect the safety chains, service and supply air lines and the electrical connection to the lead trailer. Open air valves to the *Super C* converter dolly.

   d. Lock the steering axle with the toggle switch located on the left drawbar.

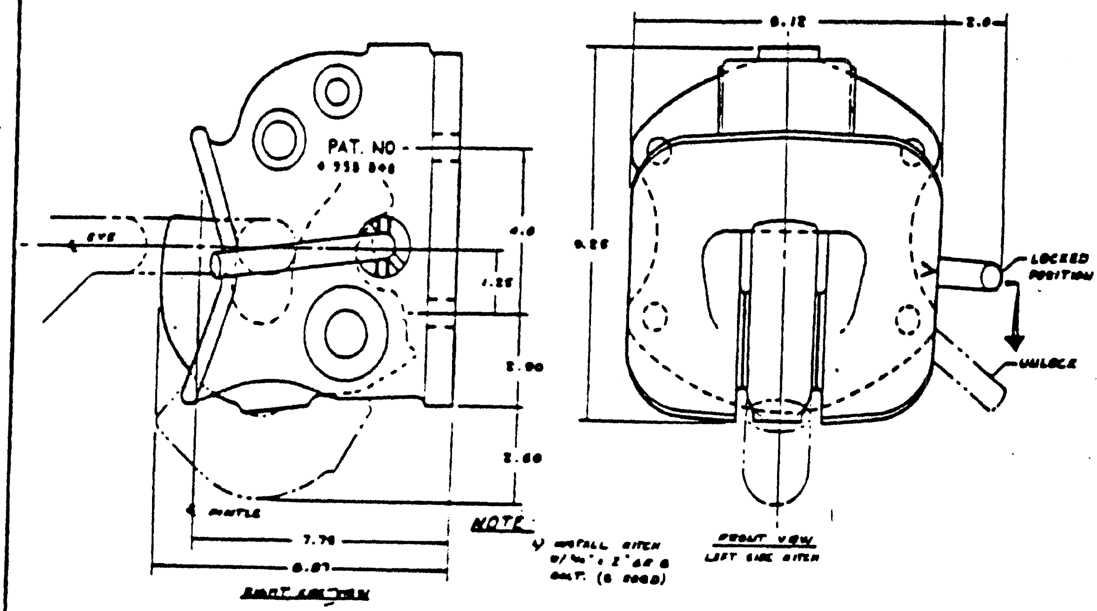
   e. Prior to backing to the rear trailer, make sure that the landing gear and trailer are at a safe height to receive the *Super C* converter dolly 5th wheel.

   f. Ensure that the *Super C* converter dolly 5th wheel locking mechanism is in the open position (see figure 2.1).

OPERATION OF HITCH & HITCH PLATE REQUIREMENTS



I T R STANDARD HITCH PLATE REQUIREMENTS AND HOLE DIMENSIONS



I T R HITCH DIMENSIONS AND OPERATING PROCEDURE

4. The *Super C* converter dolly is now ready to back under the rear trailer.

5. After backing the *Super C* converter dolly under the rear trailer, perform the following procedures to prepare for operation.

   a. Attach the service air line (color coded blue) and the supply air line (color coded red) to the rear trailer from the *Super C* converter dolly.

   b. Attach the electrical cable from the *Super C* converter dolly to the rear trailer.

   c. Open the air valves on the *Super C* converter dolly to the rear trailer.

   d. Unlock the *Super C* converter dolly steering axle.

   e. Ensure that the *Super C* converter dolly 5th wheel is locked to the king pin of the rear trailer.

   f. On models equipped with a slider 5th wheel, position 5th wheel in proper position for travel.

   g. On models equipped with emergency brakes, ensure that brakes are released for travel.

6. The *Super C* converter dolly is now ready for operation.

UNHITCHING PROCEDURE.

The unhitching procedures of the *Super C* converter dolly are basically the reverse of the hitching procedure. Perform the following to unhitch the *Super C* converter dolly.

1. Disconnect rear trailer from *Super C* converter dolly as follows:

   a. Lower landing gear of rear trailer to a safe height for disconnection from the *Super C* converter dolly.

   b. Close air valves on the *Super C* converter dolly to the rear trailer.

   c. Disconnect electrical cable and service and supply air lines from *Super C* converter dolly to the rear trailer.

   d. Unlock *Super C* converter dolly 5th wheel by pulling out on fifth wheel release handle (see figure 2.1).

   e. Pull *Super C* converter dolly out from under rear trailer.

2. To disconnect the *Super C* converter dolly from the lead trailer, proceed as follows

   a. Lock the steering axle with the toggle switch located on the left drawbar.

   b. On models with emergency brakes lock brakes in the parked position.

   c. Disconnect safety chains service and supply air lines and electrical cable from *Super C* converter dolly to lead trailer.

   d. Raise *Super C* converter dolly with jackleg to a safe height for disconnection from the lead trailer.

INTRODUCTION.

This chapter contains information and instructions for performing scheduled maintenance on the *Super C* converter dolly. These maintenance actions shall be followed to ensure a long and safe operating life of the *Super C* converter dolly.

SCHEDULED MAINTENANCE.

Scheduled maintenance for the *Super C* converter dolly consists of the following periodic maintenance requirements.

Periodic Inspections

1. Inspect oil level in wheel hubs (Daily).
2. Ensure proper operating air pressure in tires (Daily).
3. Inspect dolly frame, axle, fifth wheel and all other components for any visual signs of bends, cracks, stress, or any other physical damage (Daily).
4. Inspect all pneumatic hoses and components for any visual signs of damage and for proper connections (Daily).
5. Ensure fifth wheel top plate has a suitable coating of grease (Daily).
6. Drain water from air tank (Daily).
7. Inspect, clean and lubricate wheel bearings (30,000 miles or bi-annually).
8. Inspect brake linings for wear (30,000 miles or bi-annually).
9. Inspect brake drum oil seals for leakage (whenever wheels are removed).

Wheel Hub Oil Level Inspection

The inspection of the wheel hub oil level is performed by inspection of the sight gauge located on the wheel hub cap.

Tire Air Pressure Inspection

The tire air pressure inspection is performed using an air pressure gauge and inflating the tires to the manufacturer's recommended air pressure

Frame, Axle and Fifth Wheel Structural Inspection

Visually inspect all structural components of the *Super C* converter dolly for cracks, bends, stress or any other physical damage. Repair or replace components as necessary.

Fifth Wheel Top Plate Lubrication Inspection

Keep a water-resistant lithium-base grease applied to the trailer contact surface of the fifth wheel plate.

Air Tank Water Drainage

Water can be drained from the air tank (when air pressure is not applied to the *Super C* converter dolly pneumatic system by means of a drain cock located at the bottom of the air tank.

Wheel Bearing Inspection

Approximately every 30,000 miles or bi-annually the following procedures shall be performed on the wheel bearings.

1. Remove wheel assembly and bearing cones. Clean all old grease from hub of wheel, bearings and hub cap with a good grade commercial cleaner and a stuff brush, NOT STEEL. DO NOT use gasoline and DO NOT use compressed air in cleaning operation. Avoid spinning cone while cleaning.

2. Allow cleaned parts to dry and wipe them with a clean, absorbent cloth or paper. Lubricant will not adhere to a surface which is wet with solvent, and the solvent may dilute the lubricant. Cleanliness is most important.

3. Inspect bearing cups and bearing cones for indications of wear or damage. Handle all parts carefully during inspection and packing so the cage will not be bent or the rollers and cone damaged.

4. Place bearing cones in cups and check for proper fit and proper number.

5. Spread a light coat of gear type oil (SAE-90) on all parts before assembly.

Brake Lining Inspection

After adjustment of the brakes, if the brake will not release (cam returns to closed position), the linings should be replaced. Under no circumstances should linings be used to the point where the rivets or screws are above or level with the lining surface.

Brake Drum Oil Seal Inspection

Whenever the wheels are removed from the dolly, visually inspect the brake drum oil seals for any leakage of lubricant from the wheel hub.

Periodic Lubrication

The following lubrication procedures shall be performed monthly or every 3,000 miles using the recommended lubricant.

1. Lubricate the axle king pins (four locations) using an all purpose grease. Grease fittings are located above and below each king pin

2. Lubricate axle tie rod ends (two locations) using an all purpose grease. Grease fittings are located on each tie rod ball stud socket.

3. Lubricate the brake camshafts (two locations) using an all purpose grease. Grease fittings are located on the camshaft tube of each spindle.

4. Lubricate the brake slack adjusters (two locations) using an all purpose grease. Grease fittings are located on each slack adjuster at the back side of each spindle.

5. Lubricate the jack leg (one location, optional models only) using an all purpose grease. A grease fitting is provided at the top of the outer tube below the handle.

6. Lubricate the fifth wheel mounting bracket bushing (two locations) using an all purpose grease. Grease fittings are provided in the mounting bracket at each side of the fifth wheel top plate at the fifth wheel pivot point.

7. Lubricate the fifth wheel top plate by applying a water-resistant lithium base grease to the trailer contact surface of the top plate.

8. Lubricate wheel hubs by filling hubs with SAE 80/90 gear lubricant. The lubricant can be applied through the wheel hub cap.

Torque Inspections

A torque inspection shall be performed monthly or every 30,000 miles on the following components to ensure security of these components.

1. Tie rod clamp bolts.
2. Damper clevis bolts.
3. Damper pot push rod locknut.
4. Damper pot mounting bolts.
5. Brake pot mounting bolts
6. Slack adjuster attachment hardware.
7. King pin cover plate bolts
8. Wheel nuts.
9. Fifth wheel mounting hardware
10. Torque arm bolts.

INTRODUCTION.

This chapter contains the adjustment and alignment procedures which may be necessary to perform during the operational life of the *Super C* converter dolly. The following adjustment and alignment procedures shall be performed as required.

Wheel Toe-In Adjustment

1. Adjustment must be done on a flat level surface.
2. Wheels and tires must be installed on the axle.
3. Raise steering axle so that the tires are clear of the ground and block so that the tire to floor level clearance is the same on both left and right sides. This distance can not vary more than 1/16 inch from one side to the other.
4. When blocking, do not interfere with the axle's ability to steer by restricting tie rod movement.
5. Apply air pressure to the steering damper.
6. Locate a toe-in scriber instrument in front of the steering axle on the roadside of the unit.
7. Place the scriber point approximately in the center of a tire rib on the inside roadside tire.
8. Hold the scriber base so that no movement is possible and have and assistant rotate the wheel.
9. The scriber should leave a recognizable mark on the tire around its entire circumference.
10. If the tire was scribed properly (if there was no movement), the scribe line should meet perfectly at the point where the line started and finishes.
11. If, as you return to the start of the line, there is a spread separating the lines, the scriber has moved. Move the scriber over one tire rib and try again.
12. Repeat the procedure on the inside curbside tire.
13. It is not critical that the scribed line be on the same rib on each tire.
14. Measure from floor level to spindle center.
15. Measure the distance from the scribe line on the curbside tire to the scribe line on the left tire at the rear of the tires at spindle height. (This height can be varied slightly if there are mechanical obstructions).
16. Repeat the process at the same height on the front face of the tires.
17. Front and rear measurements should be the same, or a maximum of 1/16 inch greater at the rear of the tire.
18. If the above measurements are not achieved, the following adjustment procedure shall be performed.
    a. Leave damper pressure on during adjustment
    b. Loosen tie rod end jam nuts

c. Loosen lock out bracket clamp bolts.

d. Rotate tire rod until desired measurement is achieved and re-tighten fasteners.

Steering Damper Adjustment Procedure

1. With toe-in adjusted properly, locate and mark the center of the axle beam (the best reference points are the thrust bearings outer diameters).
2. Raise the axle so that tires clear the floor and support the axle so that the steering will function.
3. Apply damper air pressure.
4. Measure from the tie rod end center to the center mark on the axle beam.
5. This distance should be the same on both sides. If not adjustment is necessary.
6. Loosen damper pot jam nuts.
7. By turning the damper sleeve the clevis will extend one and retract the other to achieve the measurement desired.
8. When this is done, tighten jam nuts.
9. If a large adjustment is necessary, it may be necessary to relocate the lock plate on the tie rod so that the lock pin will engage the hole.

Wheel Alignment

1. Toe-in and damper adjustments must be done prior to wheel alignment.
2. With above operations completed and damper pressure on, adjust suspension to provide proper wheel alignment using the same procedures as with a conventional beam axle.
3. Only one special procedure is necessary during this operation and that is that the axle should be supported on a floor jack with rollers and the tires should be clear of the floor.

Slack Adjuster Adjustment (Models without Automatic Slack Adjusters)

1. Raise wheel off the ground.
2. With the wheel turning slightly (by hand), rotate the adjusting screw on the slack adjuster until the wheel is locked by the brakes.
3. Back off the adjusting screw until the wheel turns freely with no evidence of brake "drag". Usually two "clicks" of the slack adjuster screw is sufficient to provide the proper clearance).

Torque Arm Adjustment

1. Before attempting alignment, make sure suspension is free and loose in order to obtain a true alignment.

2. Measure the distance from the king pin to the centerline of the spindles. It is recommended that spindle extensions be utilized.

3. The roadside and curbside dimensions should be equal in order for correct alignment.

4. Alignment can be accomplished by loosening the torque arm clamp screws on both ends of the torque arm and turning the adjustment screw.

5. After alignment has been accomplished, tighten the torque arm clamp bolts 45-50 foot-pounds torque in order to lock the alignment of the axle.

APPENDIX F

FLEET ROUTES

This appendix contains a brief review of the most common routes traveled by the five participating fleets during the study. Figure F-1 is a map of the region showing the location of the two distribution centers (Portland and Boise) and the most common routes and destinations of the study.

Albertsons, Route 1, Portland/Spokane

This route is approximately 740 miles, round trip. Interstate 84 for 140 miles is a divided highway with two lanes each way and no major hills or sharp curves. There are some gradual inclines but nothing serious. The posted truck speed is 55 mph with most at traveling 60-65 mph. There are some maintenance and construction projects that require merging and slowing. All of this section of the trip is subject to wind gusts and there is normally a 10-15 mph wind. (The Columbia River gorge is the home of the best wind surfing in the world because of this constant breeze.) The wind compounds the winter weather. I-84 is sometimes closed for short durations and use of triples is often restricted. Traffic is basically light.

Highway 395 north to I-90 is two-lanes with a ten mile grade from the Columbia River. There is little room to pass except at the designated passing lanes. There are at least eight miles of construction projects. This is a good two-lane road with medium traffic. Winter weather in this area is pretty rough. There are over thirty miles of construction in the sixty miles from Ritzville to Spokane. Ritzville is where I-90 and 395 intersect. Traffic on this entire route is light except in the Spokane area. There are no lights or stops. There are many hills, but no major six- or seven-percent grades.

Albertsons, Route 2, Portland/Medford/Klamath Falls/Christmas Valley/Bend/Portland

On Albertsons second route we will cover about 750 miles, making a south, east, north, and west loop. Even in the extreme weather, doubles are not restricted as triples would be.

This route follows approximately 290 miles of Interstate 5. All of which is four-lane, divided highway. The first 150 miles south of Portland are pretty flat with heavy traffic. Weather for this section is usually rainy. There is normally a couple of weeks out of the year that snow and ice are a factor. The 130 miles north of Medford are much dryer, but there are four major grades (2,000-foot elevations) and several smaller ones. During the winter months snow is common. Traffic is very light and most of this is trucks. Most cruising speeds are more than 60 mph. There are some pretty good curves in this section. There is the rutting in the slow lane, and there are several maintenance programs that slow traffic.

From Medford we travel Oregon highway 140 east to Klamath Falls, about 70 miles. Highway 140 is a good, two-lane highway with passing lanes. We cross a summit of 5,150-foot elevation. There is one six-percent grade of over two miles in length. During the winter months there is plenty of snow in this region.

From Klamath Falls we travel north on U.S. highway 97 to Oregon 232. U.S. 97 is a good two-lane highway with few grades. There are few stops and some sections of 97 are divided, four-lane highway.

We travel east on Oregon 232, about 50 miles on good two-lane highway with very little traffic. We travel on Oregon 31 east of Christmas Valley for a 45,000 lb. backhaul of cat litter. We will travel west on good, two-lane highway until we reach Oregon 31. We travel north on 31 to back to U.S. 97.

This section of U.S. 97 is a very good, two-lane highway. Traffic around Bend is terrible since 97 goes right through town. We will be in heavy four-lane, stop-and-go traffic for 15 miles until north of Redmond. Traveling to Madras is on a good, two-lane highway.

At Madras we take U.S. 26 north across the Warm Springs Indian Reservation, and then west across Mount Hood. U.S. 26 is very similar to U.S. 97 and is a good, two-lane highway. We have about two miles of downgrade and two miles uphill after crossing the Deschutes River. Other than this we are on pretty flat plains with a slow incline as we near Mount Hood. This is good highway with passing lanes and plenty of curves. After the summit of 5,000-foot elevation, we will have six miles of six-percent downgrade. Some of this is five-lane road and after the six-percent grade we are four-lane all the way to Portland. Weather on the mountain is severe in the winter with plenty of snow. East of Mount Hood the weather is colder in the winter but a lot dryer.

Fred Meyer, Route 1 Portland/Medford

This route is approximately 560 miles of Interstate 5. It is a four-lane divided highway. The first 150 miles south of Portland are pretty flat with fairly heavy traffic. Weather for this section is usually rainy. There are normally a couple of weeks out of the year that snow and ice are a factor. The last 130 miles north of Medford is much dryer, but there are four major grades (2,000-foot elevation) and several smaller ones. During the winter months snow is common. Traffic is very light and most of this is trucks. Most travel is in excess of 60 mph. There are some pretty good curves in this section. Supposedly, the worst on I-5 is at Myrtle Creek and is marked at 40 mph. The highway is pretty good, but there is rutting in the slow lane. There are several maintenance programs on bridges and pavement and slow the traffic when it merges to one lane. There are no planned stops or lights on I-5.

PayLess, Route 1, Wilsonville/Seattle

This route is approximately 360-400 miles round trip with divided highway of at least two lanes each way. There are no significant sharp turns, only gradual sweeping curves. There are no significant hills, but a few grades of two- to three-percent incline of 200 to 500 foot elevations. There are no stop signs or lights on I-205 or I-5. There are some construction projects that require traffic to merge into reduced lanes. Basic speed is either 55 mph or 60 mph. Most truck traffic is traveling at 60 mph all the time. There are wind gusts and posted signs around the Columbia River. Traffic congestion is the major problem on this route with the density increasing the closer you get to Seattle, WA. The morning and evening rush-hour traffic is a major cause of the congestion. The forty miles from Olympia to Seattle is constant heavy traffic. Weather on this route is pretty good, and only a few weeks out of the year are ice and snow a concern. Rain is normal for the fall, winter, and spring months. There are no restrictions due to weather for the PayLess Rocky Mountain combinations.

PayLess, Route 2, Wilsonville/Medford

This route is approximately 500 miles of Interstate 5, all four-lane, divided highway. The first 120 miles south of Portland are pretty flat with heavy traffic. Weather for this section is usually rainy. There is normally a couple of weeks out of the year that snow and ice are a concern. The last 130 miles north of Medford are much dryer, but there are four, major grades (2,000-foot elevations) and several smaller ones. During the winter months, snow is common. Traffic is very light, and most of this is trucks. Most travel is in excess of 60 mph. There are some pretty good curves in this section. The highway is pretty good, but there is rutting in the slow lane, and there are several maintenance programs that slow traffic when it merges into one lane.

PayLess, Route 3, Wilsonville/Baker City

This route is approximately 700 miles on Interstate 205 and 84. Both are divided four-lane highways with no stopping or congestion. There are construction projects, but normally just the combining of lanes on that section. East of Portland, 160 to 200 miles, there are a signs for "blowing dust." This can be a serious problem when the wind and farming preparations are combined. East of Pendleton, or 220 miles east of Portland there is a six-mile six-percent grade. On the eastern side of these mountains there are several smaller grades. Traffic is light and most of the trucks are traveling in excess of 60 mph.

PayLess, Route 4, Wilsonville/Klamath Falls via highway 58

This route starts with the good, four-lane, Interstate 5 south to Eugene Oregon. It is flat but has plenty of traffic. Oregon highway 58 east is primarily a two-lane highway with steady climbs and plenty of curves. The road is very rough (bumpy, pot holes, etc.). This is probably the shortest route to Klamath Falls from Wilsonville and could be turned in one day. It is 260 miles one way. I don't think our test equipment would hold up under a lot of use on this road because of the pot holes. It is by far the worst maintained of all the possible test routes. Only one, five-percent decline. Traffic is light.

PayLess , Route 4, Wilsonville/Klamath Falls via Santiam Pass

I-5 south from Wilsonville is a six-lane, divided highway that is without any major hills. It is a good highway with plenty of traffic.

At Salem, we travel east on highway 20. Highway 20 is a very good, two-lane, primary highway. The highway surface is the best of the three passes across the Cascades. There are several passing lanes for east bound traffic. There is a steady incline with 4.5 miles of six-percent grade. The elevation at the summit is 4,817 feet. The highway travels through Sisters. This small town has plenty of congestion with many tourists, both walking and driving. We travel about twenty miles into Bend, which has four-lane, stop-and-go traffic all the way through town with very heavy congestion.

South of Bend, traveling on highway 97, there are no major hills between Bend and Klamath Falls. Highway 97 is very good, heavily traveled two-lane and some divided four-lane highway. There is plenty of truck traffic.

The Santiam pass is a very good route, with good highway surface. Most of the traffic congestion is in Bend or Sisters. Portland to Klamath Falls via Santiam Pass is 520 - 560 miles, depending on where you start.

ShopKo Stores, Route 1, Boise/Spokane

This route is approximately 900 miles round trip on two-lane, U.S. 95 highway. This highway will give us a very good test. It has very severe corners and very difficult grades. There are five sections of seven-percent grades that range from two miles to ten miles in each direction. Several of these will cover more than 2,000 feet of elevation both up and down. There are not many passing lanes on this two-lane highway. The highway itself is pretty good and traffic is low density. Weather will be a major problem in the winter months. There will be congestion problems in the small towns with frequent stops. This is a very rough run that will give the ultimate in ABS and C-dolly testing.

ShopKo Stores, Route 2 Boise/Reno

Highway 95 west and south out of Boise is pretty good road with a couple of very good grades of six-percent for several miles. Traffic is heavy for the first fifty miles. Once in Oregon the two-lane highway is straight for forty miles at a time. There are major repaving projects under way, and traffic is held up for thirty minutes at a time. There are four miles of very rough highway in Nevada, and one and a half miles of rough gravel both ways. There are not many curves in any of this route. There is a two mile six-percent grade north of Winnemucca, Nevada, on highway 95. This is the only major grade on the entire route. Highway I-80 west to Reno is very good, divided highway with no traffic, curves, hills, trees, people or anything except sand. There are severe wind gusts. In the winter, trucks and RVs are held up at times until wind subsides. This will be a good route of 900 miles, round trip.

Silver Eagle, Route 1, Portland/Boise

This route covers approximately 850 miles on Interstate 84. It is a divided four-lane highway with no stopping or congestion problems. There are construction projects, but normally just the merging of lanes on that section. There are fifteen-miles of rough pavement east of Baker City and rutting of the slow lanes for 50 miles in both directions near Portland. Wind and wind gusts are constant for the 100 miles east of Portland. For 160 to 200 miles east of Portland, there are signs posted for "blowing dust." This can be a serious problem when the wind and farming preparations are combined. East of Pendleton, or 220 miles east of Portland, there is a six-mile, six-percent grade known as Cabbage Hill. The east side of this run is pretty flat. There is not a lot of traffic, and most of the trucks are traveling in excess of 60 mph.

Table G-3. Albertsons

Driver	*Number of trips*	*Driver*	*Number of trips*
Tony Amundson	7	Randy Martin	5
John Archer	4	Mike Maye	1
Charlie Betts	1	Dennis McKissick	2
Tony Birkeland	1	Fred Miller	1
Wes Bittick	1	Rick Montgomery	2
Dan Bjornstrom	1	T. Nunn	1
John Brassfield	5	O'Connor	1
Chuck Byea	2	Ray Odle	3
Ron Caywood	8	David Olson	2
Frank Colten	2	Doug Paasch	1
Larry Cudney	12	Ken Paul	1
Keith Deleshmitt	2	John Percival	4
Jim Diemer	1	Dan Perin	1
Randy Ebert	3	Dwayne Peterson	2
Ken Eiseman	1	Nathan Pranger	1
Del Faulds	3	Bob Rathke	1
Mike Fogarty	1	Paul Rawson	1
Larry Fulton	2	James Reynolds	1
Bill Gleason	1	Tom Ritchie	6
Robert Grinstead	2	R. Roberts	1
Rick Hanson	8	Orville Robinett	1
Darold Hartwig	1	Dave Rose	1
Leigh Heck	1	Ron Satre	4
Richard Hernandez	1	Bob Schmidt	1
K. Hewes	1	Darrel Schmidt	1
Jim Higgs	1	Jeff Seifert	5
Jim Hoffman	5	Fred Smit	1
Don Hollenbeck	2	Thomas Sorenson	1
Joe Houston	4	Joe Speermen	1
Marv Hurtt	12	Randy Sutherland	2
Mel Hust	2	Dave Talaska	1
C. Jensen	1	Robert Tanner	3
Glenn Judd	1	Rick Turner	3
Ron Kamph	1	Vint Urie	2
Barry Kenney	6	Mike Wallace	1
Kestner	1	L. Warren	2
Alvin Kuenzi	6	Mike Weeks	1
D. LeBaron	8	Gary Wilson	1
Rick Long	1	Ed Wire	1
Rod Louden	3	Bruce Wolfley	2
S. Mallory	2	Pat Woods	1
Bill Manser	1	Other	1
Jeff Marcellus	2		

Table G-4. Fred Meyer/Distribution Trucking Company

Driver	*Number of trips*	*Driver*	*Number of trips*
Bart Adams	2	Allan Godell	2
Wayne Alexander	1	Carey Hopkins	11
Joe Amick	2	Will Houghton	1
Jerry Barber	1	Stephen Johnson	3
G. Bas	3	Tom Kerns	5
J. Bennett	1	John King	1
Ken Berns	2	P. Leavitt	2
Cliff Boatman	1	Merle McMichael	1
Bogard	2	Steve Pewonka	1
Dale Brandenburg	1	Leo McPherson	15
Ralph Brandsma	1	Raffensberger	4
Scott Brown	1	Larry Rasmusson	1
Timothy Burnett	1	Gary Reynolds	1
Tim Burt	1	Larry Rocha	8
Scott Christiansen	1	Mike Rogers	12
Jim Coburn	48	Vince Roth	1
Steve Collar	9	G. Scoles	1
Jim Comella	1	Jim Severson	8
M. Connaly	1	Doug Thomas	48
Ken Craig	1	Tom Thornbrue	1
Darrell Dix	1	Steve Trachsel	35
T. Emery	3	Wayne Tyre	2
Erickson	1	Frank Ward	1
Magge Foote	2	Pat Wheeler	3
Tom George	1	Link Wilson	2
Bill Gifford	13	Steve Wilson	1

Table G-5. ShopKo Stores/SVS Trucking

Driver	*Number of trips*	*Driver*	*Number of trips*
Robert B. Armfield	112	Jimmie W. Grist	109
Joe Colley	160	Brian Resch	139
Robert A. Cowan	8	Dennis Saari	3
Jim DeVries	120	Robert Welsh	48

Notes:

- A trip typically consisted of an outbound and a return leg, but could consist of up to six legs covered on separate driver trip forms to document changes in load or equipment.
- Trip data was entered into records only if at least two pieces of test equipment (tractor and test trailer, two test trailers, etc.) were included in the combination.
- Many Silver Eagle (75) and Fred Meyer (95) trips contain only one leg due to non-test equipment being used on the other leg of the trip.
- Many (88) Albertsons' trips were reported as round trips (on one driver trip form), because equipment was not changed and backhauls were loaded.

APPENDIX H

ABS ACTIVITY AND BRAKE-LIGHT-CIRCUIT VOLTAGE

This appendix contains additional results on the performance of antilock braking systems on long combination vehicles.

Contents:

Table H-1. The occurrence of LCV braking events according to vehicle load and the number of units experiencing ABS activity

Rocky Mountain doubles						
Load	*Travel time, hrs.*	*Distance, miles*	*1 Unit*	*2 Units*	*3 Units*	*4 Units*
Full	1,461	73,822	111	9	4	1
Empty	1,321	69,045	223	33	5	0
Mixed	20	1,089	7	0	0	0
All	2,802	143,957	341	42	9	1
Western doubles						
Full	397	20,860	23	4	1	0
Empty	317	17,299	33	3	7	0
Mixed	117	6,457	22	9	3	0
All	831	44,617	78	16	11	0
Reverse Rocky Mountain doubles						
Full	244	13,128	18	1	0	0
Empty	183	10,100	11	3	0	0
Mixed	0	0	0	0	0	0
All	427	23,228	29	4	0	0
All doubles						
Full	2,101	107,810	152	14	5	1
Empty	1,821	96,445	267	39	12	0
Mixed	137	7,546	29	9	3	0
All	4,060	211,801	448	62	20	1
Triples						
Full	774	40,983	55	6	1	0
Empty	604	32,816	53	11	3	1
Mixed	204	11,112	20	5	3	0
All	1,582	84,910	128	22	7	1

Table H-2. The occurrence of LCV braking events according to vehicle speed and the number of units experiencing ABS activity

Speed, mph	*Travel time, hrs.*	*Distance, miles*	*1 Unit*	*2 Units*	*3 Units*	*4 Units*
Rocky Mountain doubles						
0 - 25	246	3,713	142	24	3	1
25 - 45	364	13,204	134	16	5	0
45+	2,193	127,040	65	2	1	0
All	2,802	143,957	341	42	9	1
Western doubles						
0 - 25	47	586	29	9	8	0
25 - 45	82	2,939	27	4	3	0
45+	702	41,092	22	3	0	0
All	831	44,617	78	16	11	0
Reverse Rocky Mountain doubles						
0 - 25	24	297	17	2	0	0
25 - 45	29	1,021	9	2	0	0
45+	374	21,910	3	0	0	0
All	427	23,228	29	4	0	0
All doubles						
0 - 25	317	4,596	188	35	11	1
25 - 45	474	17,164	170	22	8	0
45+	3,269	190,042	90	5	1	0
All	4,060	211,801	448	62	20	1
Triples						
0 - 25	112	1,590	52	9	2	0
25 - 45	152	5,404	47	8	2	1
45+	1,319	77,916	29	5	3	0
All	1,582	84,910	128	22	7	1

Table H-3. The occurrence of LCV braking events according to vehicle load and the number of ABS cycles during the event

Rocky Mountain doubles						
Load	*Travel time, hrs.*	*Distance, miles*	*0 Cycles*	*1 Cycle*	*2-3 Cyc.*	*4+ Cyc.*
Full	1,461	73,822	107	35	10	1
Empty	1,321	69,045	224	51	24	10
Mixed	20	1,089	6	1	0	0
All	2,802	143,957	337	87	34	11
Western doubles						
Full	397	20,860	13	13	6	3
Empty	317	17,299	42	16	3	6
Mixed	117	6,457	28	17	4	3
All	831	44,617	83	46	13	12
Reverse Rocky Mountain doubles						
Full	244	13,128	15	5	0	0
Empty	183	10,100	12	4	1	0
Mixed	0	0	0	0	0	0
All	427	23,228	27	9	1	0
All doubles						
Full	2,101	107,810	135	53	16	4
Empty	1,821	96,445	278	71	28	16
Mixed	137	7,546	34	18	4	3
All	4,060	211,801	447	142	48	23
Triples						
Full	774	40,983	54	11	4	2
Empty	604	32,816	71	13	8	3
Mixed	204	11,112	30	11	1	0
All	1,582	84,910	155	35	13	5

Table H-4. The occurrence of LCV braking events according to vehicle speed and the number of ABS cycles during the event

Speed, mph	*Travel time, hrs.*	*Distance, miles*	*0 Cycles*	*1 Cycle*	*2-3 Cyc.*	*4+ Cyc.*
Rocky Mountain doubles						
0 - 25	246	3,713	120	57	27	6
25 - 45	364	13,204	146	28	7	5
45+	2,193	127,040	71	2	0	0
All	2,802	143,957	337	87	34	11
Western doubles						
0 - 25	47	586	27	34	12	6
25 - 45	82	2,939	31	9	1	6
45+	702	41,092	25	3	0	0
All	831	44,617	83	46	13	12
Reverse Rocky Mountain doubles						
0 - 25	24	297	11	9	1	0
25 - 45	29	1,021	13	0	0	0
45+	374	21,910	3	0	0	0
All	427	23,228	27	9	1	0
All doubles						
0 - 25	317	4,596	158	100	40	12
25 - 45	474	17,164	190	37	8	11
45+	3,269	190,042	99	5	0	0
All	4,060	211,801	447	142	48	23
Triples						
0 - 25	112	1,590	43	22	9	4
25 - 45	152	5,404	63	12	3	1
45+	1,319	77,916	49	1	1	0
All	1,582	84,910	155	35	13	5

Table H-5. The occurrence of LCV braking events according to vehicle load and the number of ABS cycles during the event

Rocky Mountain doubles						
Load	Tractor	1st Trailer	1st Dolly	2nd Trailer	2nd Dolly	3rd Trailer
Full	52	49	14	38	–	–
Empty	53	126	93	37	–	–
Mixed	1	4	1	1	–	–
Western doubles						
Full	17	3	7	8	–	–
Empty	7	15	28	17	–	–
Mixed	4	3	22	23	–	–
Reverse Rocky Mountain doubles						
Full	1	2	0	17	–	–
Empty	2	5	1	9	–	–
Mixed	0	0	0	0	–	–
All doubles						
Full	70	53	21	59	–	–
Empty	61	144	122	61	–	–
Mixed	5	7	23	24	–	–
Triples						
Full	14	8	13	8	16	12
Empty	32	12	26	6	12	7
Mixed	1	0	8	1	24	8

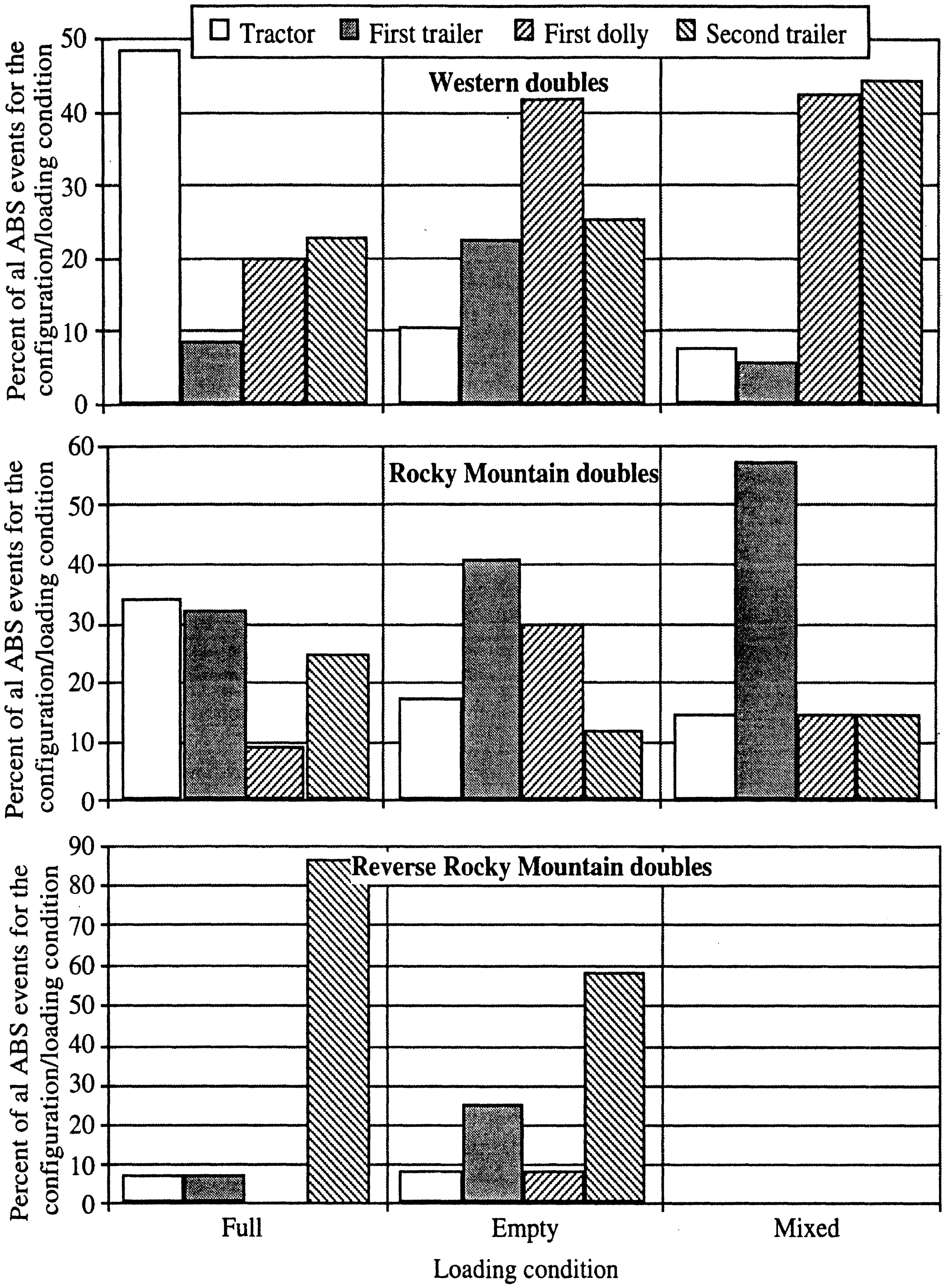


Figure H-1. Distribution of ABS events among the units of three different doubles combinations as a function of loading condition

Table H-6. ABS event times for single modulator activity on doubles and triples using incandescent brake lamps

	First trailer	*First dolly*	*Second trailer*	*Second dolly*	*Third trailer*
All doubles with incandescent brake lamps					
Time below 9.7 volts, sec.	0.1	10.7	5.8		
Time below 9.0 volts, sec.	0.0	4.5	2.9		
Time below 8.5 volts, sec.	0.0	2.0	0.6		
Total ABS event time, sec.	85.9	140.1	41.9		
All triples with incandescent brake lamps					
Time below 9.7 volts, sec.	0.0	0.0	0.3	9.7	2.8
Time below 9.0 volts, sec.	0.0	0.0	0.0	4.9	1.2
Time below 8.5 volts, sec.	0.0	0.0	0.0	2.9	0.7
Total ABS event time, sec.	11.2	39.7	25.8	46.9	5.7

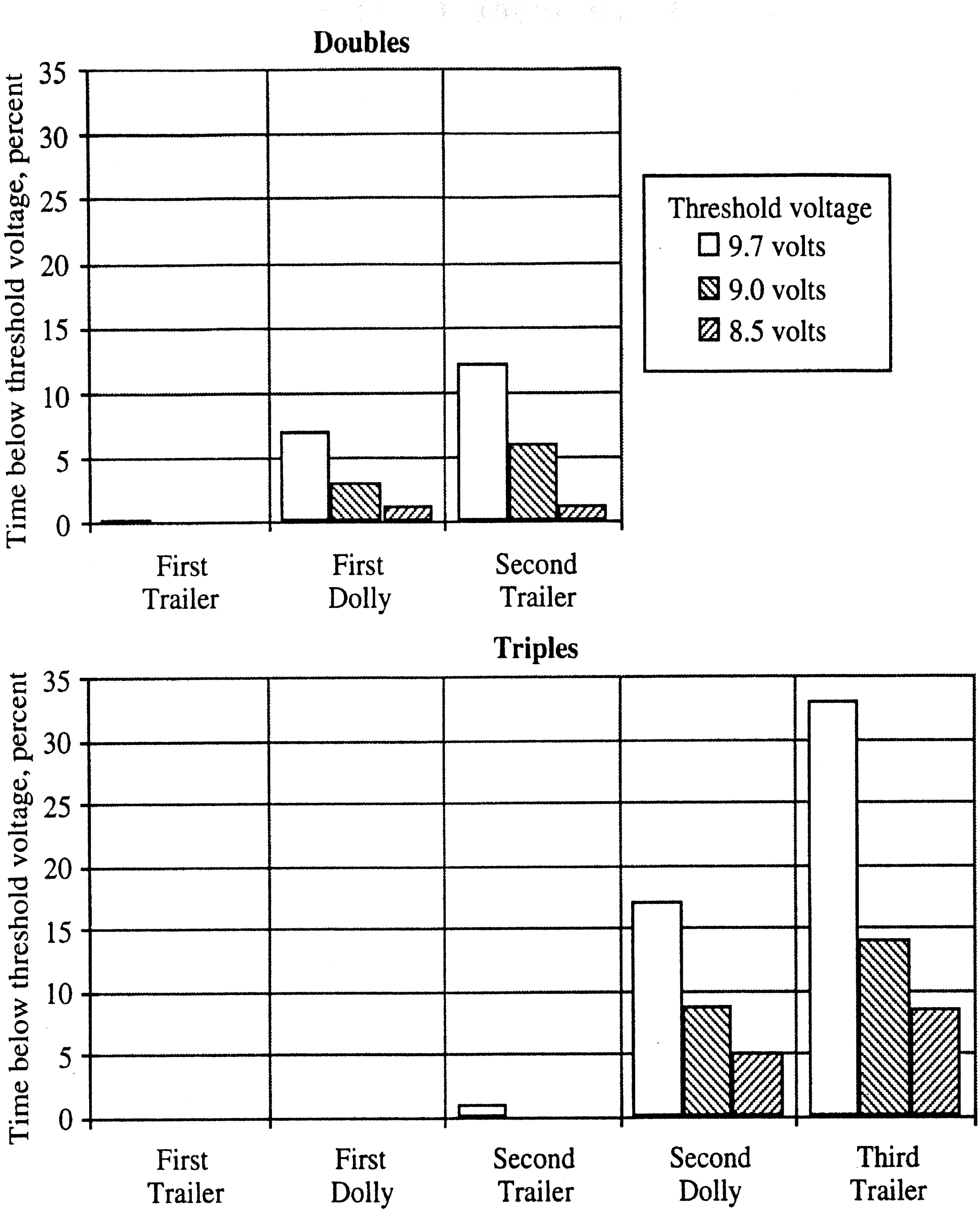


Figure H-2. Percentage of time during single modulator, ABS braking events when the brake-light-circuit voltage was less than the indicated threshold voltage: for all LCVs with incandescent brake lamps

Table H-7. ABS event times for single modulator activity using incandescent brake lamps and with tractor supply voltages less than or equal to 13.3 volts

	First trailer	*First dolly*	*Second trailer*	*Second dolly*	*Third trailer*
All doubles with incandescent brake lamps					
Time below 9.7 volts, sec.	0.1	10.7	5.8		
Time below 9.0 volts, sec.	0.0	4.5	2.9		
Time below 8.5 volts, sec.	0.0	2.0	0.6		
Total ABS event time, sec.	59.3	109.7	34.0		
All triples with incandescent brake lamps					
Time below 9.7 volts, sec.	0.0	0.0	0.2	9.4	2.7
Time below 9.0 volts, sec.	0.0	0.0	0.0	4.9	1.2
Time below 8.5 volts, sec.	0.0	0.0	0.0	2.9	0.7
Total ABS event time, sec.	5.1	18.8	2.1	26.0	2.9

Table H-8. ABS event times for single modulator activity using incandescent brake lamps and with tractor supply voltages greater than 13.3 volts

	First trailer	*First dolly*	*Second trailer*	*Second dolly*	*Third trailer*
All doubles with incandescent brake lamps					
Time below 9.7 volts, sec.	0.0	0.0	0.0		
Time below 9.0 volts, sec.	0.0	0.0	0.0		
Time below 8.5 volts, sec.	0.0	0.0	0.0		
Total ABS event time, sec.	26.5	30.4	7.9		
All triples with incandescent brake lamps					
Time below 9.7 volts, sec.	0.0	0.0	0.0	0.3	0.1
Time below 9.0 volts, sec.	0.0	0.0	0.0	0.0	0.0
Time below 8.5 volts, sec.	0.0	0.0	0.0	0.0	0.0
Total ABS event time, sec.	6.1	20.8	23.7	20.9	2.8

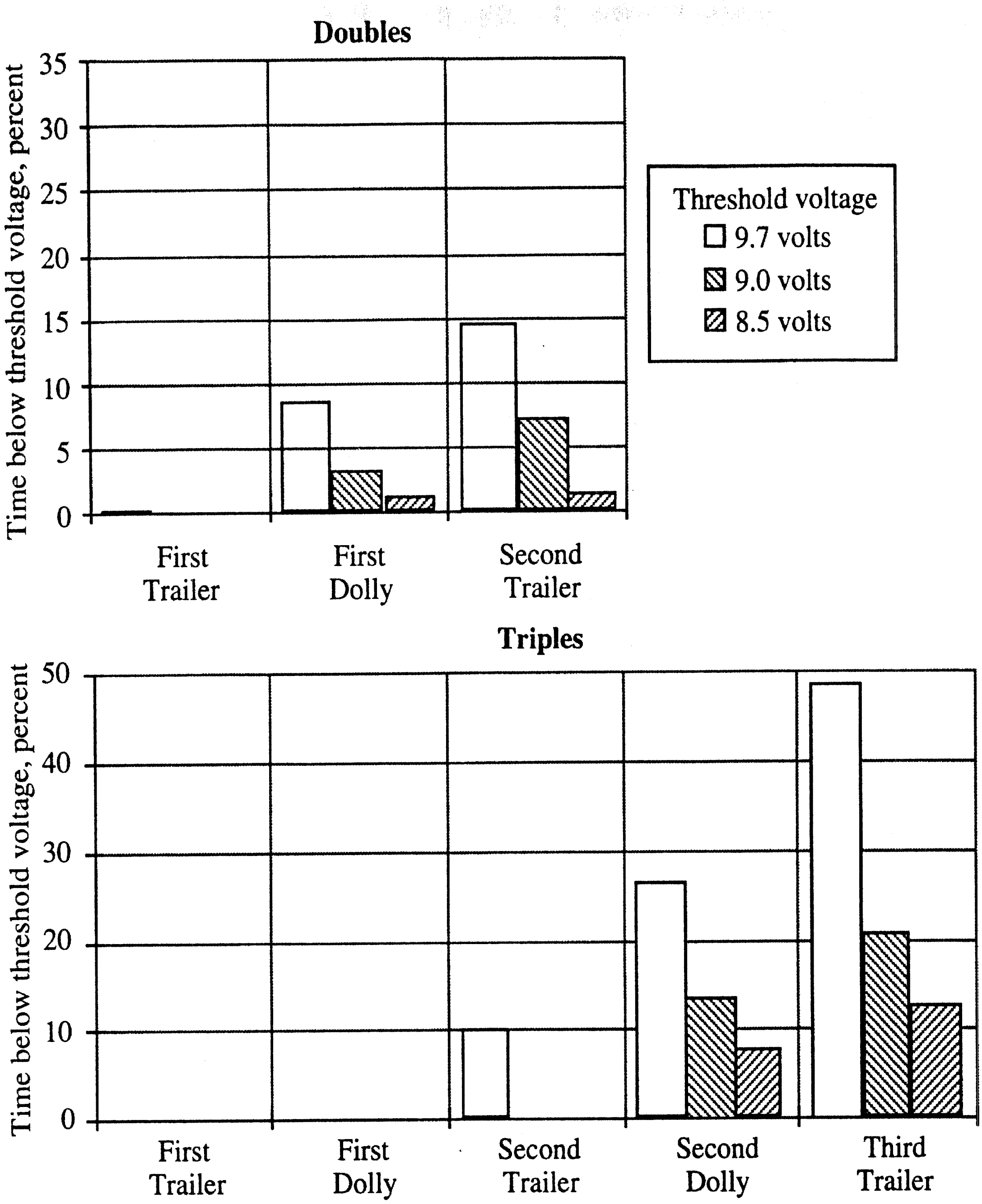


Figure H-3. Percentage of time during single modulator ABS braking events when the brake-light-circuit voltage was less than the indicated threshold voltage: for all LCVs with incandescent brake lamps and for a tractor supply voltage less than or equal to 13.3 volts

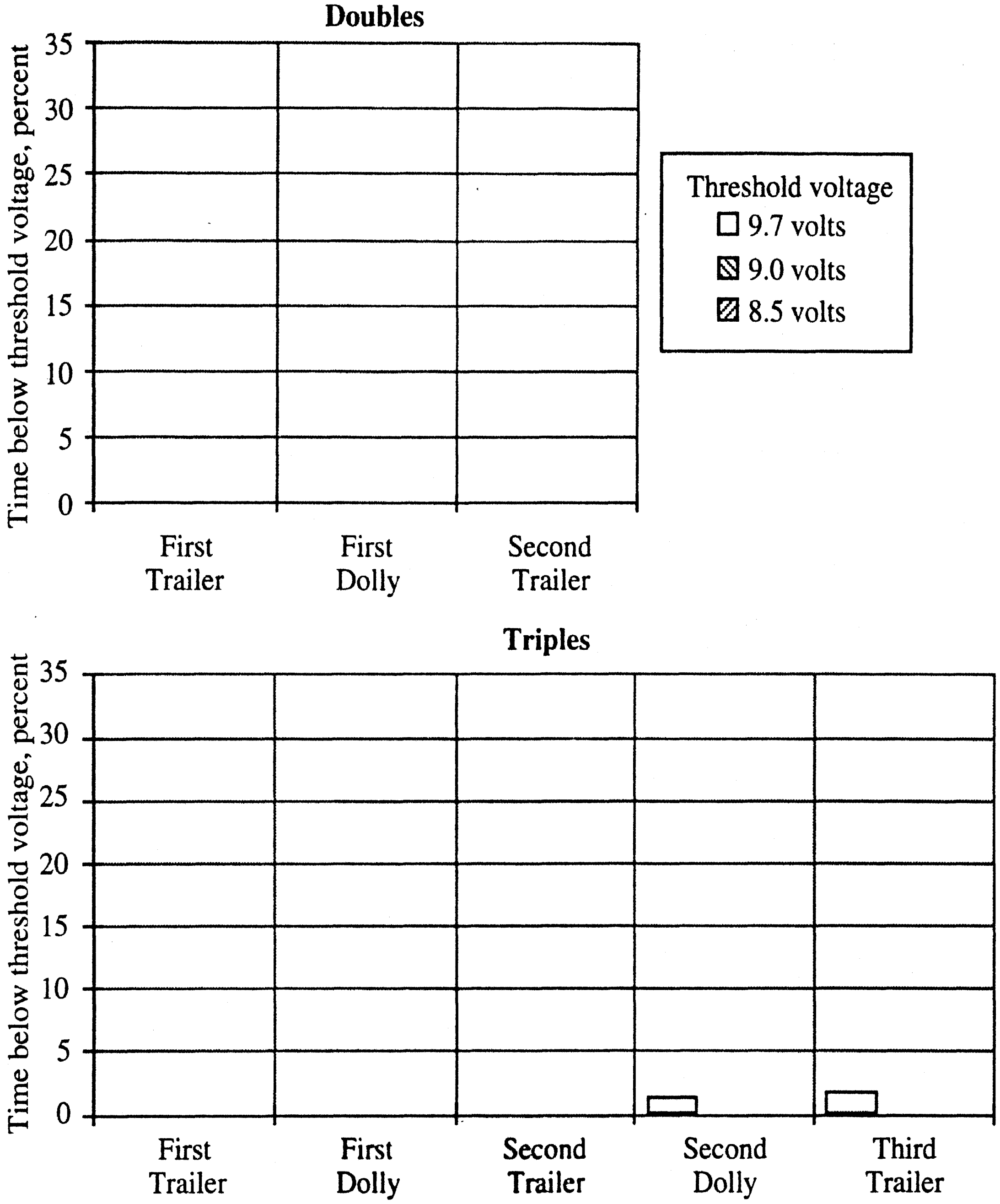


Figure H-4. Percentage of time during single modulator ABS braking events when the brake-light-circuit voltage was less than the indicated threshold voltage: for all LCVs with incandescent brake lamps and for a tractor supply voltage greater than 13.3 volts

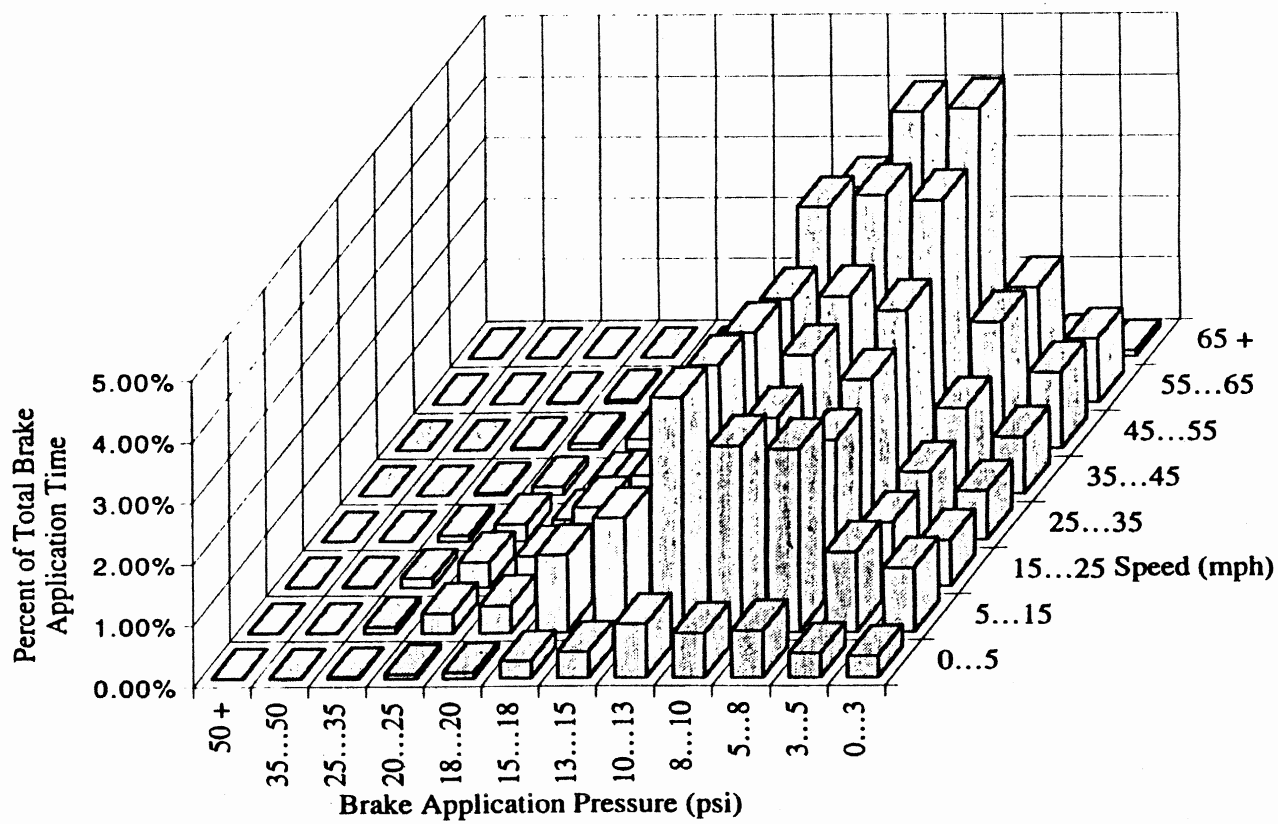
APPENDIX I

BRAKE PRESSURE HISTOGRAMS

This appendix presents histograms of brake application time as functions of the applied brake pressure and vehicle speed, segregated for different vehicle configurations and load conditions.

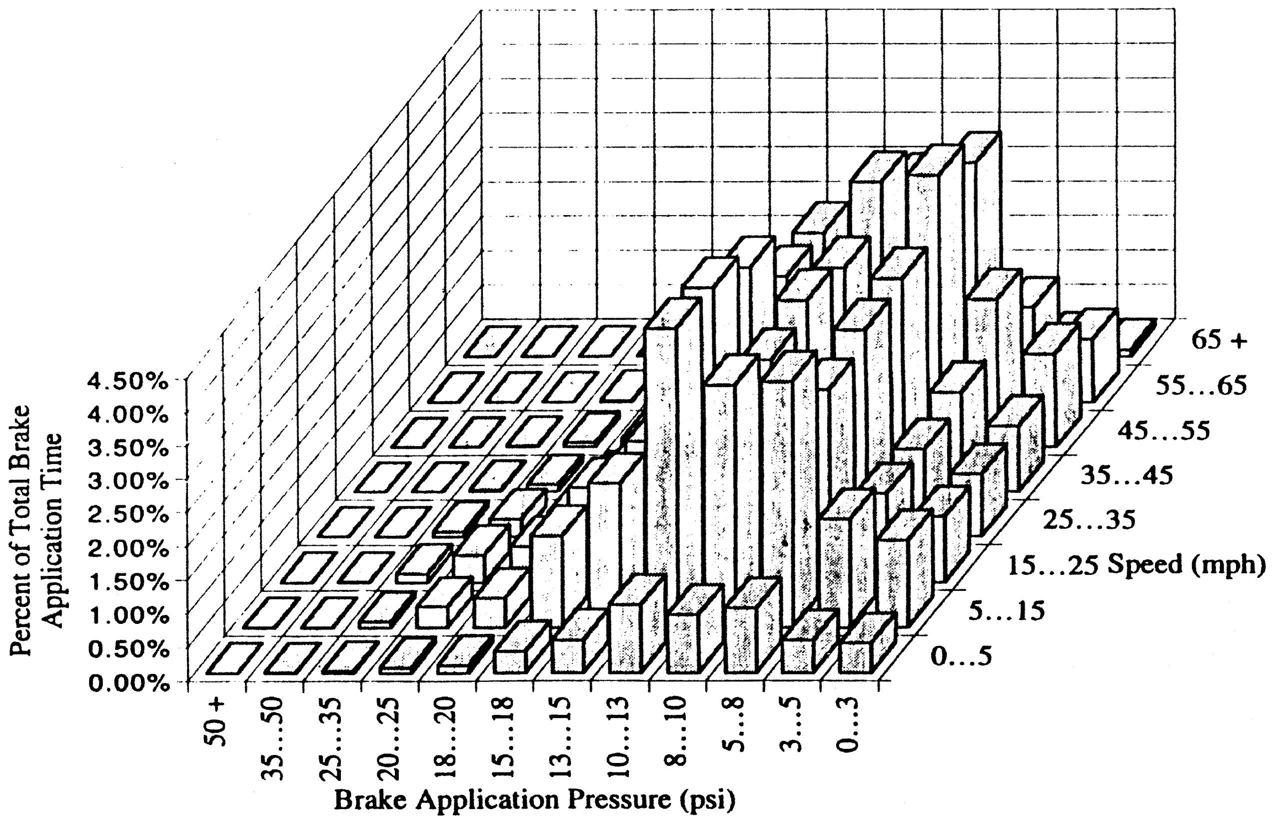
Table of Contents:

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



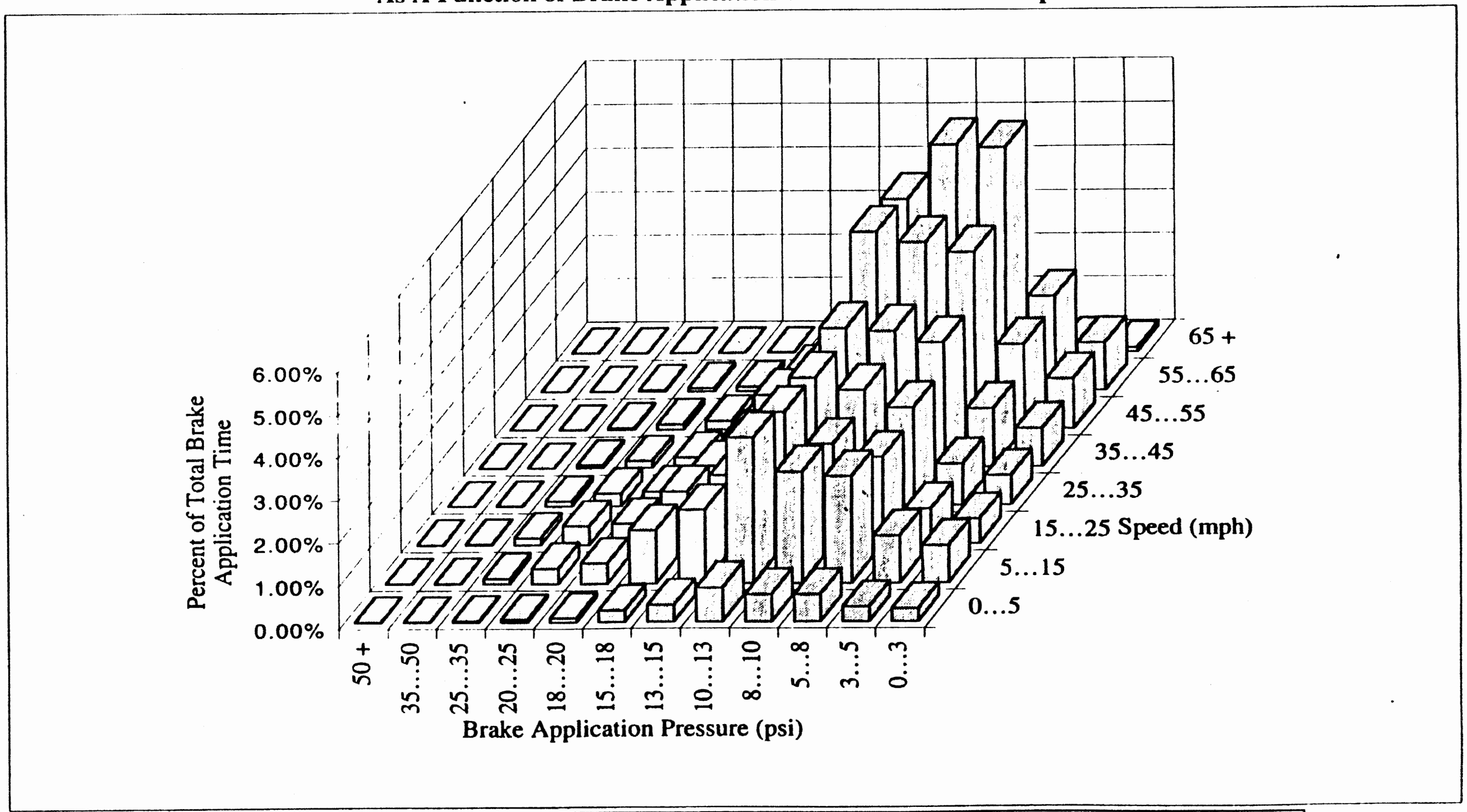
Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	185
Vehicle Load Condition:	All	Total time (hrs):	6094
Number of histograms:	763	Percent of time braking:	3.04%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



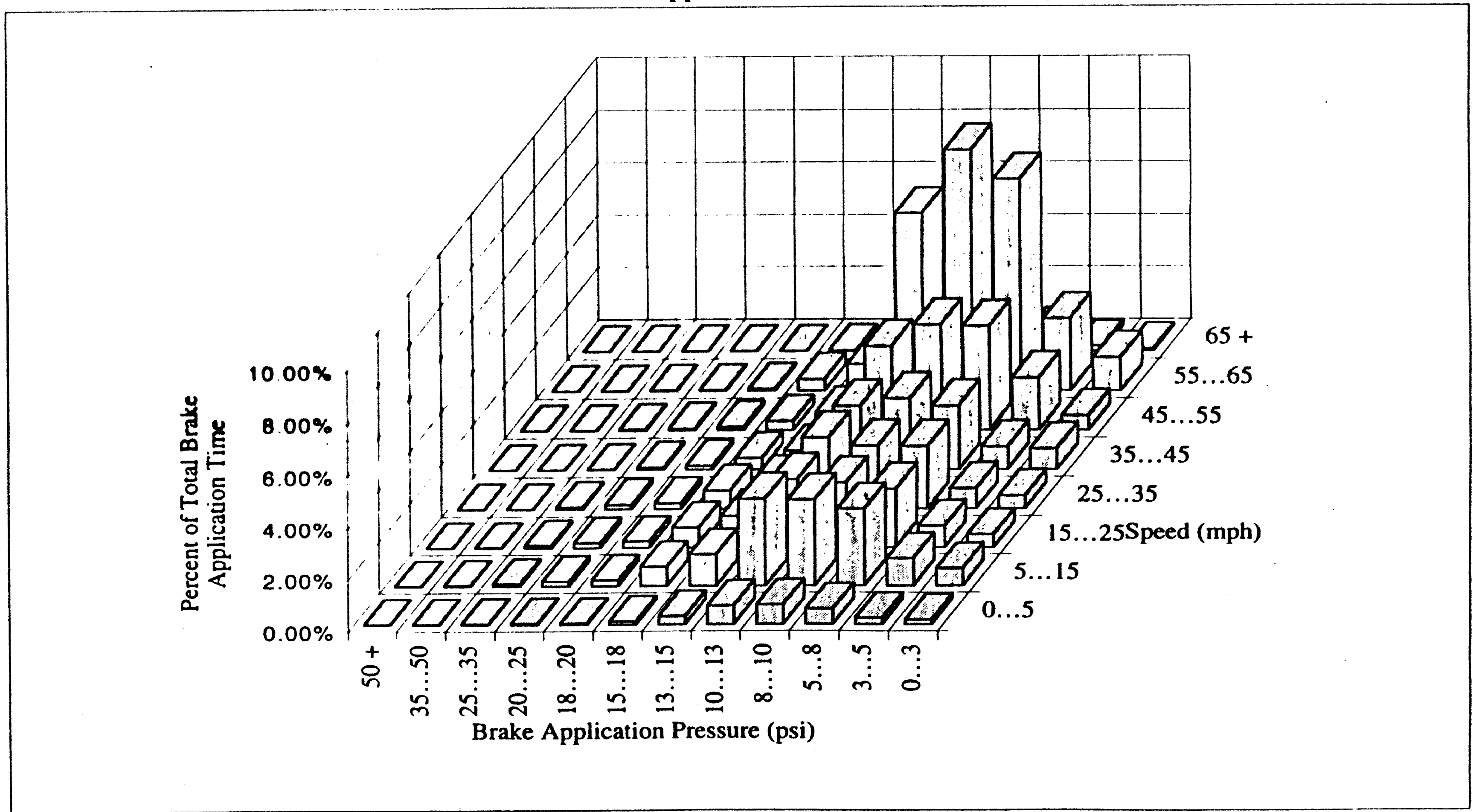
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	76
Vehicle Load Condition:	Empty	Total time (hrs):	2580
Number of historgrams:	320	Percent of time braking:	2.96%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



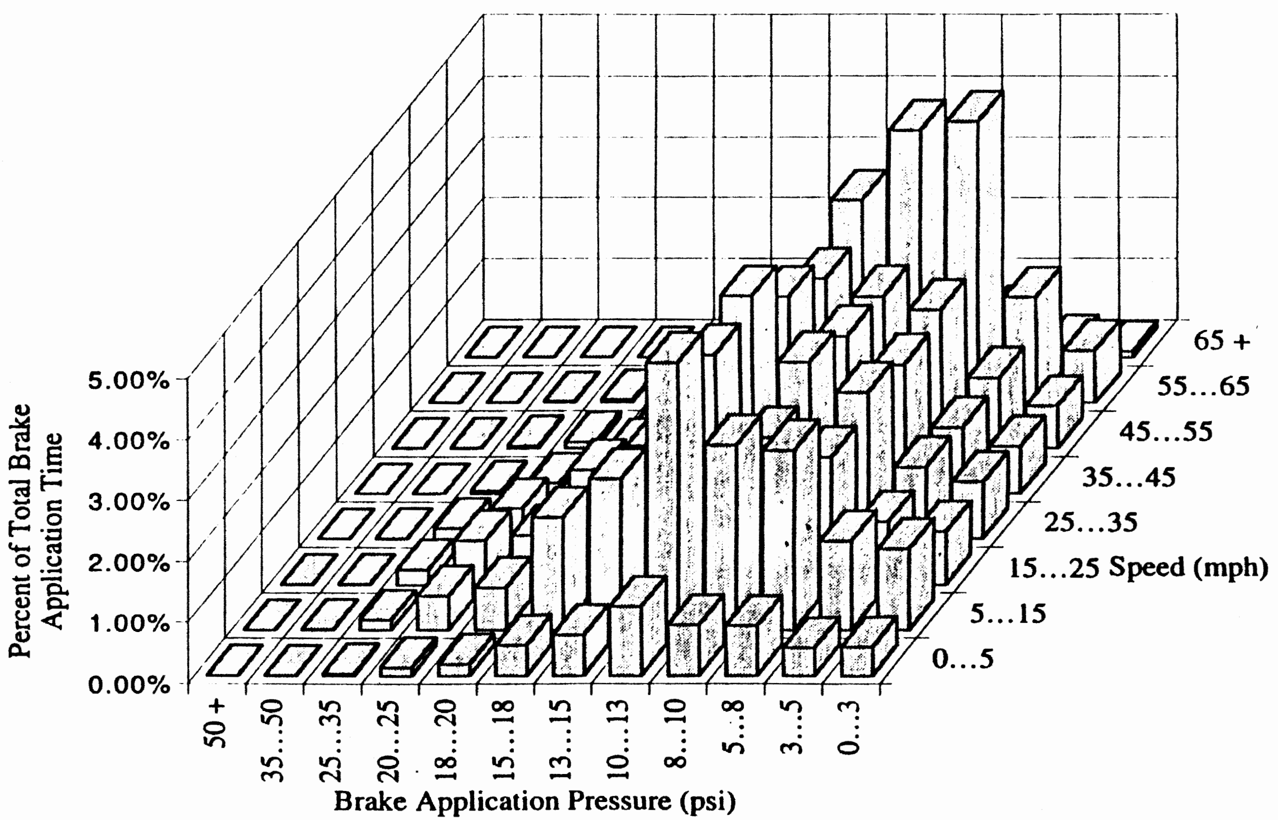
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	102
Vehicle Load Condition:	Full	Total time (hrs):	3174
Number of historgrams:	395	Percent of time braking:	3.23%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



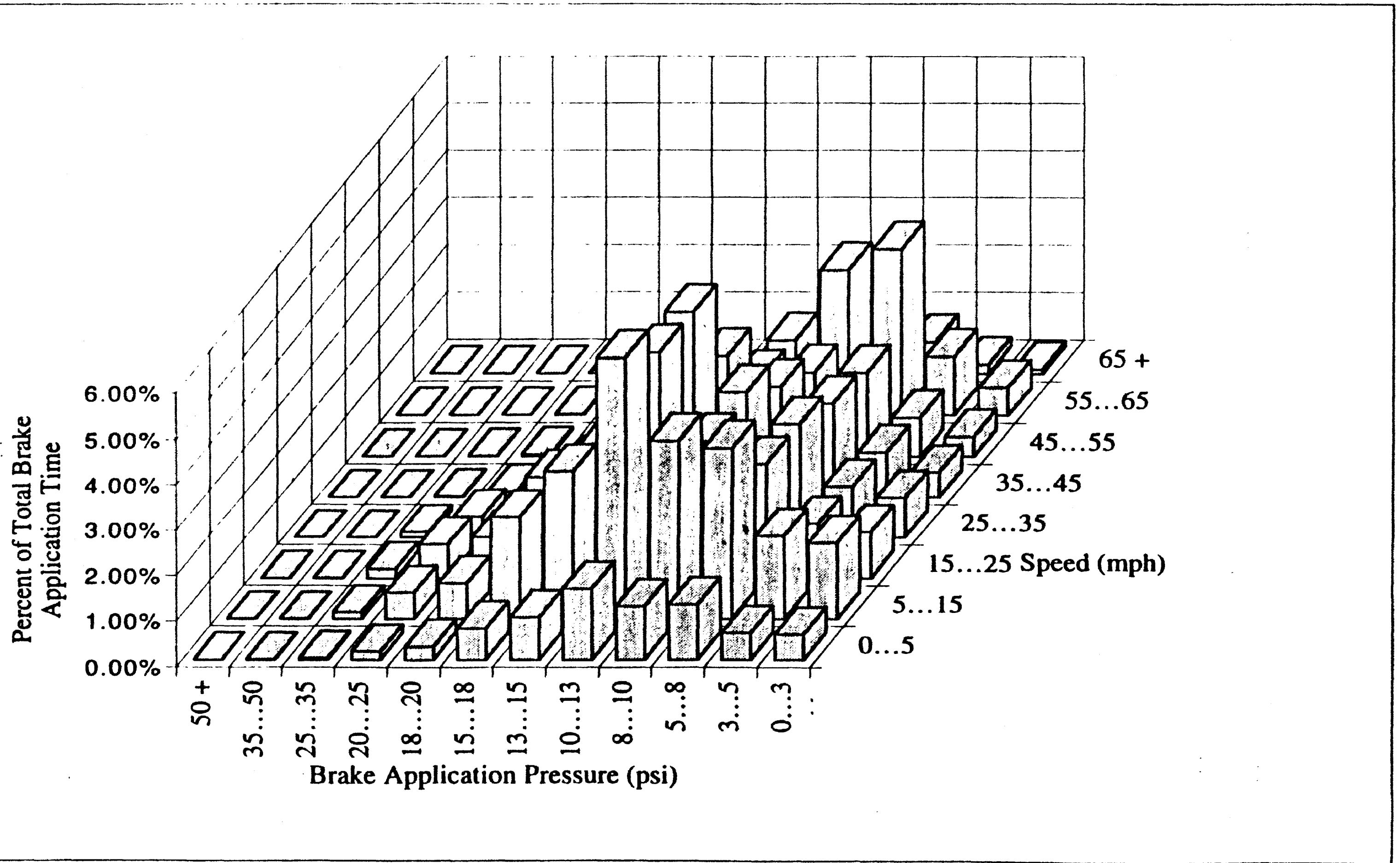
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	6
Vehicle Load Condition:	Mixed	Total time (hrs):	340
Number of historgrams:	48	Percent of time braking:	1.80%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



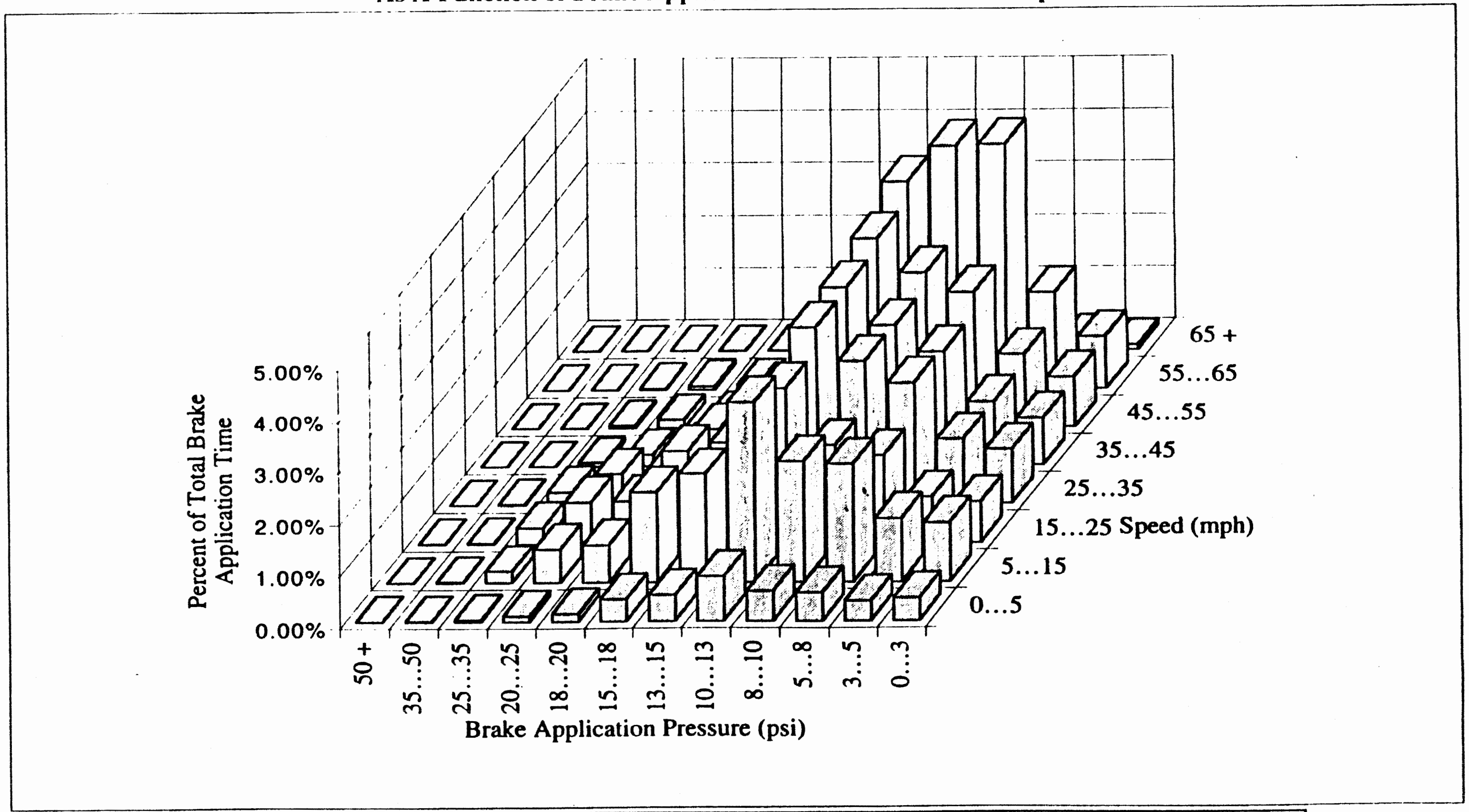
Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	Triple	Total braking time (hrs):	39
Vehicle Load Condition:	All	Total time (hrs):	1675
Number of historgrams:	198	Percent of time braking:	2.31%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



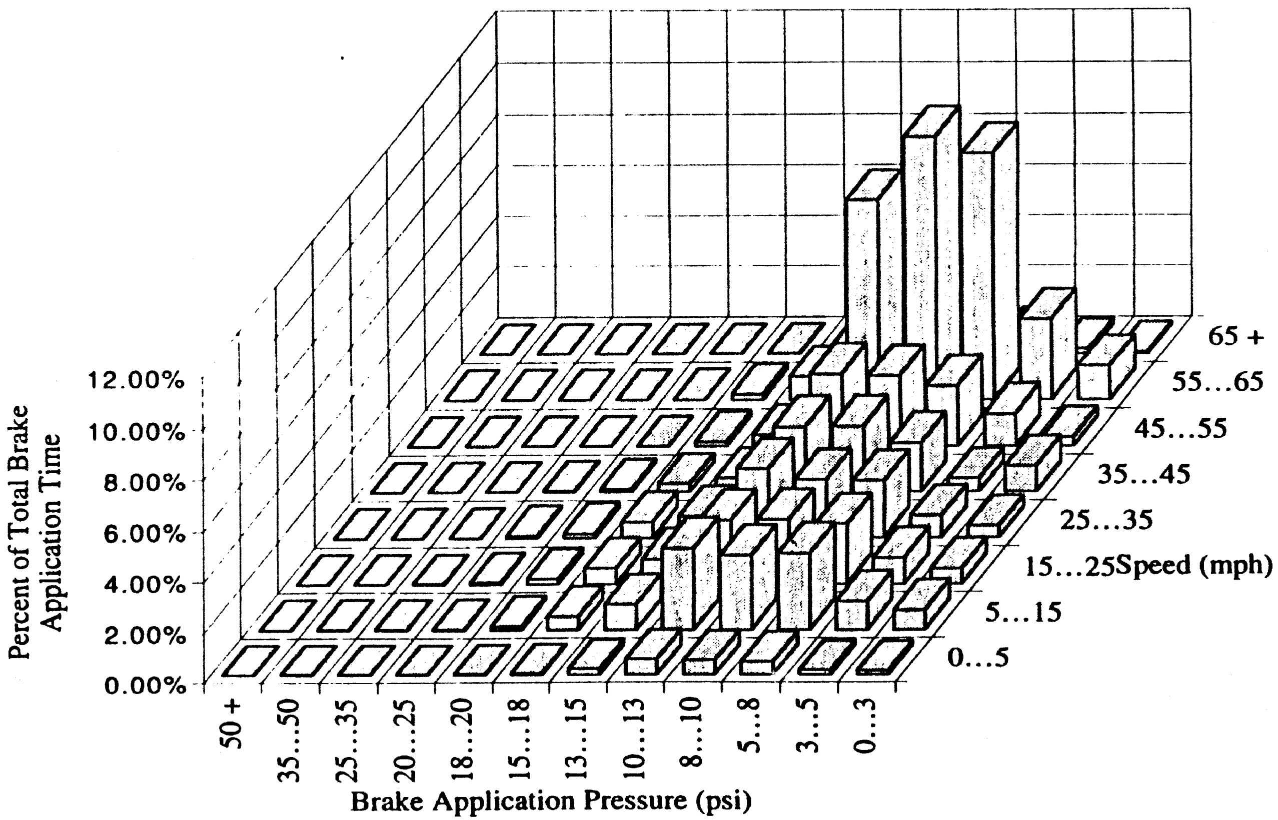
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Triple	Total braking time (hrs):	16
Vehicle Load Condition:	Empty	Total time (hrs):	637
Number of historgrams:	74	Percent of time braking:	2.52%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



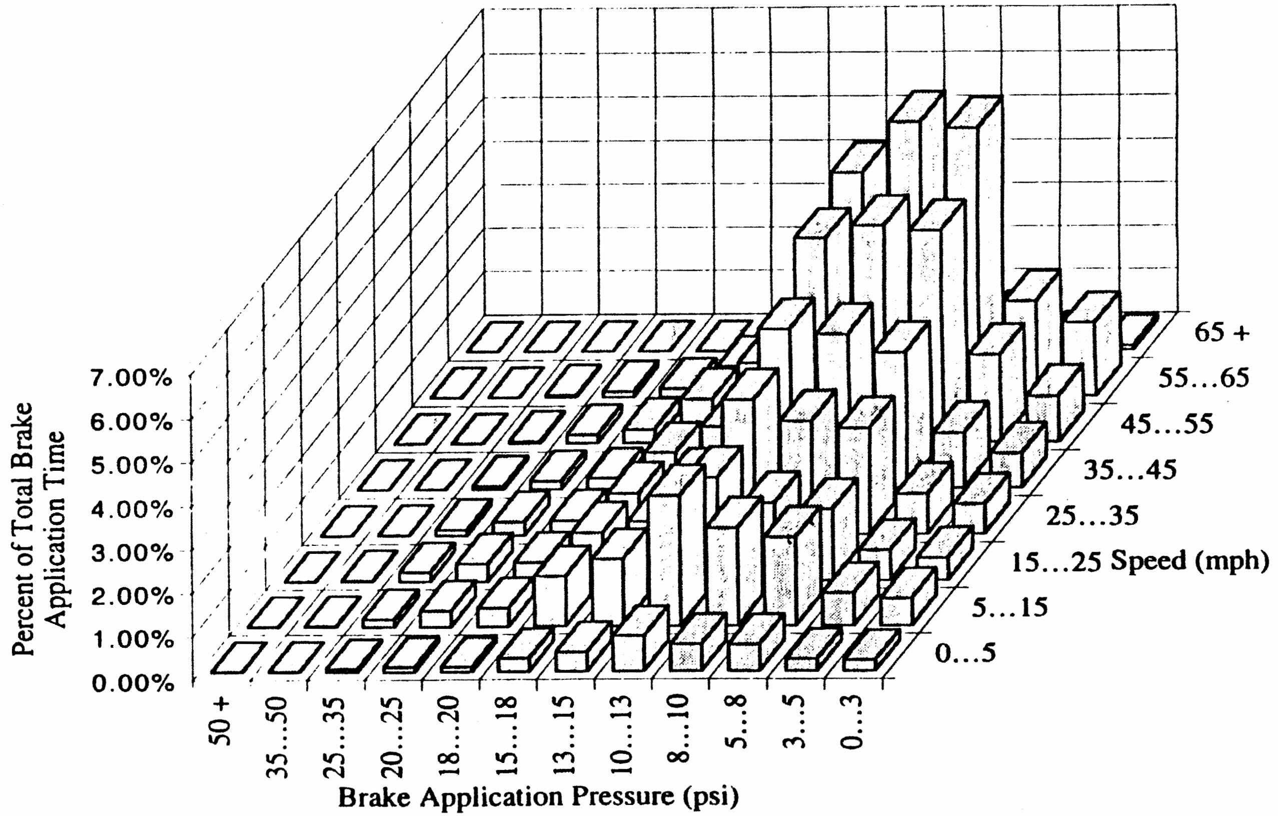
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Triple	Total braking time (hrs):	20
Vehicle Load Condition:	Full	Total time (hrs):	831
Number of historgrams:	97	Percent of time braking:	2.35%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



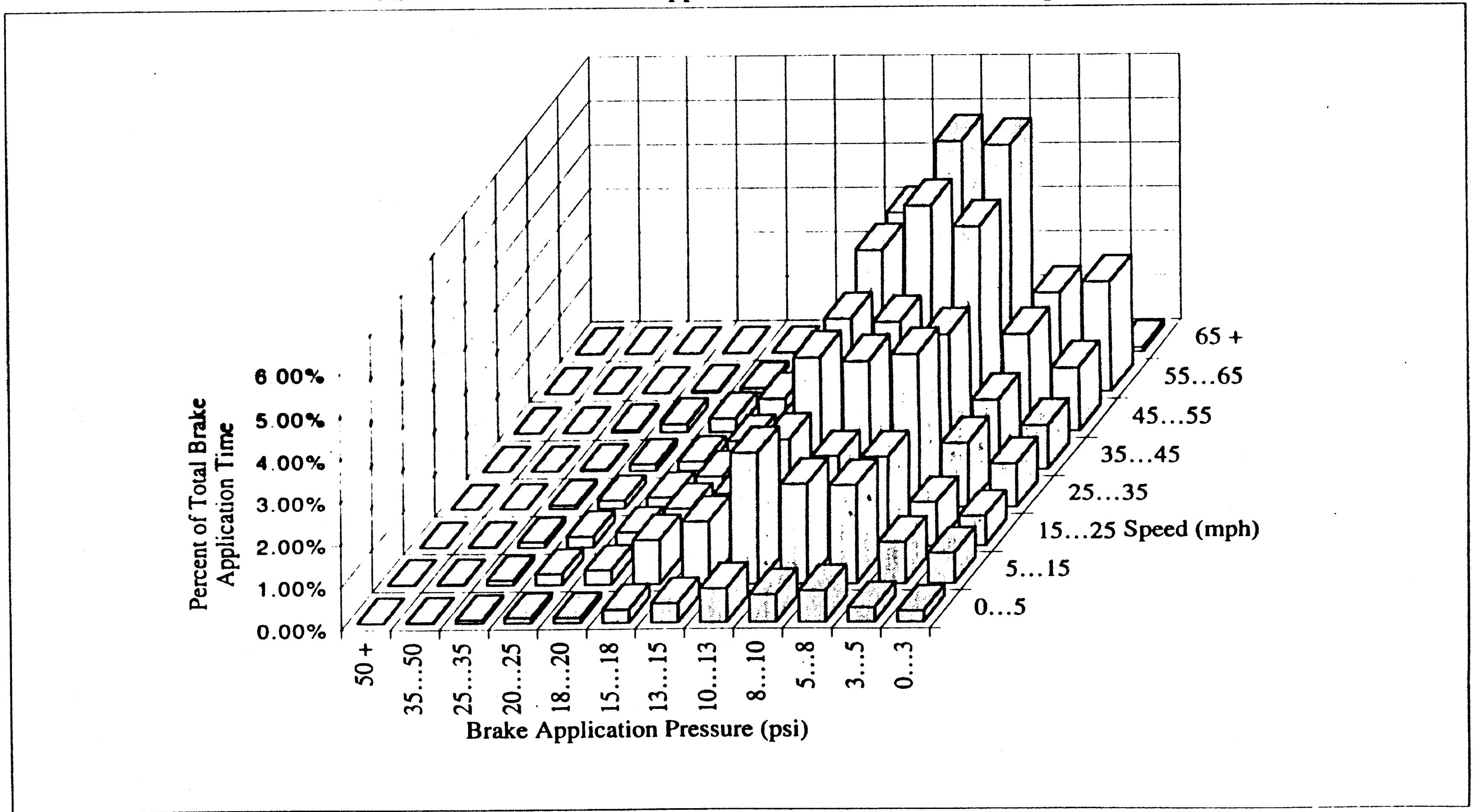
Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	Triple	Total braking time (hrs):	3
Vehicle Load Condition:	Mixed	Total time (hrs):	207
Number of historgrams:	27	Percent of time braking:	1.50%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



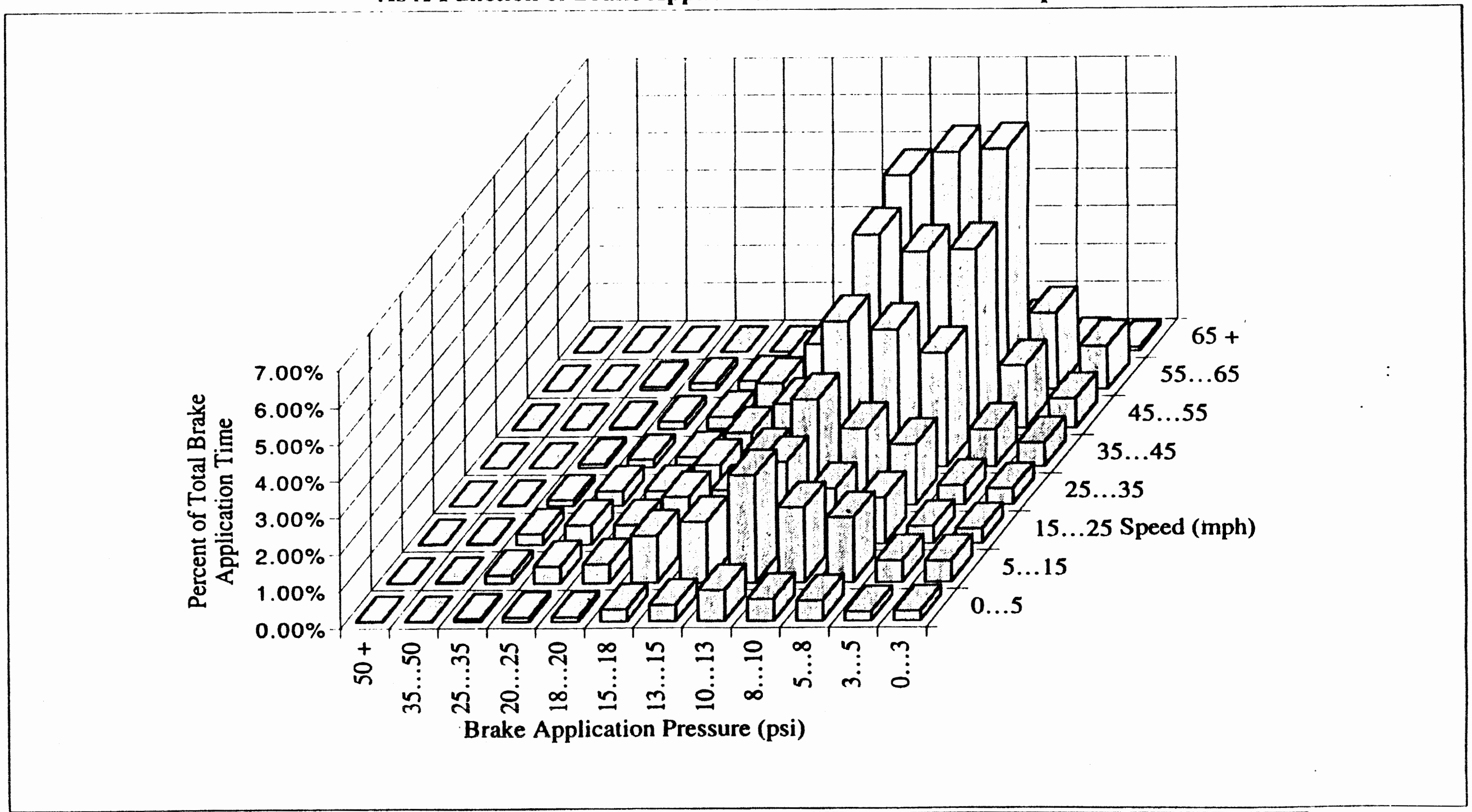
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Double	Total braking time (hrs):	32
Vehicle Load Condition:	All	Total time (hrs):	1037
Number of historgrams:	153	Percent of time braking:	3.08%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



Results are based on the following:			Date:	5-May-95
Vehicle Configuration:	Double	Total braking time (hrs):	12	
Vehicle Load Condition:	Empty	Total time (hrs):	388	
Number of historgrams:	62	Percent of time braking:	3.11%	

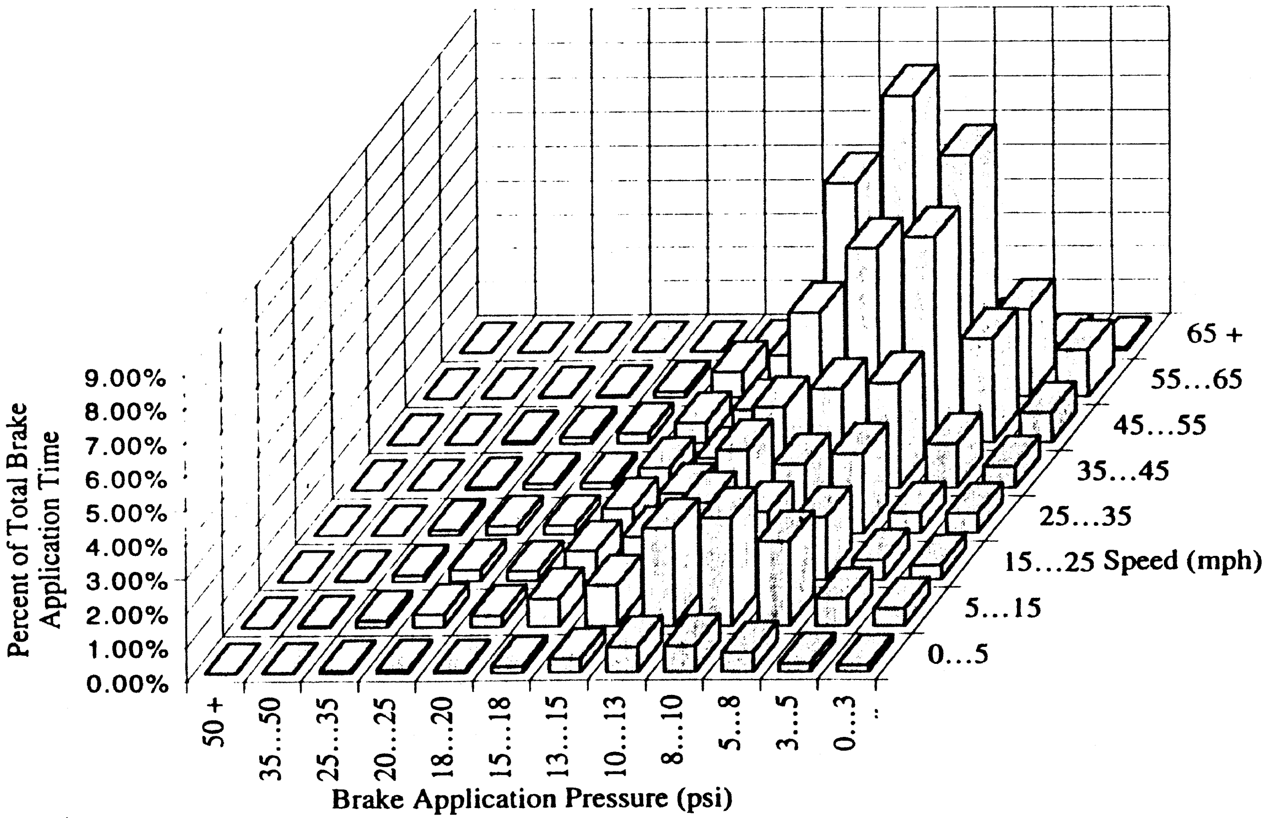
Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Double	Total braking time (hrs):	17
Vehicle Load Condition:	Full	Total time (hrs):	536
Number of historgrams:	73	Percent of time braking:	3.21%

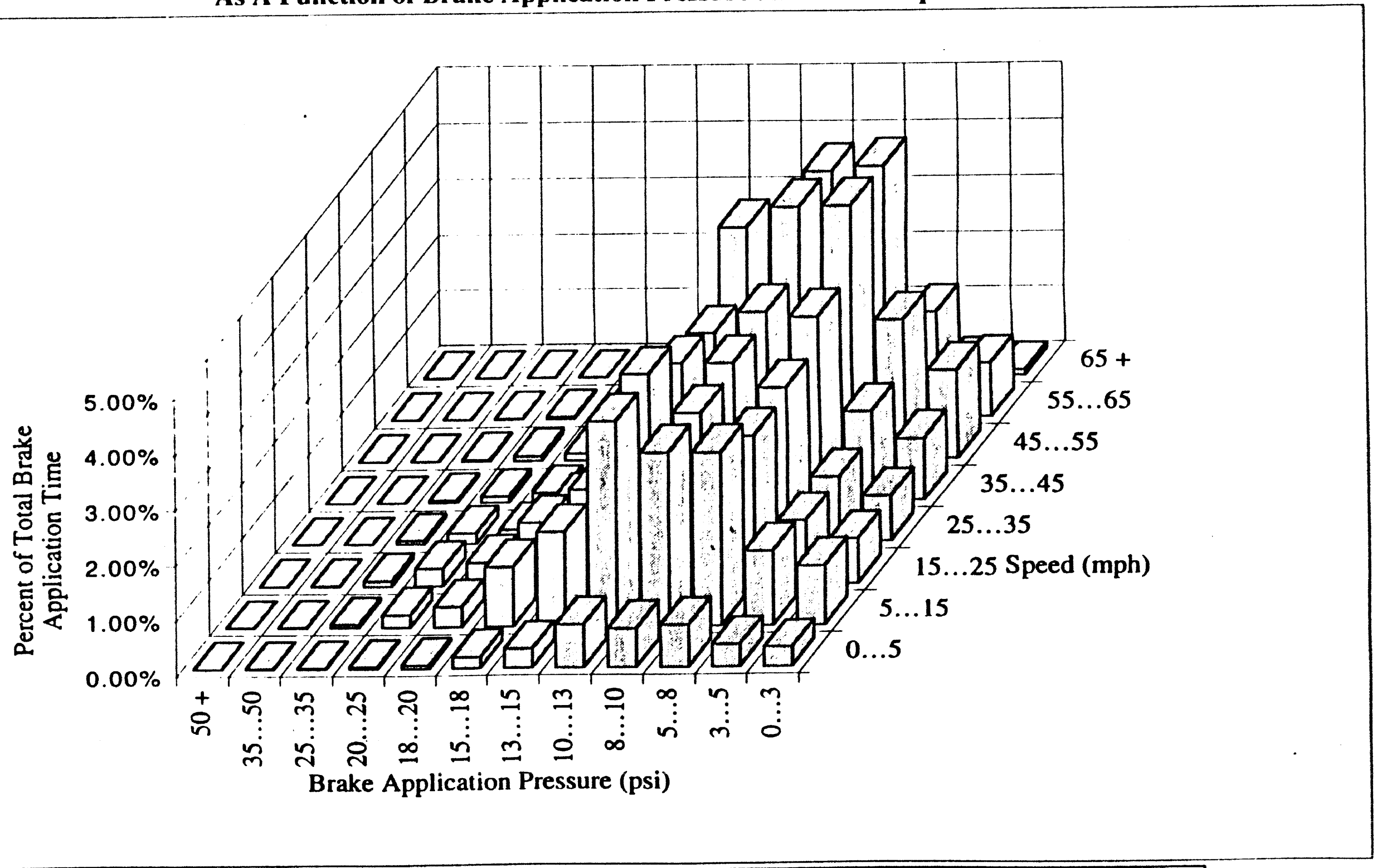
Distribution of Brake Application Time for the LCV Study Fleet

As A Function of Brake Application Pressure and Vehicle Speed



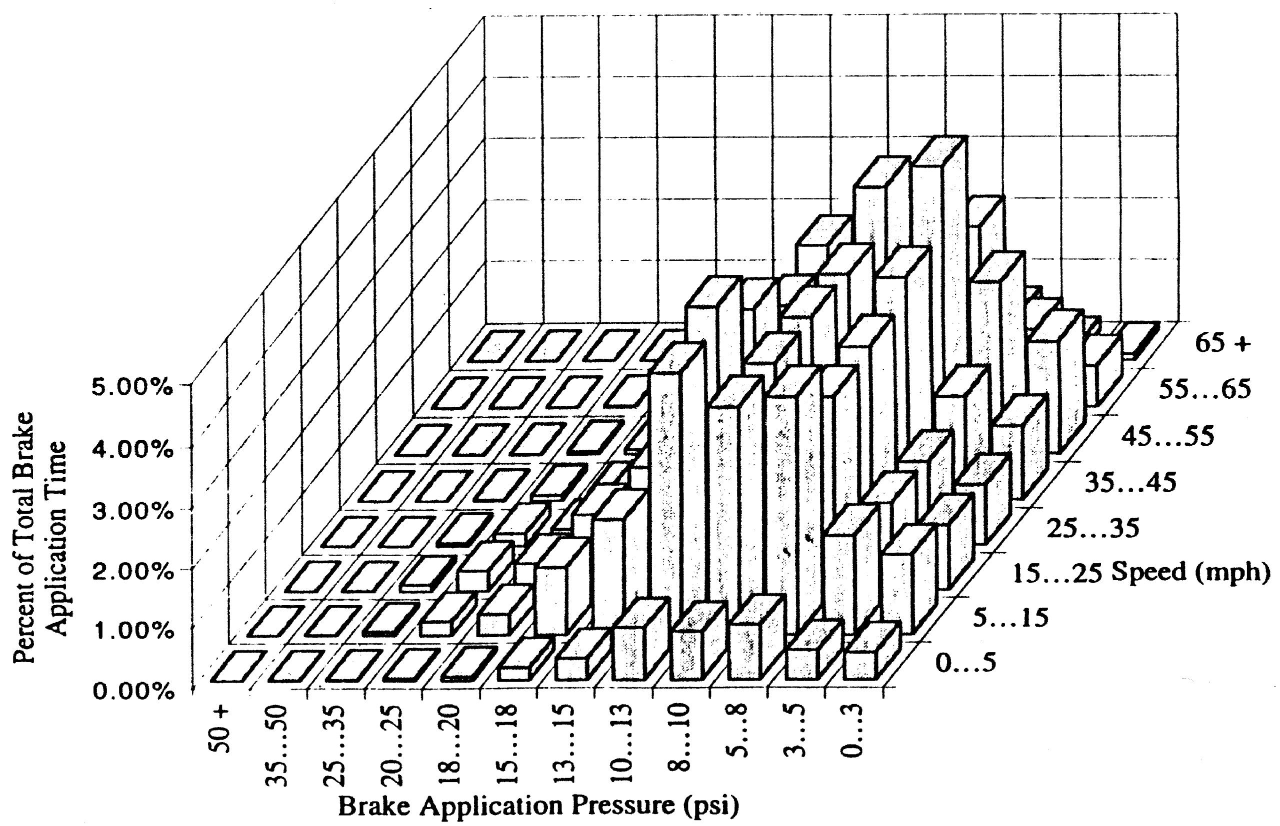
Results are based on the following:			Date:	5-May-95
Vehicle Configuration:	Double	Total braking time (hrs):		3
Vehicle Load Condition:	Mixed	Total time (hrs):		112
Number of historgrams:	18	Percent of time braking:		2.32%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Rocky	Total braking time (hrs):	103
Vehicle Load Condition:	All	Total time (hrs):	2958
Number of historgrams:	351	Percent of time braking:	3.48%

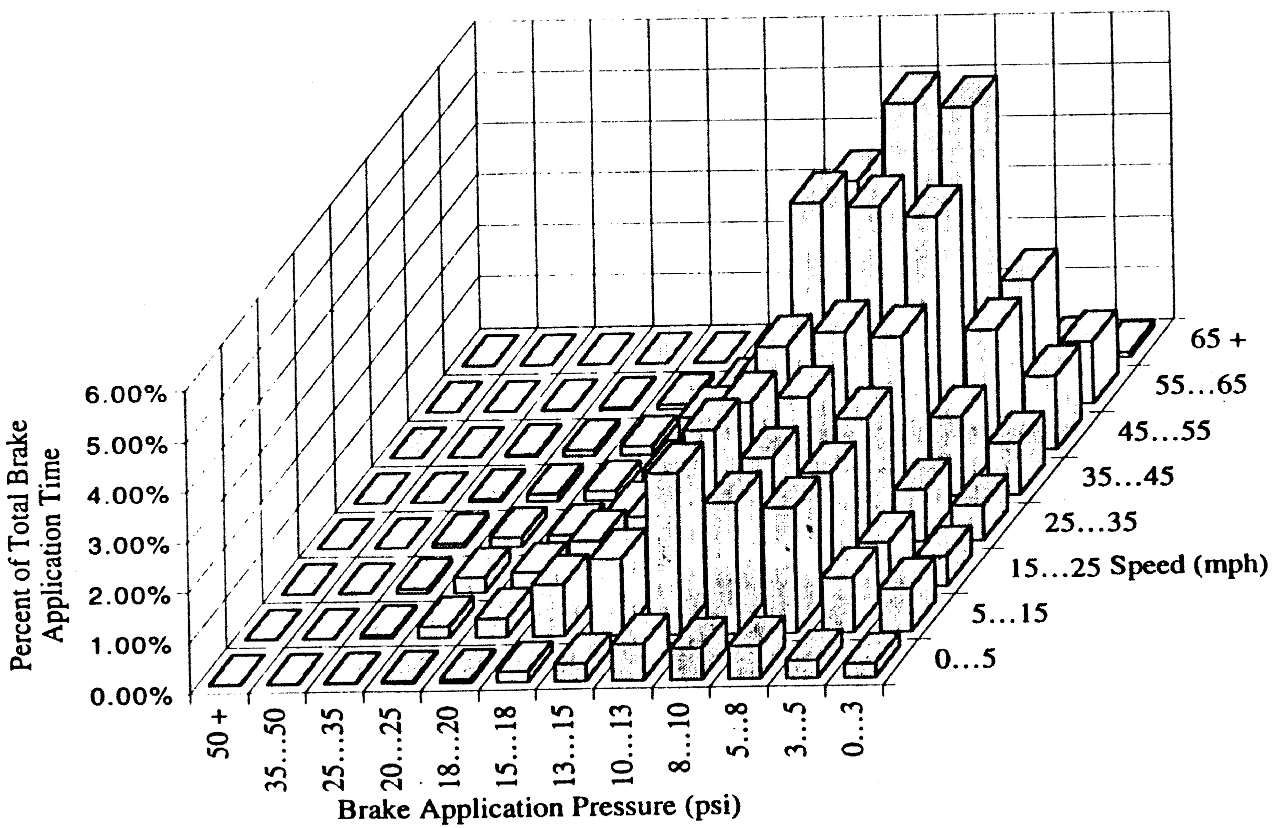
Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Rocky	Total braking time (hrs):	44
Vehicle Load Condition:	Empty	Total time (hrs):	1374
Number of historgrams:	157	Percent of time braking:	3.22%

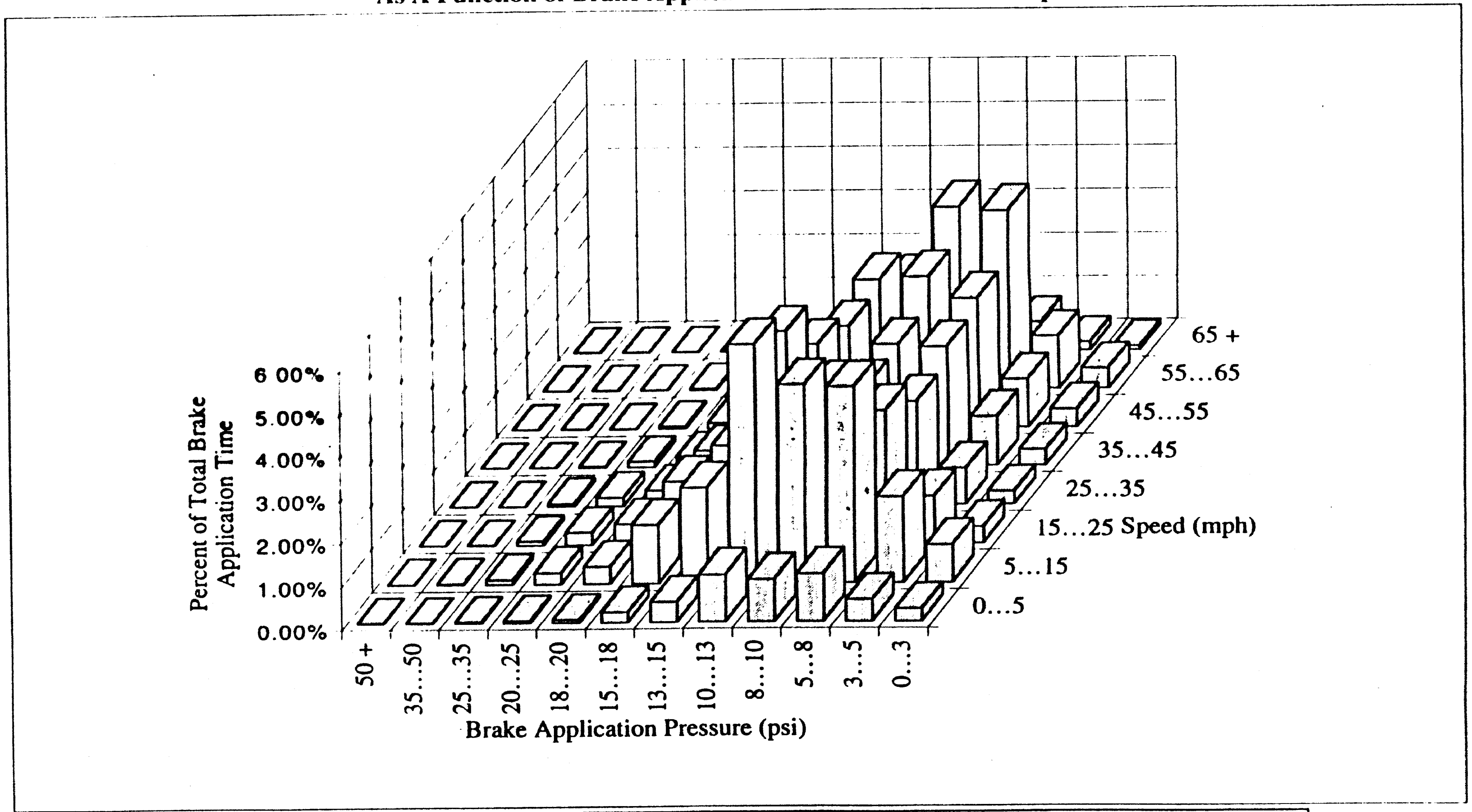
Distribution of Brake Application Time for the LCV Study Fleet

As A Function of Brake Application Pressure and Vehicle Speed



Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	Rocky	Total braking time (hrs):	58
Vehicle Load Condition:	Full	Total time (hrs):	1564
Number of historgrams:	191	Percent of time braking:	3.73%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Reverse	Total braking time (hrs):	11
Vehicle Load Condition:	All	Total time (hrs):	425
Number of historgrams:	61	Percent of time braking:	2.67%

Distribution of Brake Application Time for the LCV Study Fleet

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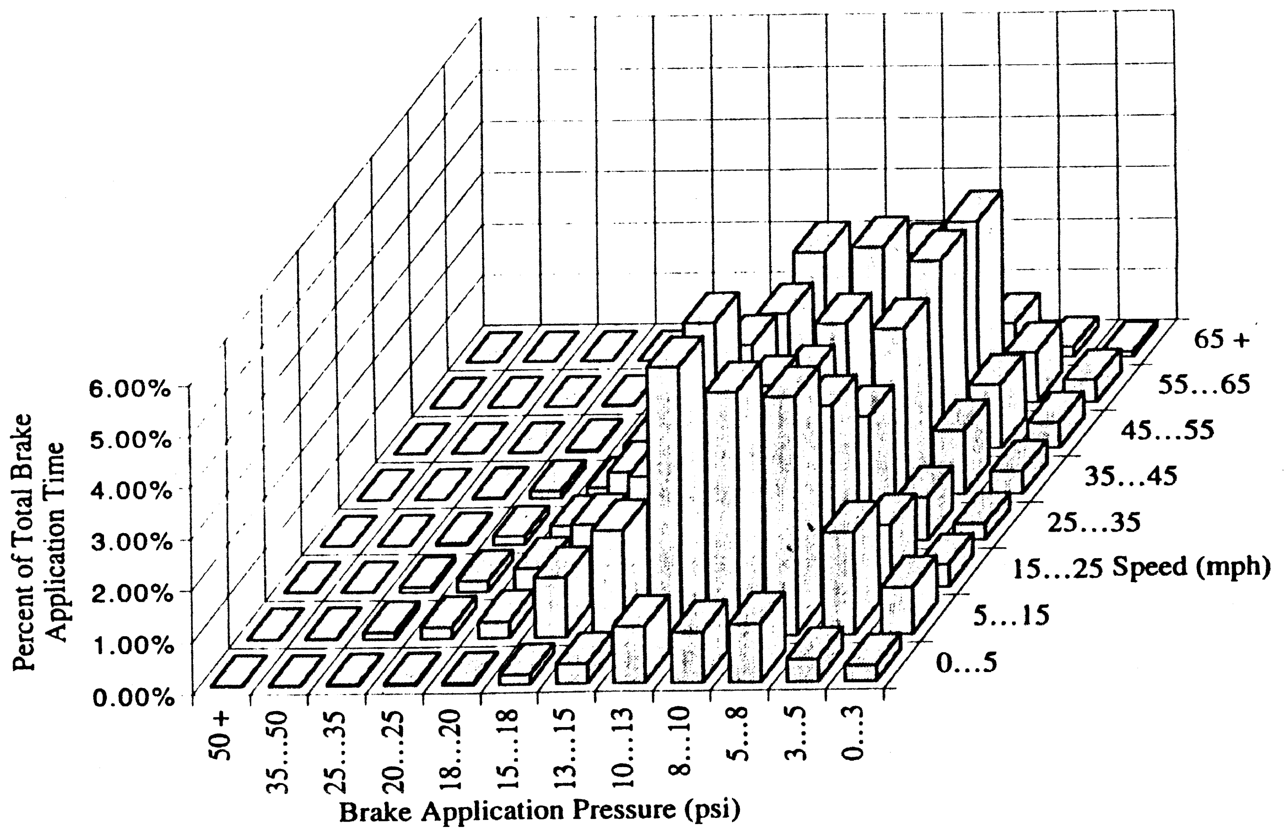
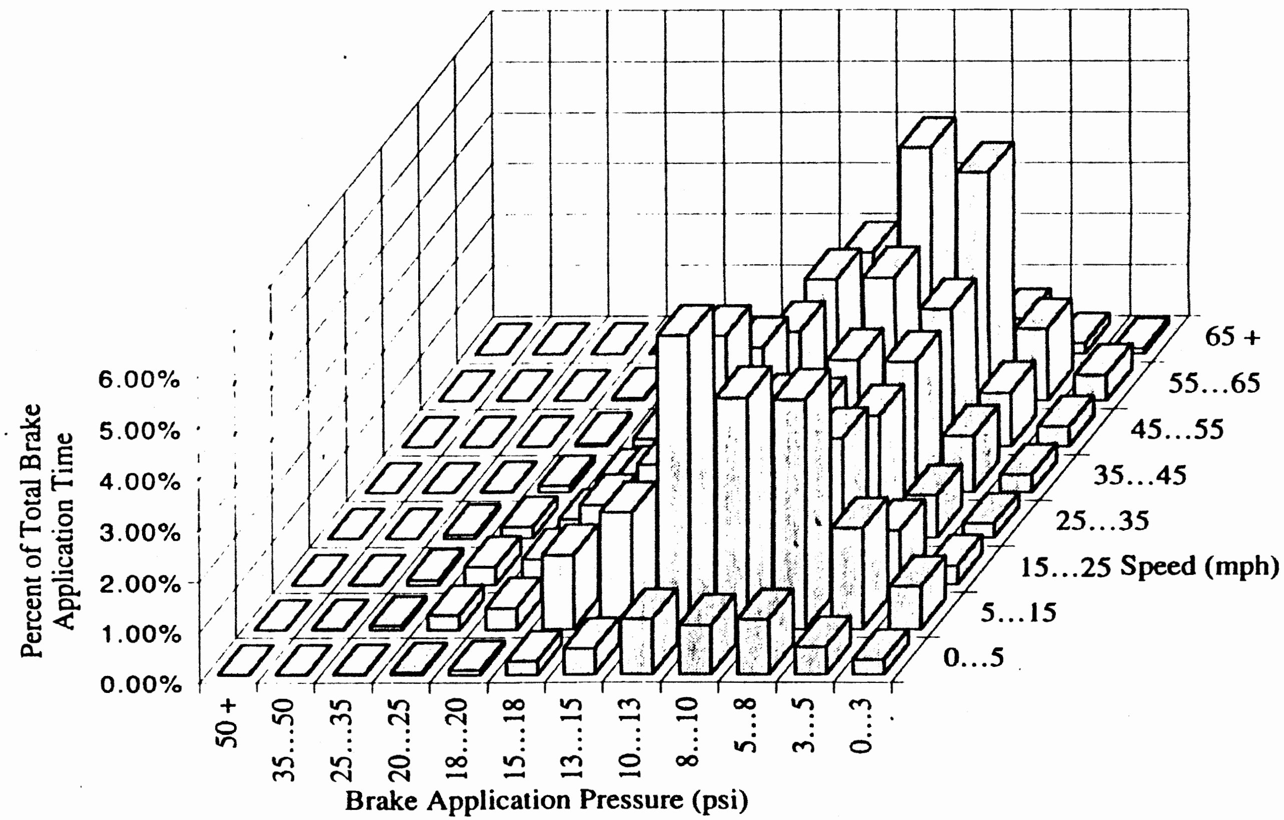


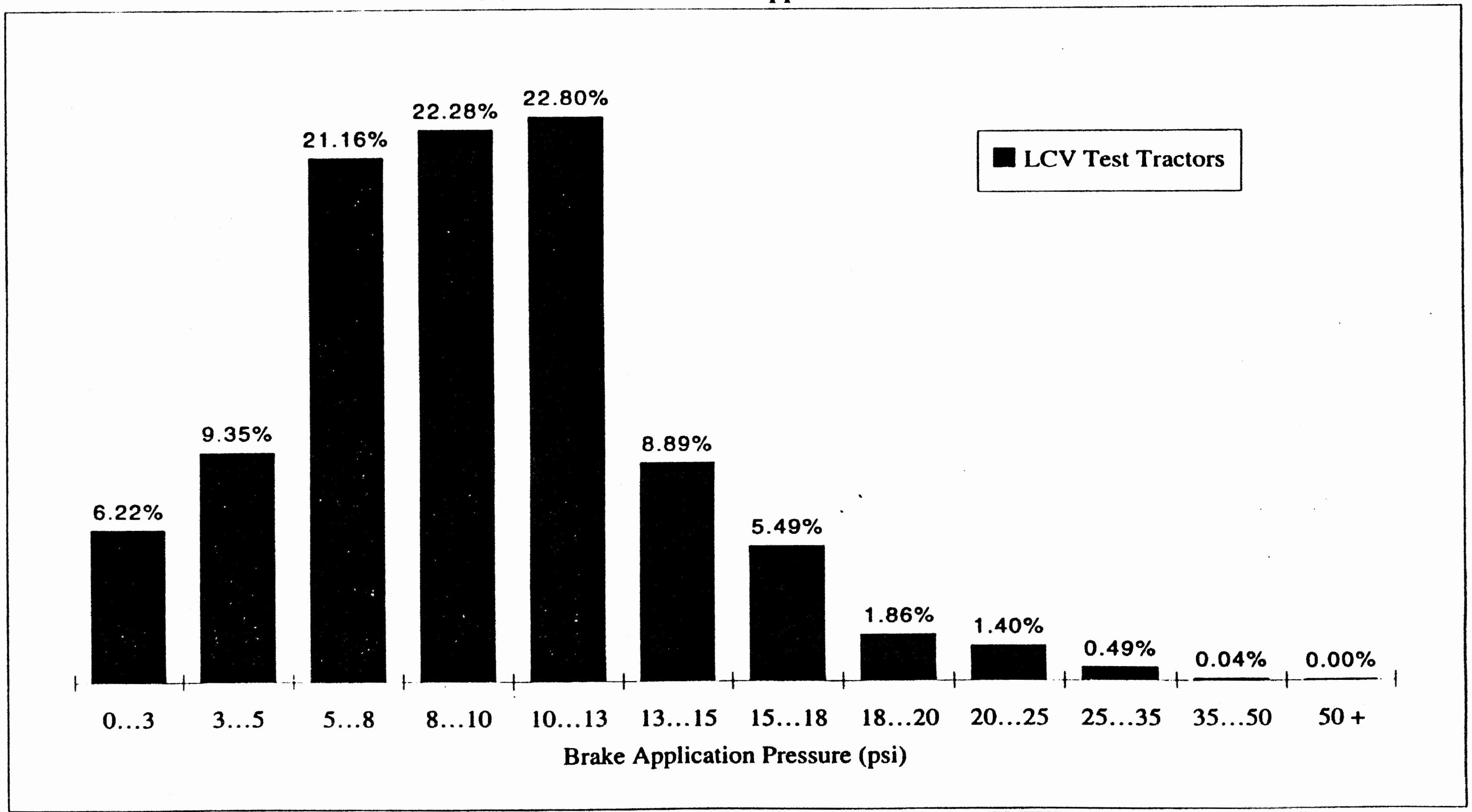
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Reverse Rocky	Total braking time (hrs):	4
Vehicle Load Condition:	Empty	Total time (hrs):	181
Number of historgrams:	27	Percent of time braking:	2.21%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure and Vehicle Speed



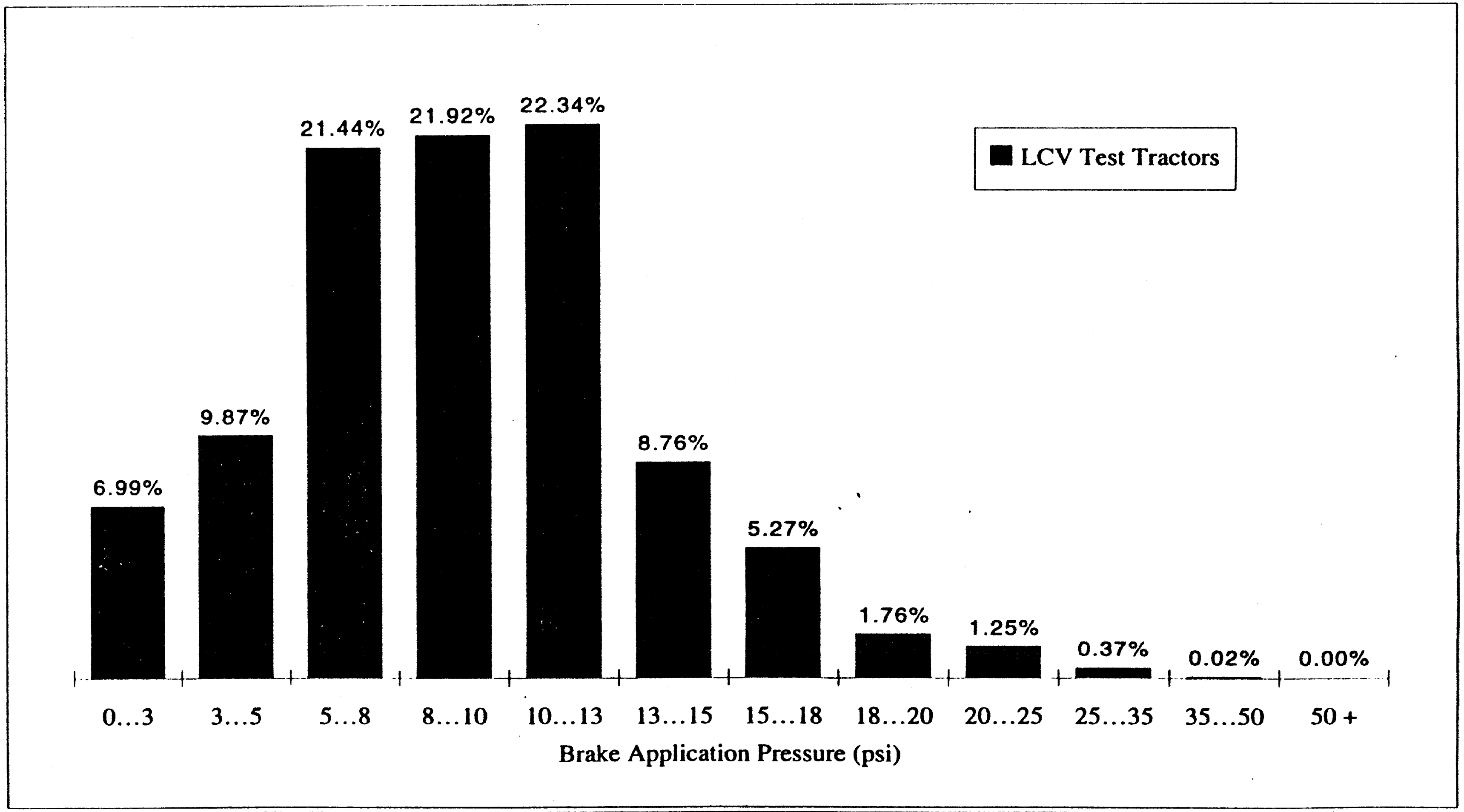
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Reverse Rocky	Total braking time (hrs):	7
Vehicle Load Condition:	Full	Total time (hrs):	243
Number of historgrams:	34	Percent of time braking:	3.01%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure



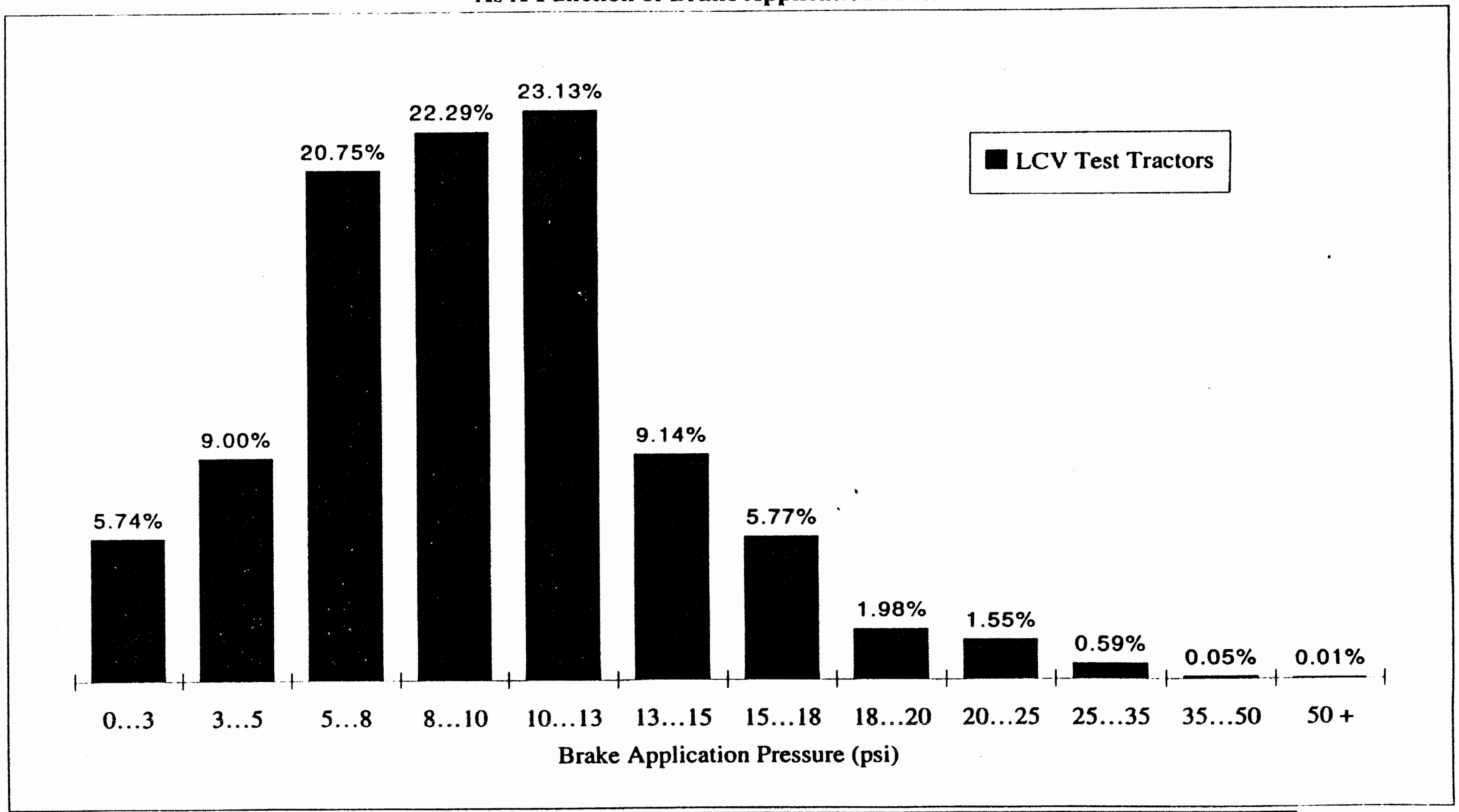
Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	185
Vehicle Load Condition:	All	Total time (hrs):	6094
Number of histograms:	763	Percent of time braking:	3.04%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure



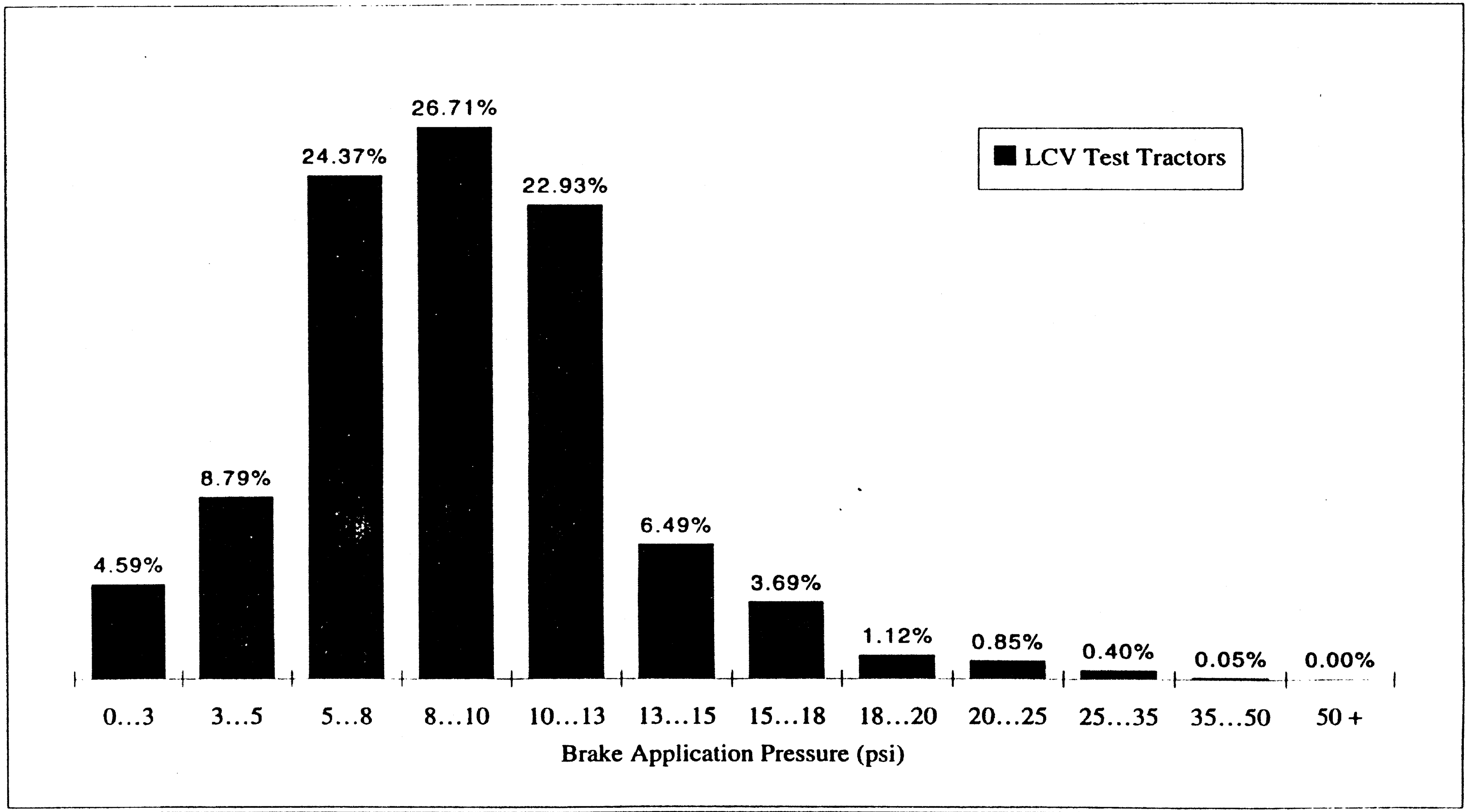
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	76
Vehicle Load Condition:	Empty	Total time (hrs):	2580
Number of historgrams:	320	Percent of time braking:	2.96%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure



Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	102
Vehicle Load Condition:	Full	Total time (hrs):	3174
Number of historgrams:	395	Percent of time braking:	3.23%

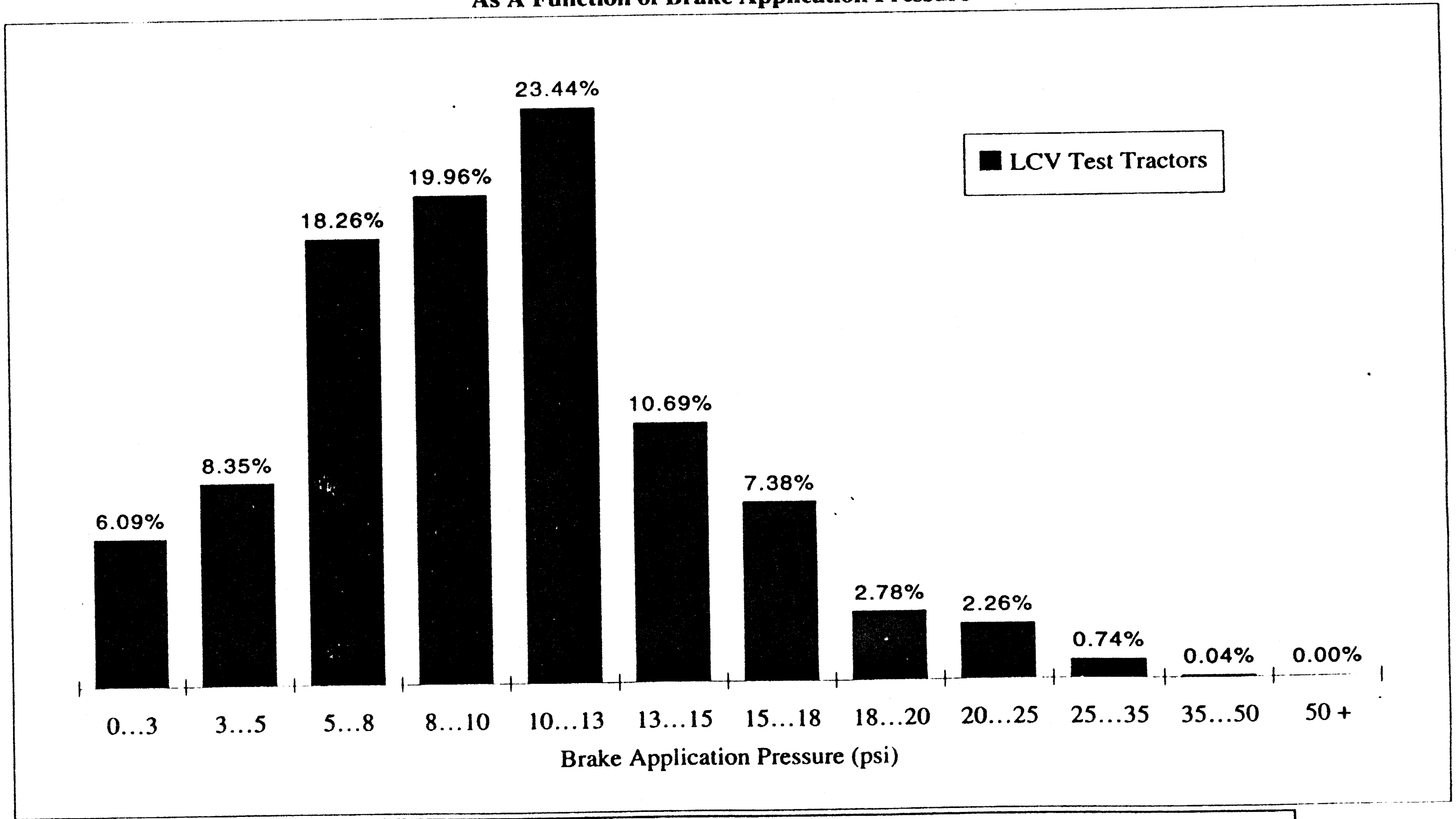
Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure



Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	6
Vehicle Load Condition:	Mixed	Total time (hrs):	340
Number of historgrams:	48	Percent of time braking:	1.80%

Distribution of Brake Application Time for the LCV Study Fleet

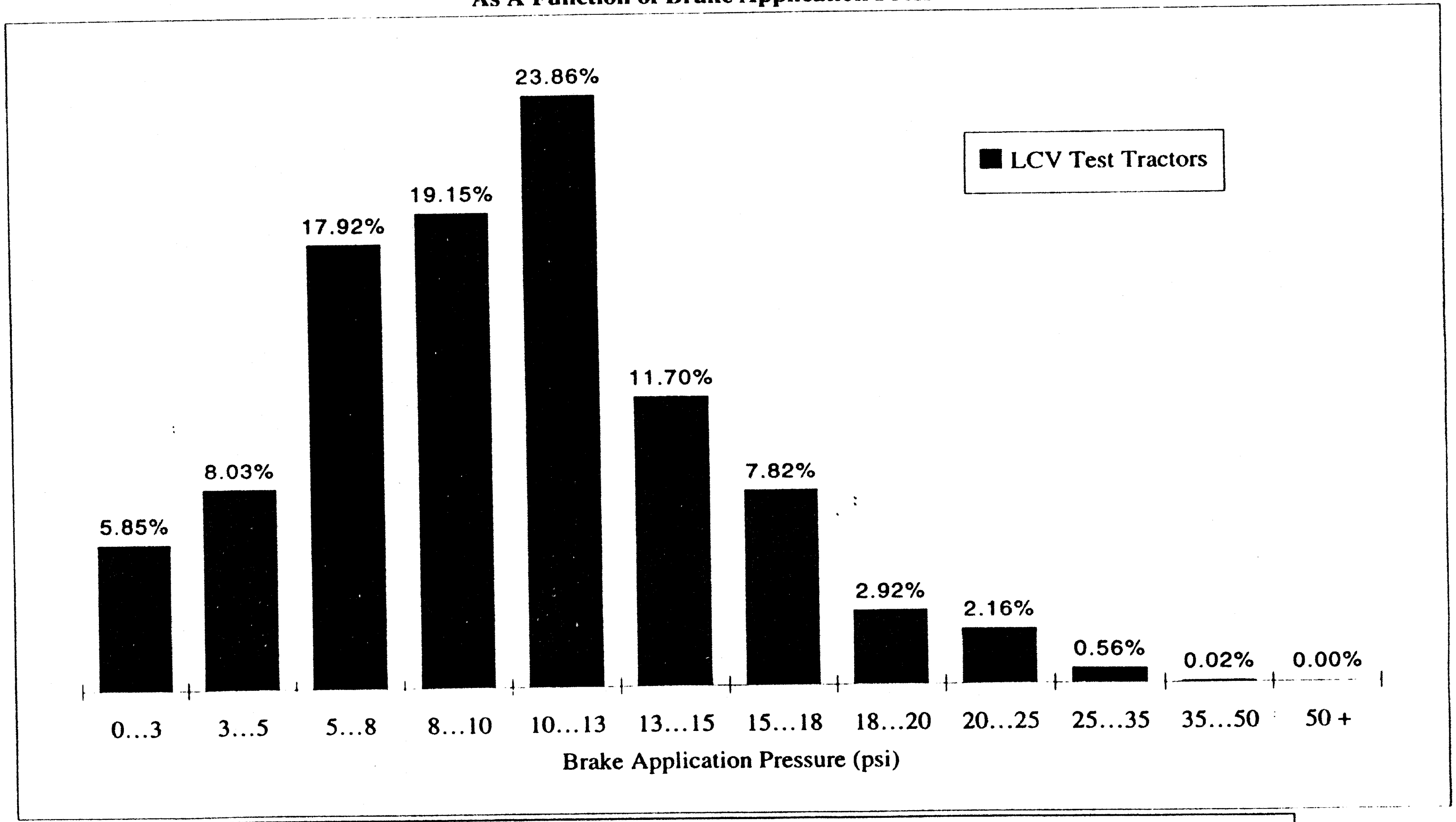
As A Function of Brake Application Pressure



Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Triple	Total braking time (hrs):	39
Vehicle Load Condition:	All	Total time (hrs):	1675
Number of historgrams:	198	Percent of time braking:	2.31%

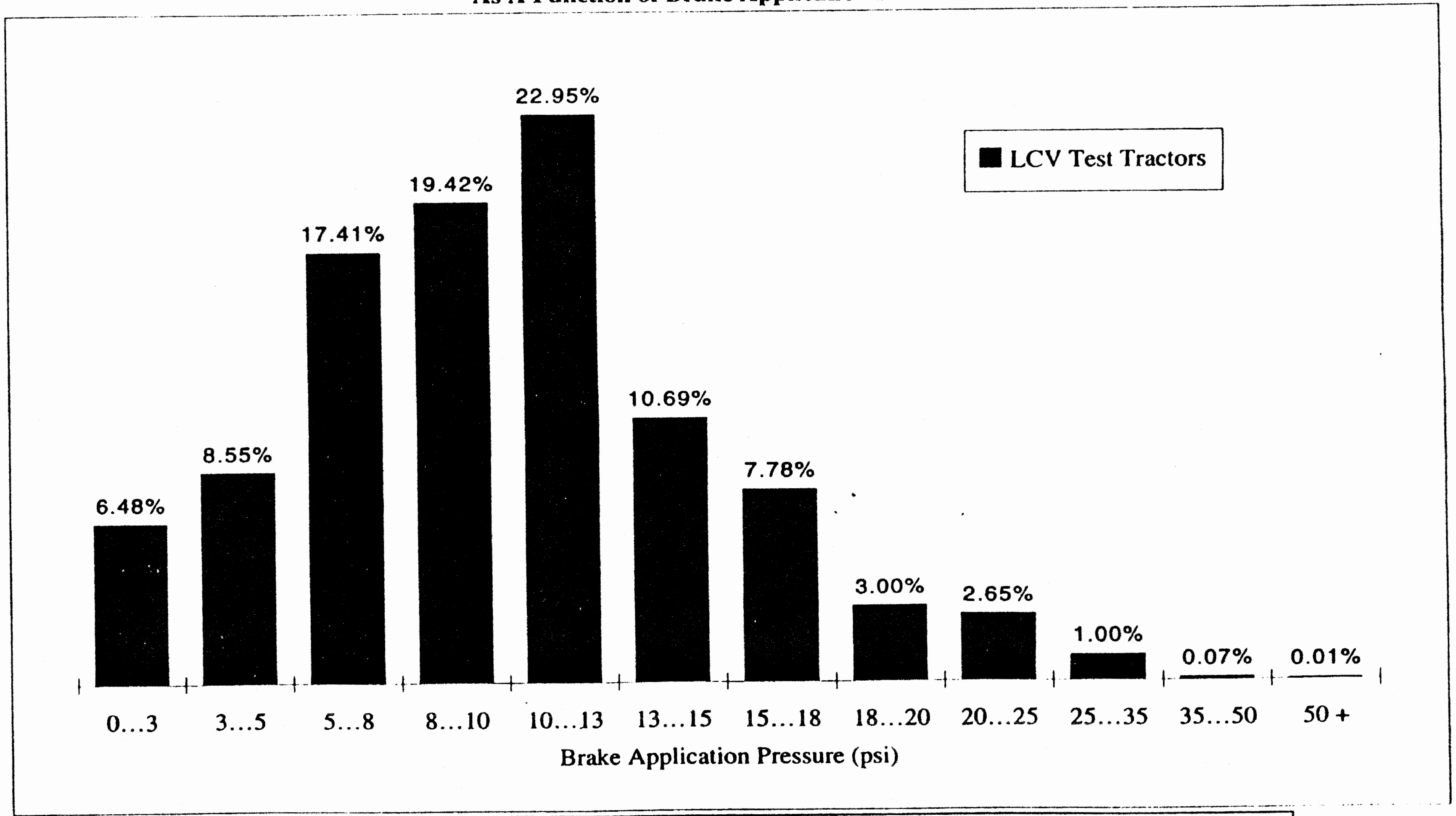
Distribution of Brake Application Time for the LCV Study Fleet

As A Function of Brake Application Pressure



Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	Triple	Total braking time (hrs):	16
Vehicle Load Condition:	Empty	Total time (hrs):	637
Number of historgrams:	74	Percent of time braking:	2.52%

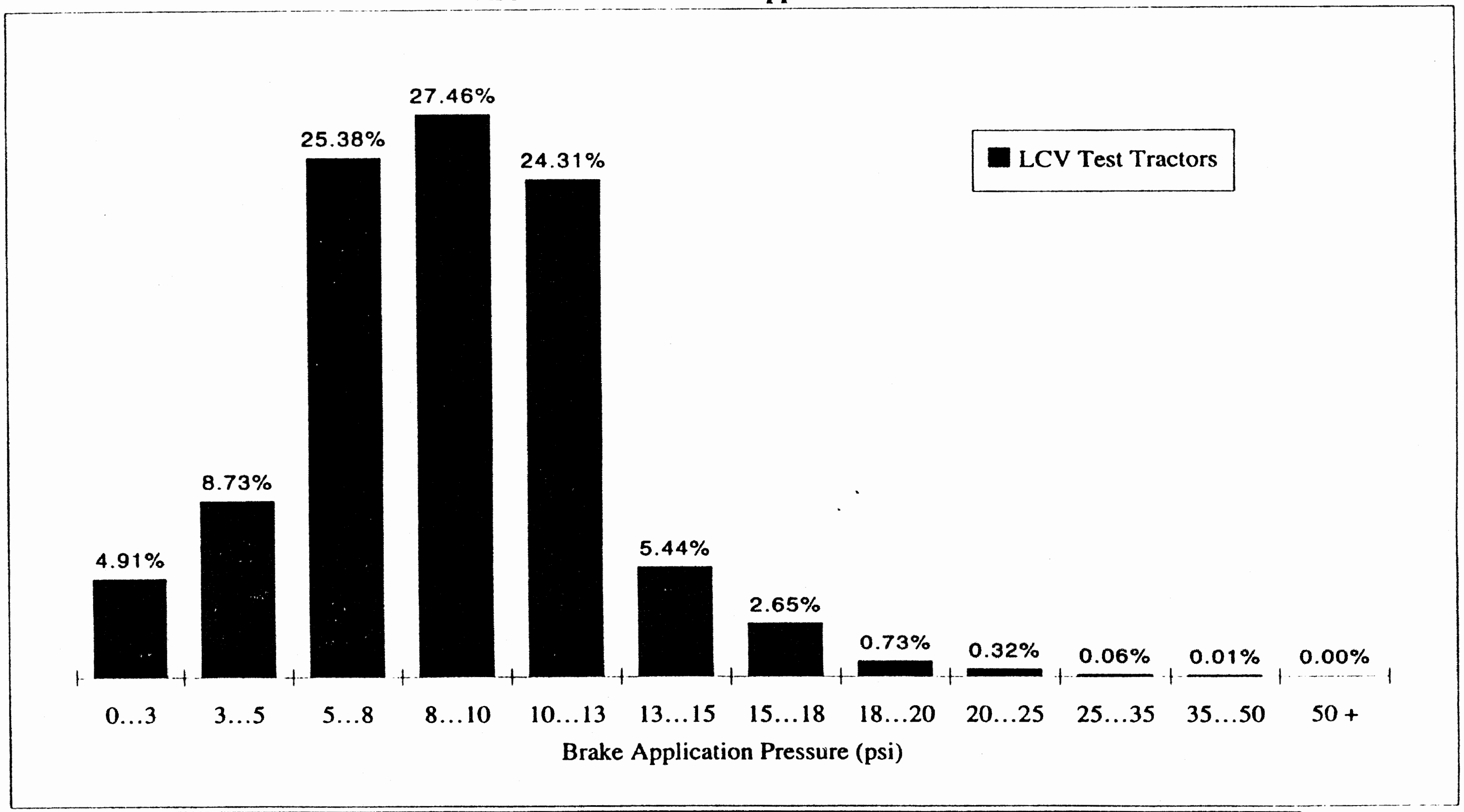
Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure



Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Triple	Total braking time (hrs):	20
Vehicle Load Condition:	Full	Total time (hrs):	831
Number of historgrams:	97	Percent of time braking:	2.35%

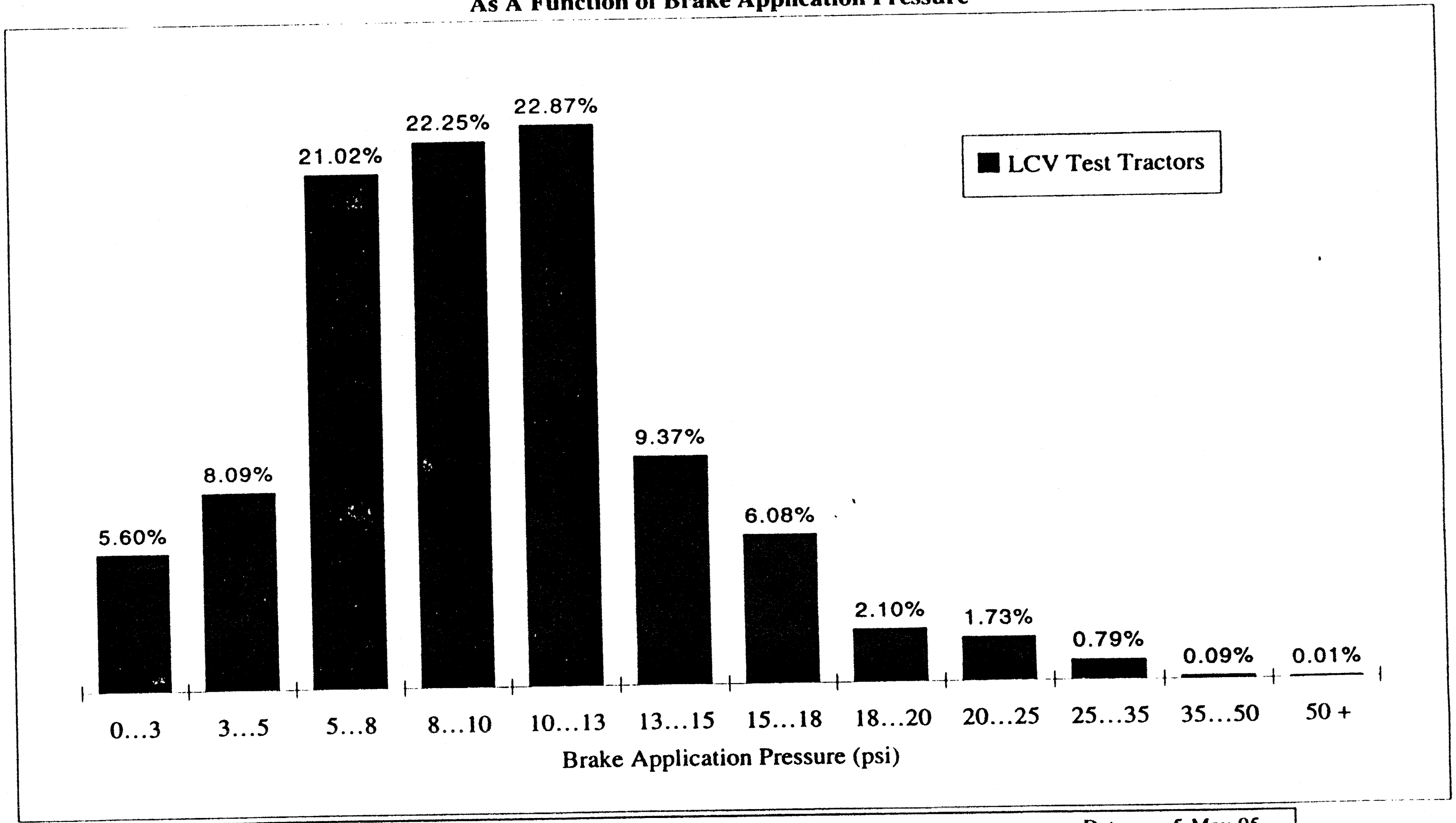
Distribution of Brake Application Time for the LCV Study Fleet

As A Function of Brake Application Pressure



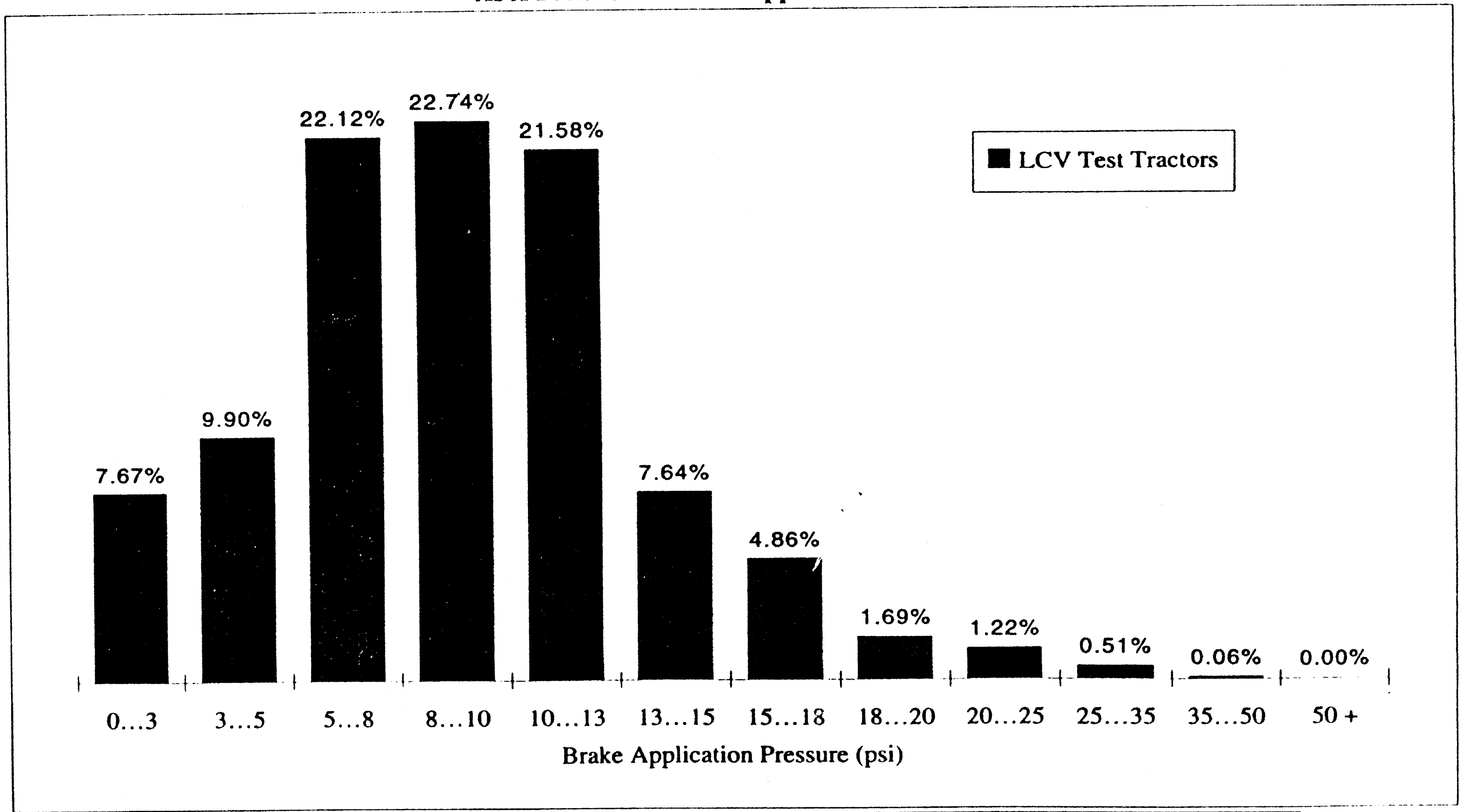
Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	Triple	Total braking time (hrs):	3
Vehicle Load Condition:	Mixed	Total time (hrs):	207
Number of historgrams:	27	Percent of time braking:	1.50%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure



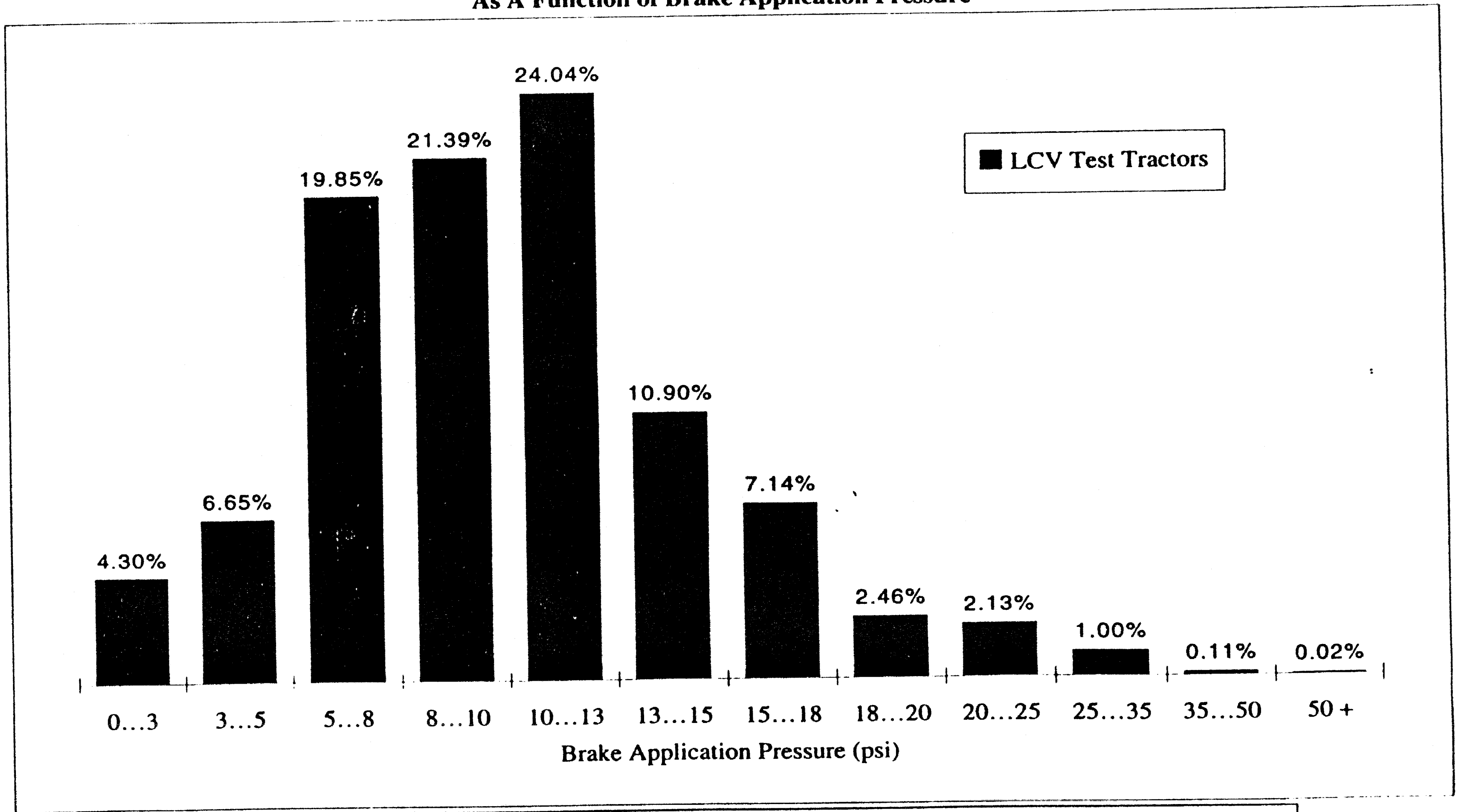
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Double	Total braking time (hrs):	32
Vehicle Load Condition:	All	Total time (hrs):	1037
Number of historgrams:	153	Percent of time braking:	3.08%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure



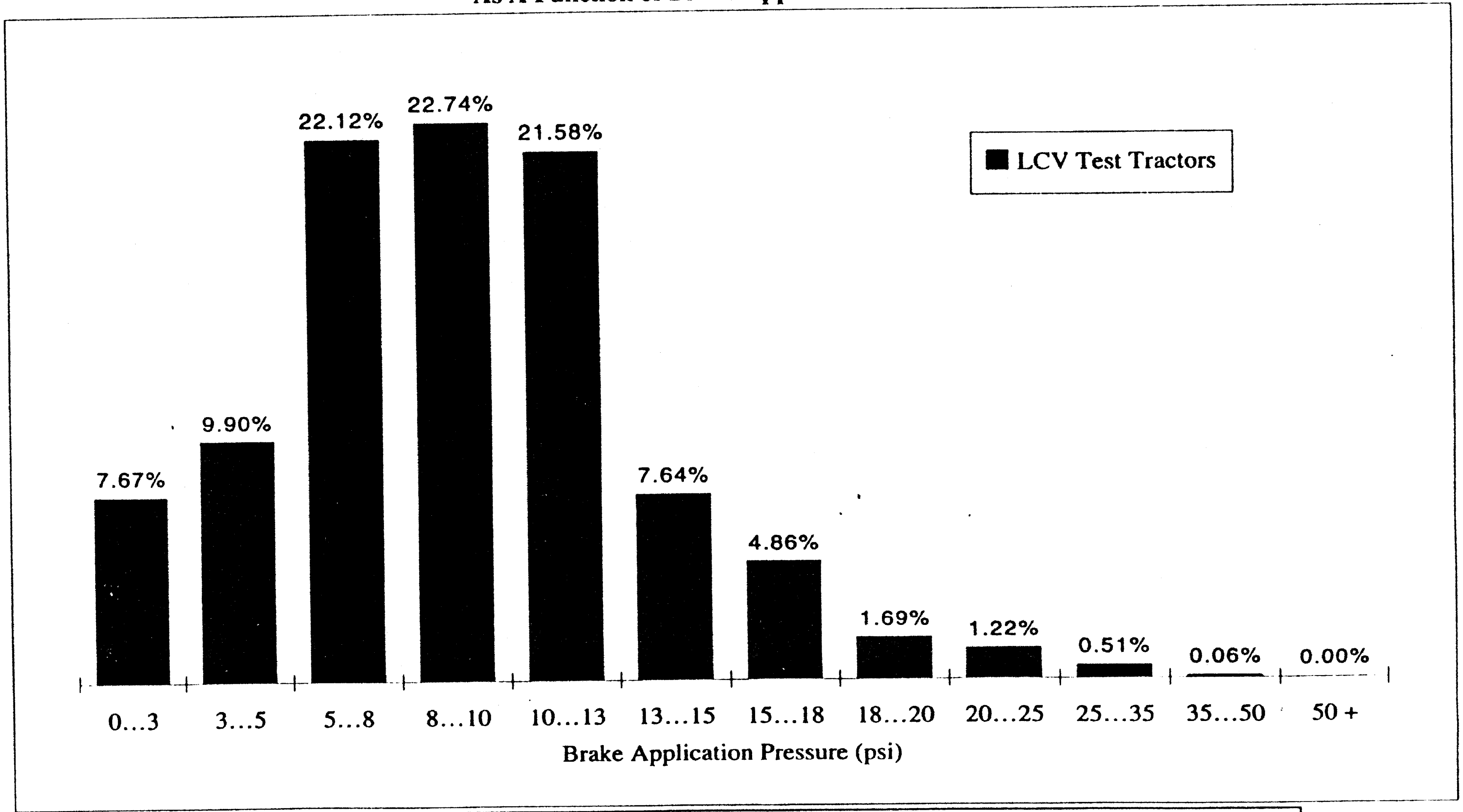
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Double	Total braking time (hrs):	12
Vehicle Load Condition:	Empty	Total time (hrs):	388
Number of historgrams:	62	Percent of time braking:	3.11%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure



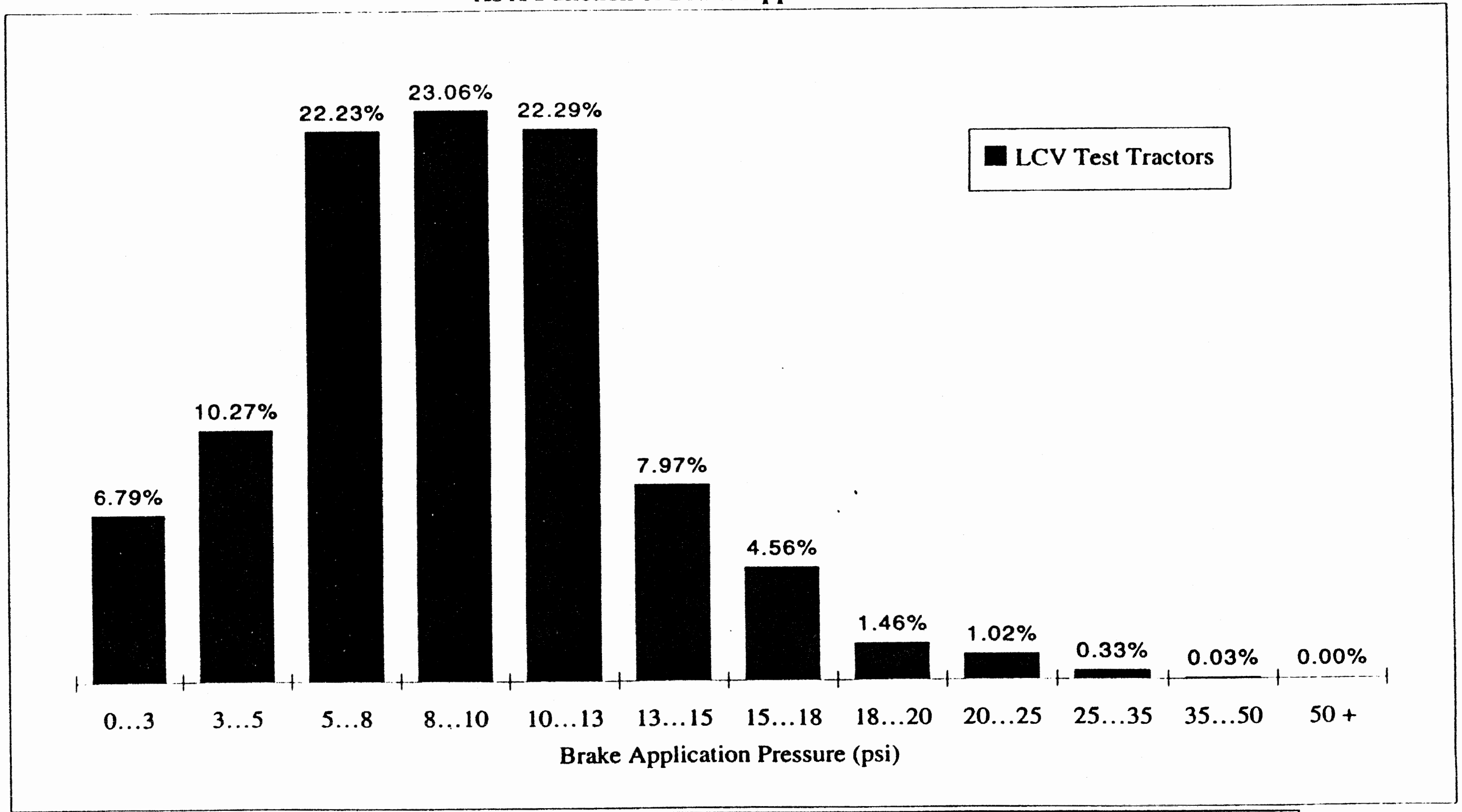
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Double	Total braking time (hrs):	17
Vehicle Load Condition:	Full	Total time (hrs):	536
Number of historgrams:	73	Percent of time braking:	3.21%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure



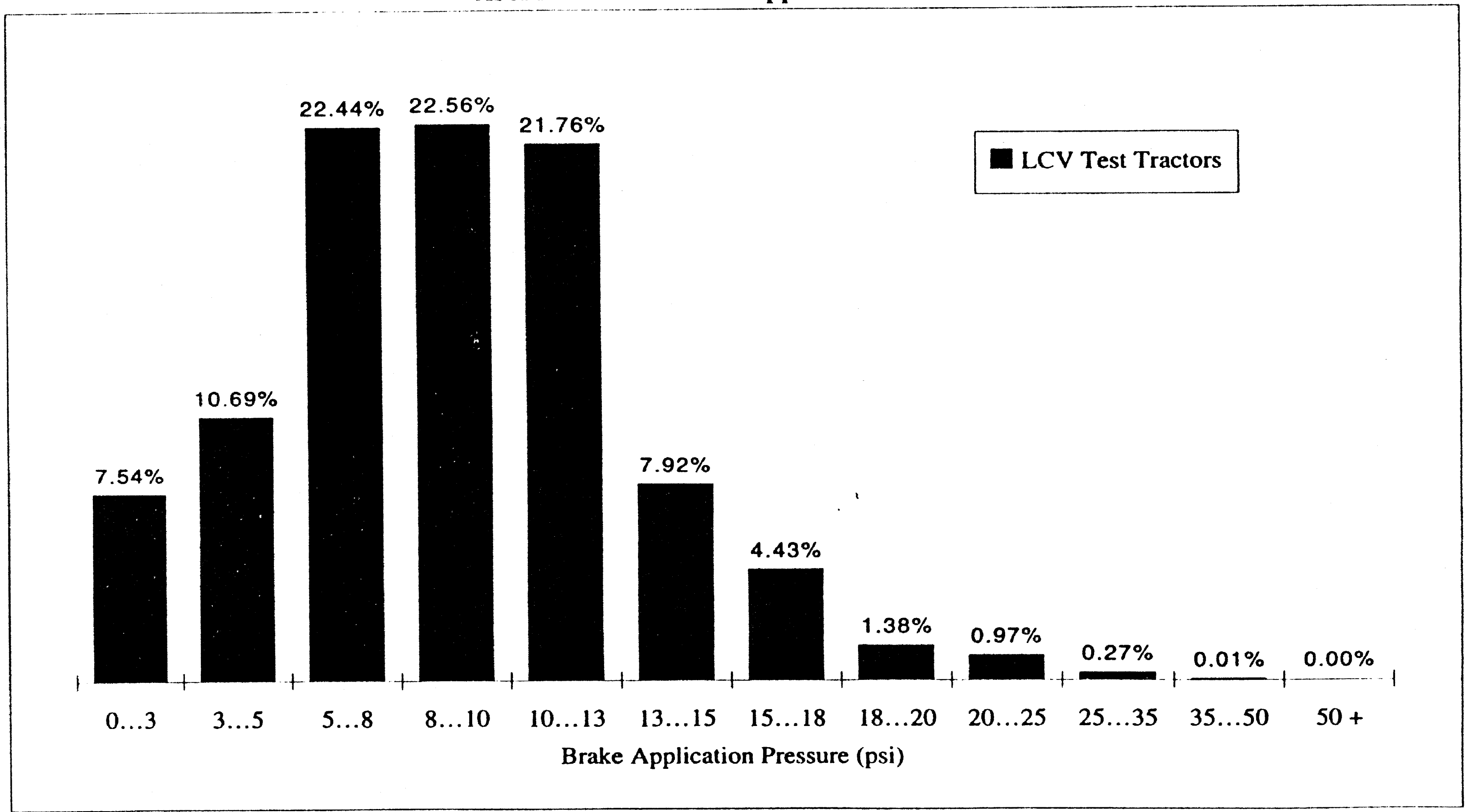
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Double	Total braking time (hrs):	3
Vehicle Load Condition:	Mixed	Total time (hrs):	112
Number of historgrams:	18	Percent of time braking:	2.32%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure



Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	Rocky	Total braking time (hrs):	103
Vehicle Load Condition:	All	Total time (hrs):	2958
Number of historgrams:	351	Percent of time braking:	3.48%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure



Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	Rocky	Total braking time (hrs):	44
Vehicle Load Condition:	Empty	Total time (hrs):	1374
Number of historgrams:	157	Percent of time braking:	3.22%

Distribution of Brake Application Time for the LCV Study Fleet
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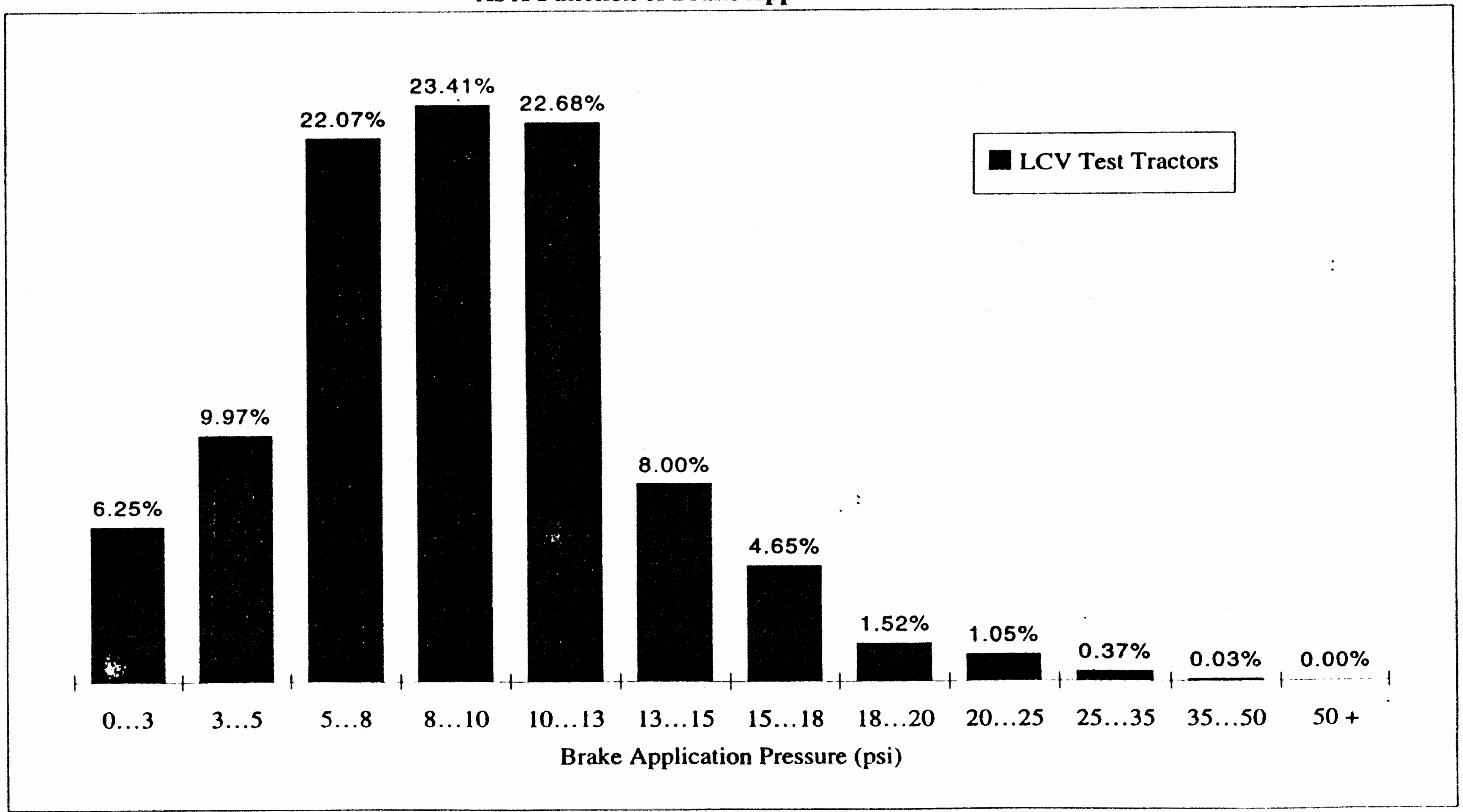
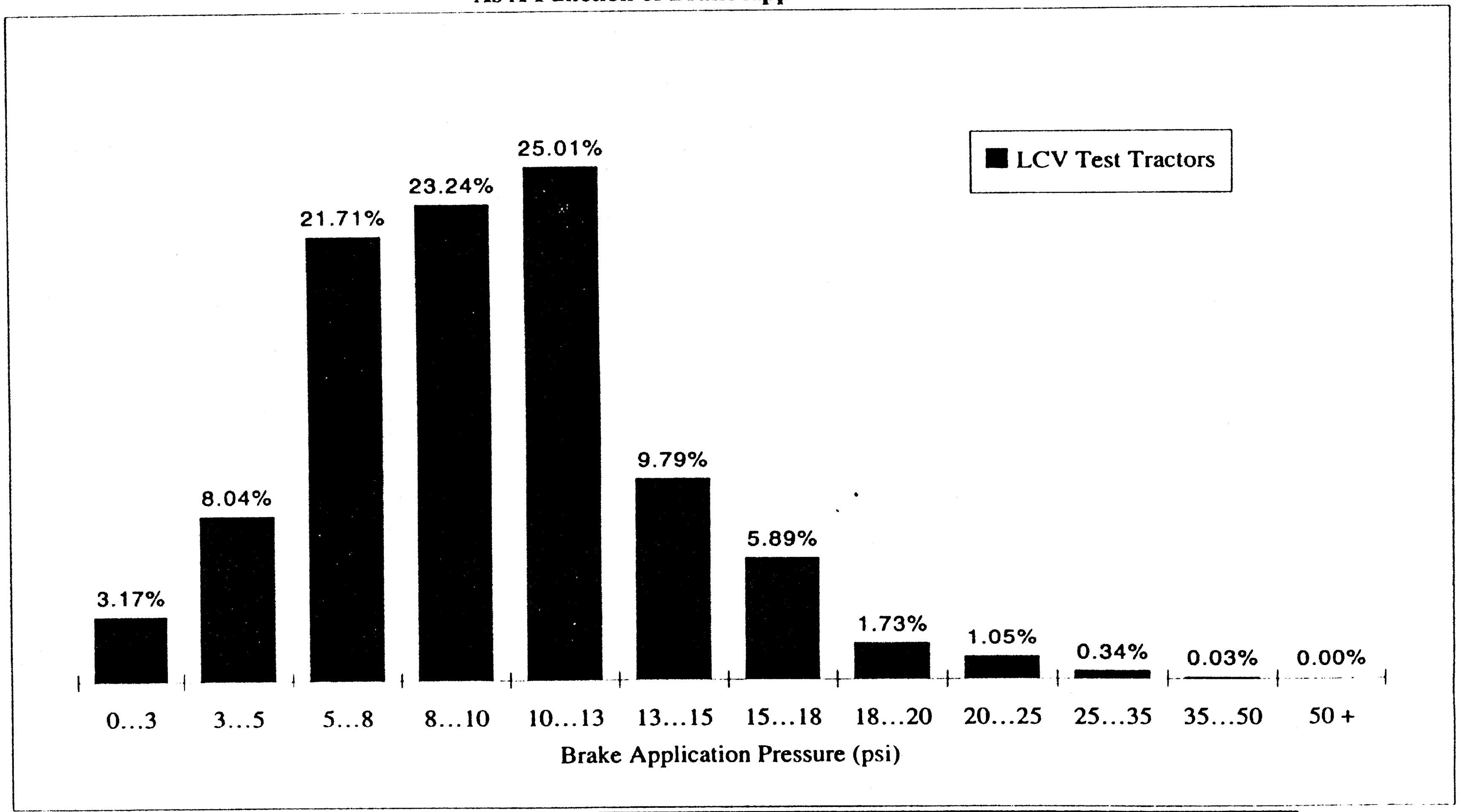


Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	Rocky	Total braking time (hrs):	58
Vehicle Load Condition:	Full	Total time (hrs):	1564
Number of historgrams:	191	Percent of time braking:	3.73%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Brake Application Pressure



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Vehicle Load Condition:	All	Total time (hrs):	425
Number of historgrams:	61	Percent of time braking:	2.67%

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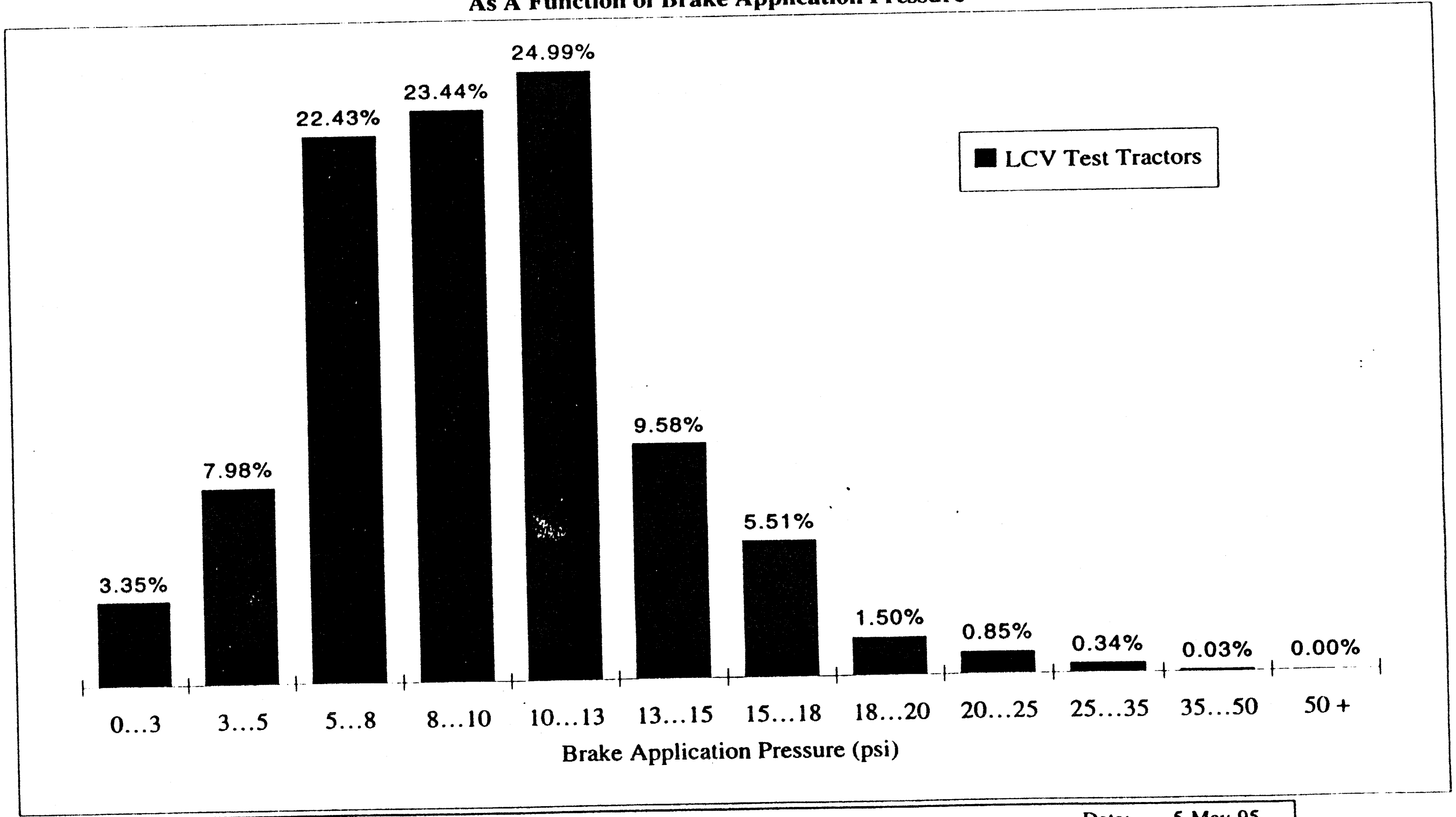

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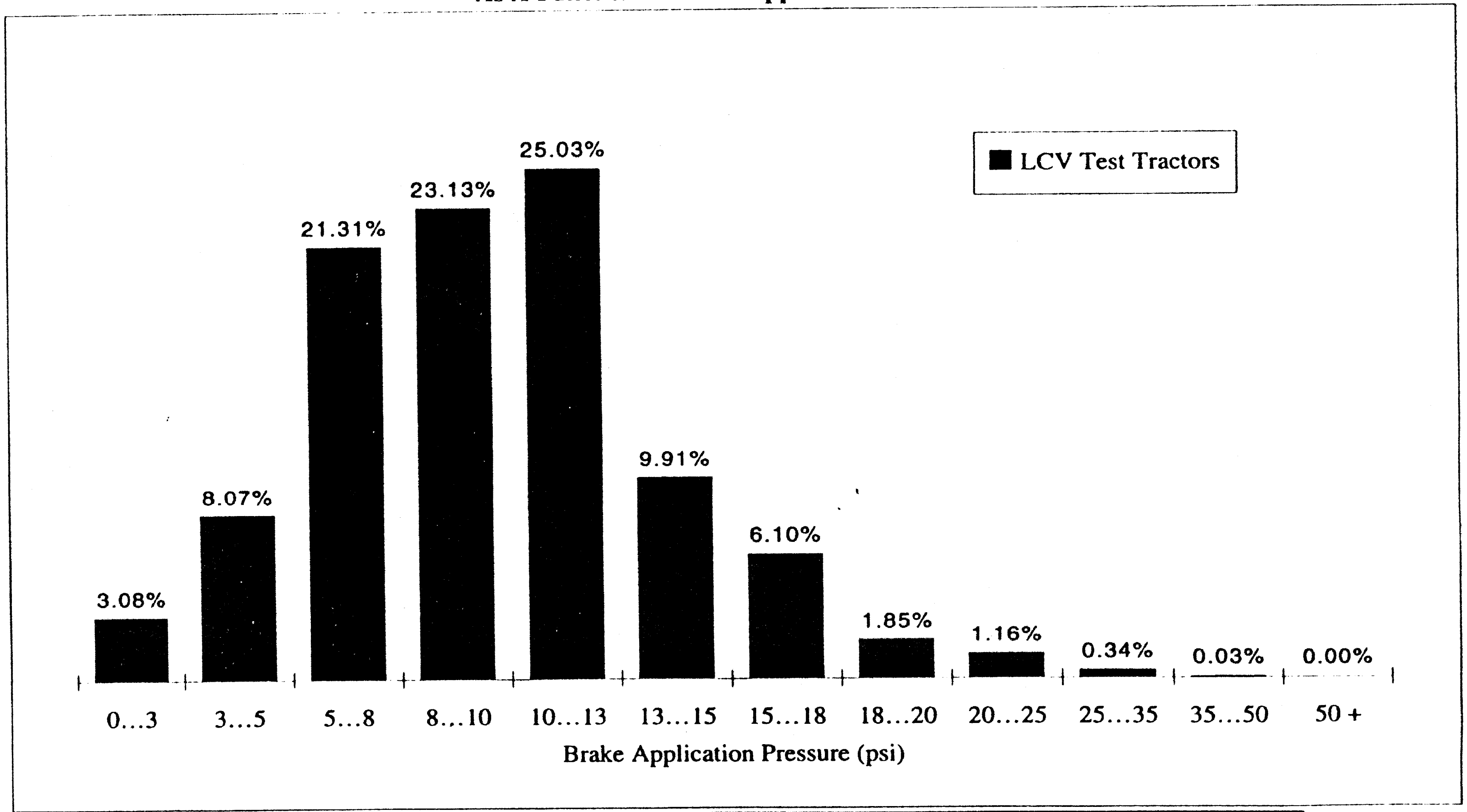

Results are based on the following:			Date: 5-May-95
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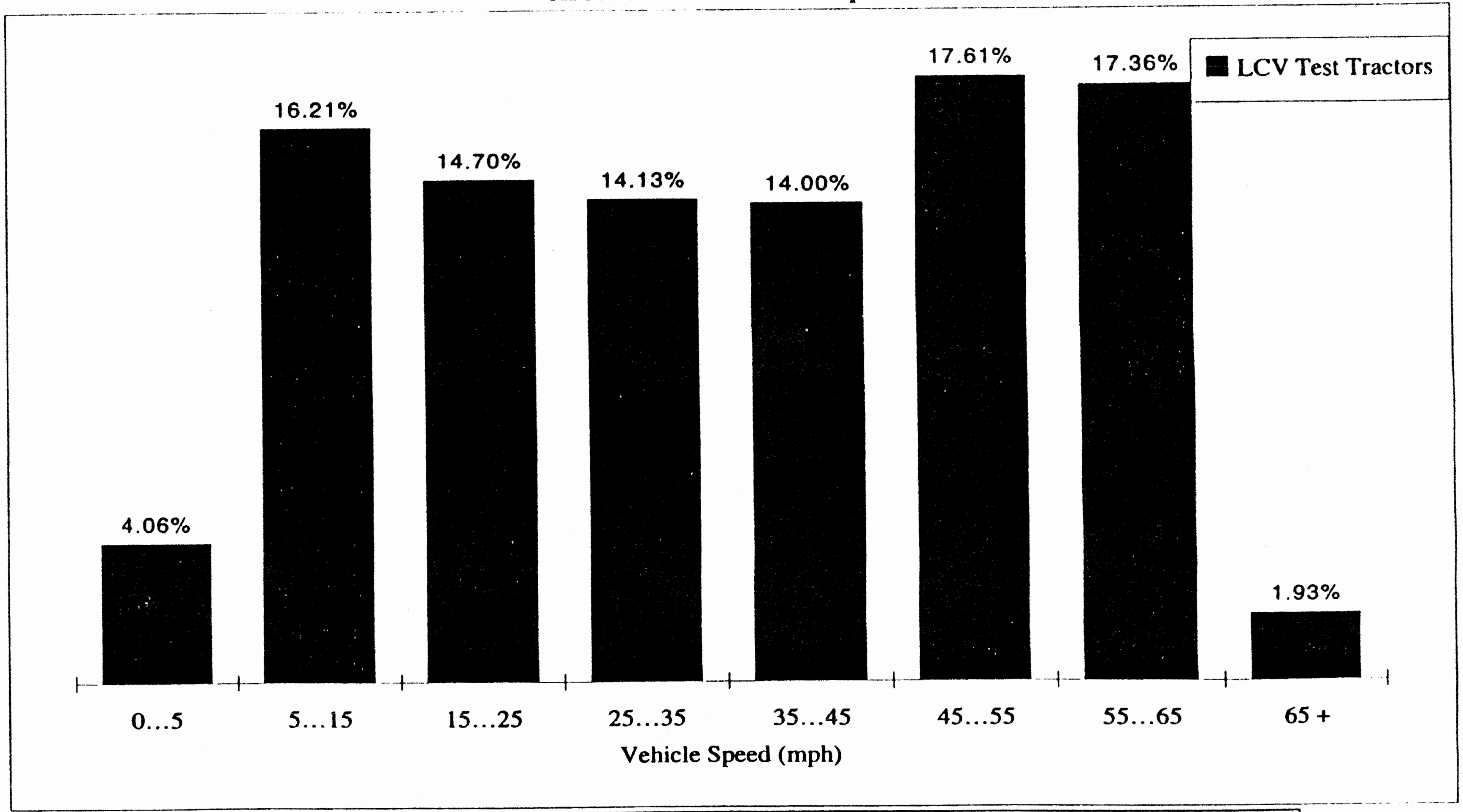
Vehicle Load Condition:	Full	Total time (hrs):	243
Number of historgrams:	34	Percent of time braking:	3.01%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Vehicle Speed



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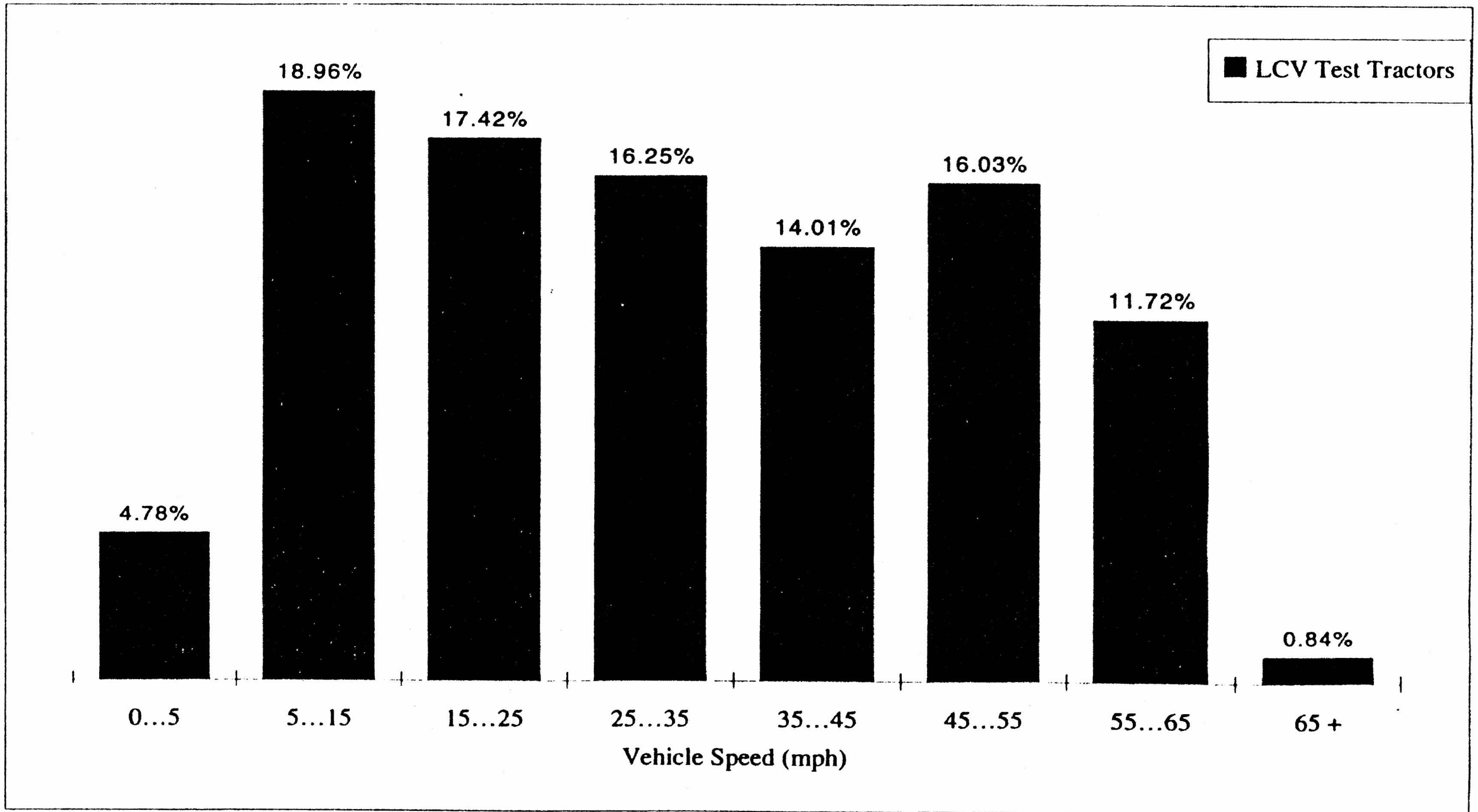

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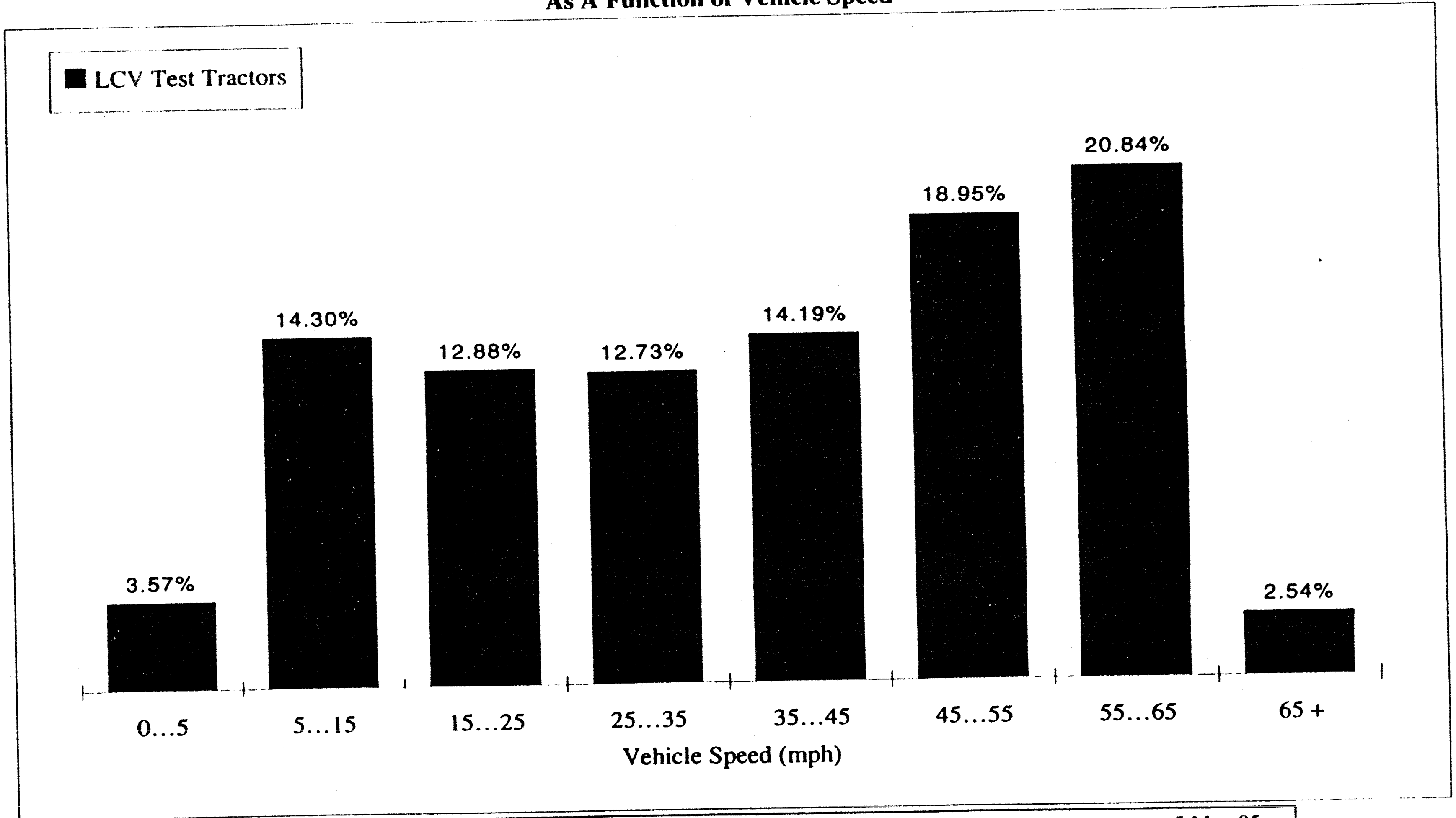

Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	102
Vehicle Load Condition:	Full	Total time (hrs):	3174
Number of historgrams:	395	Percent of time braking:	3.23%

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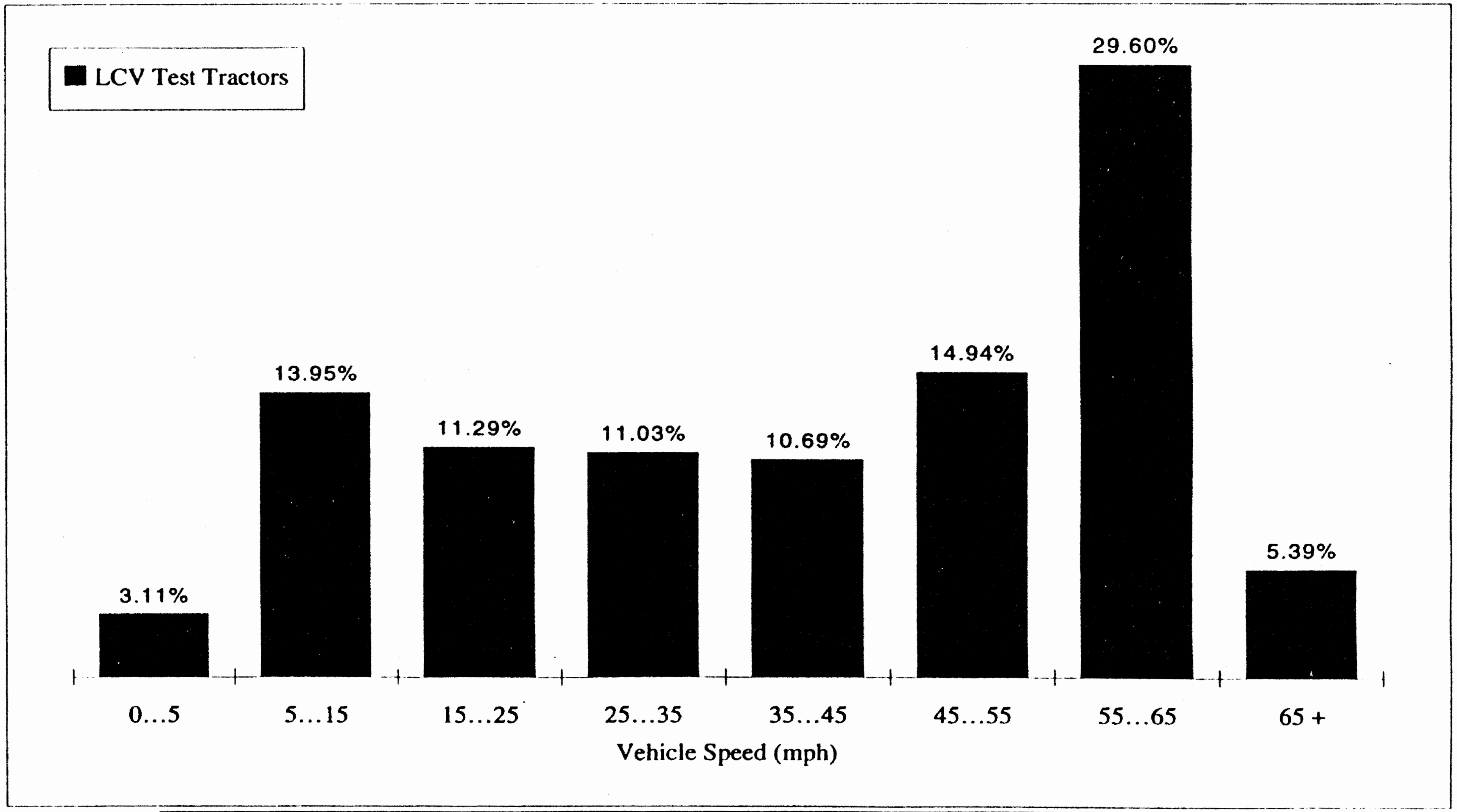

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Vehicle Configuration:	All	Total braking time (hrs):	6
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Number of historgrams:	48	Percent of time braking:	1.80%

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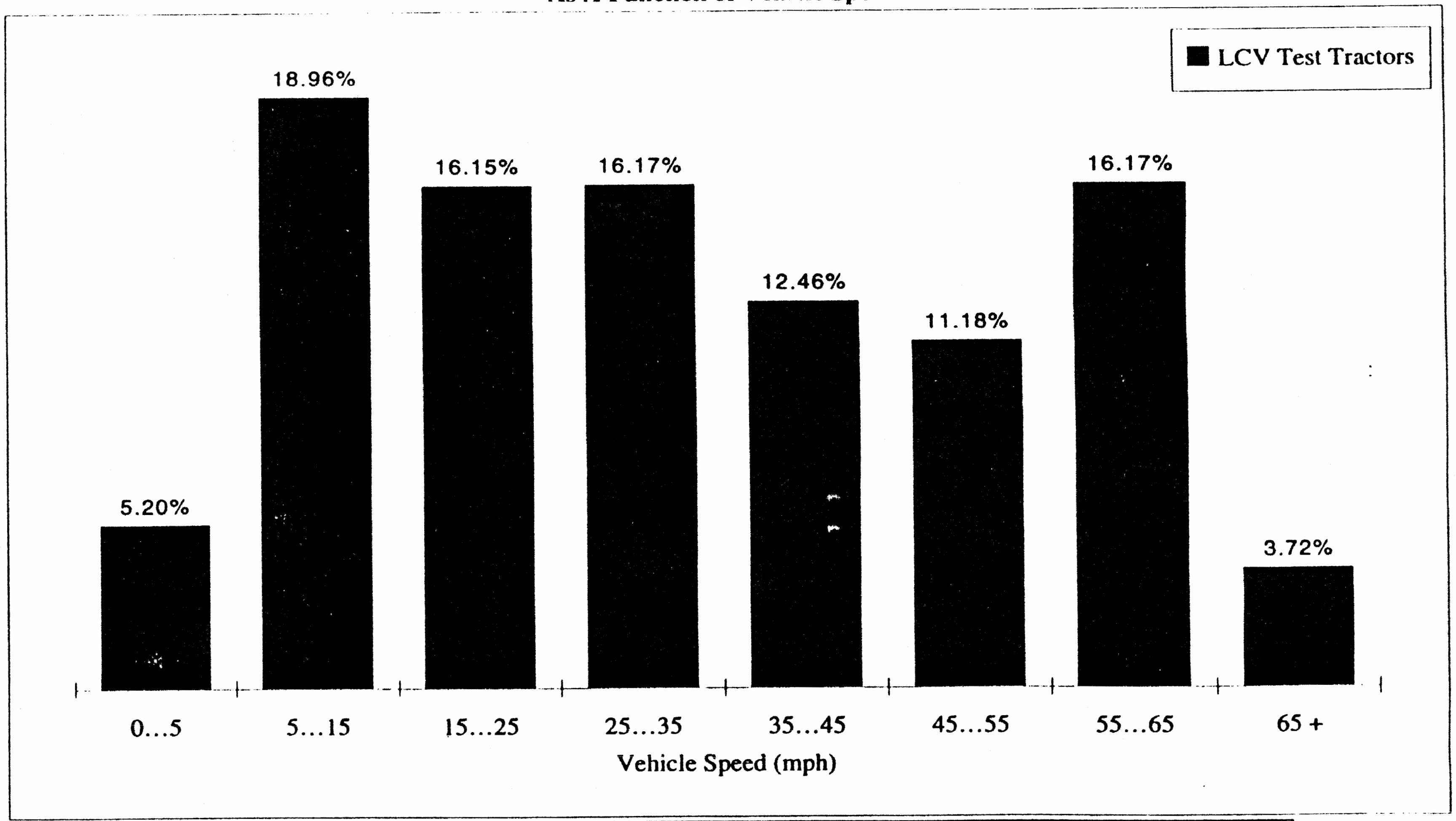

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Number of historgrams:	198	Percent of time braking:	2.31%

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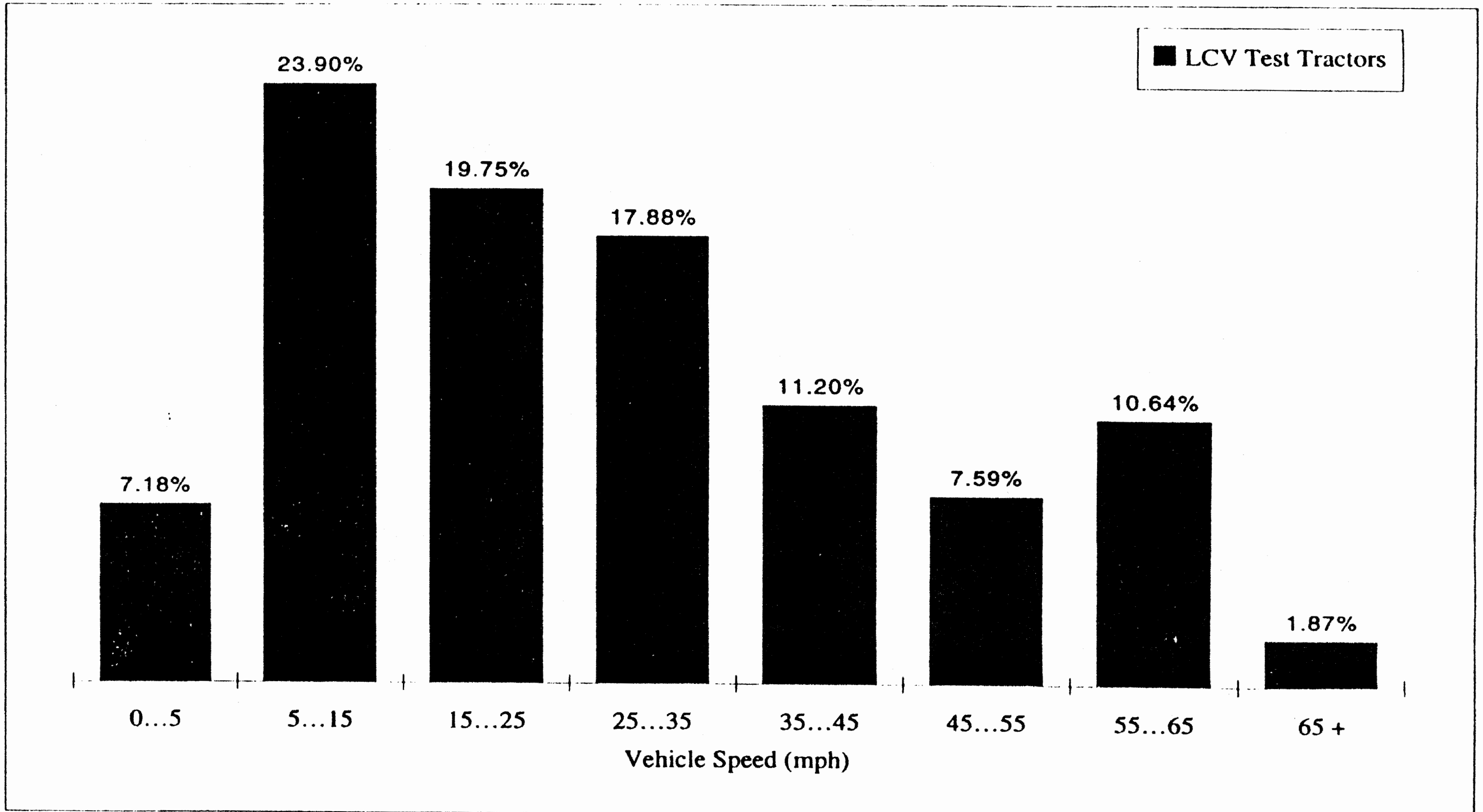

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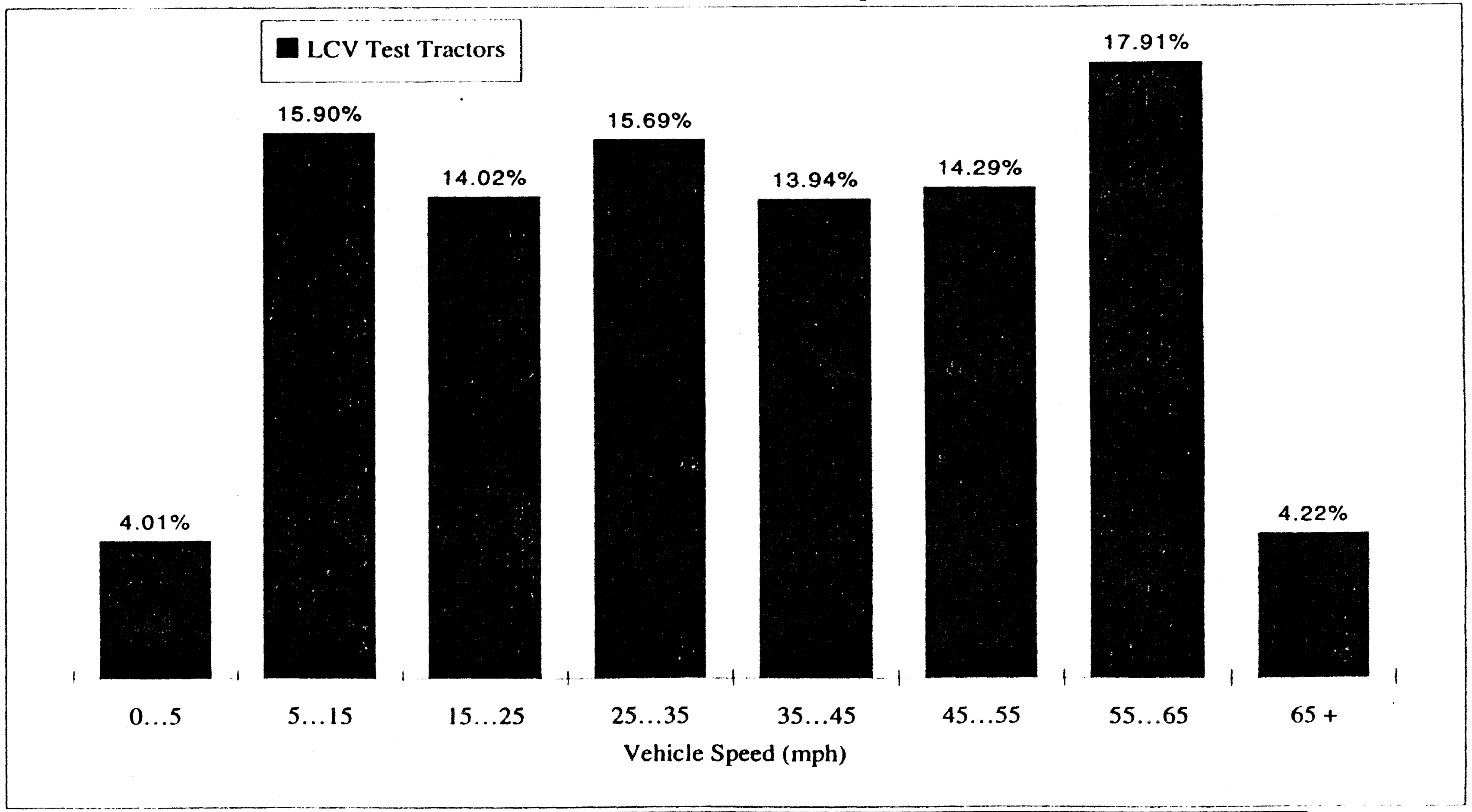

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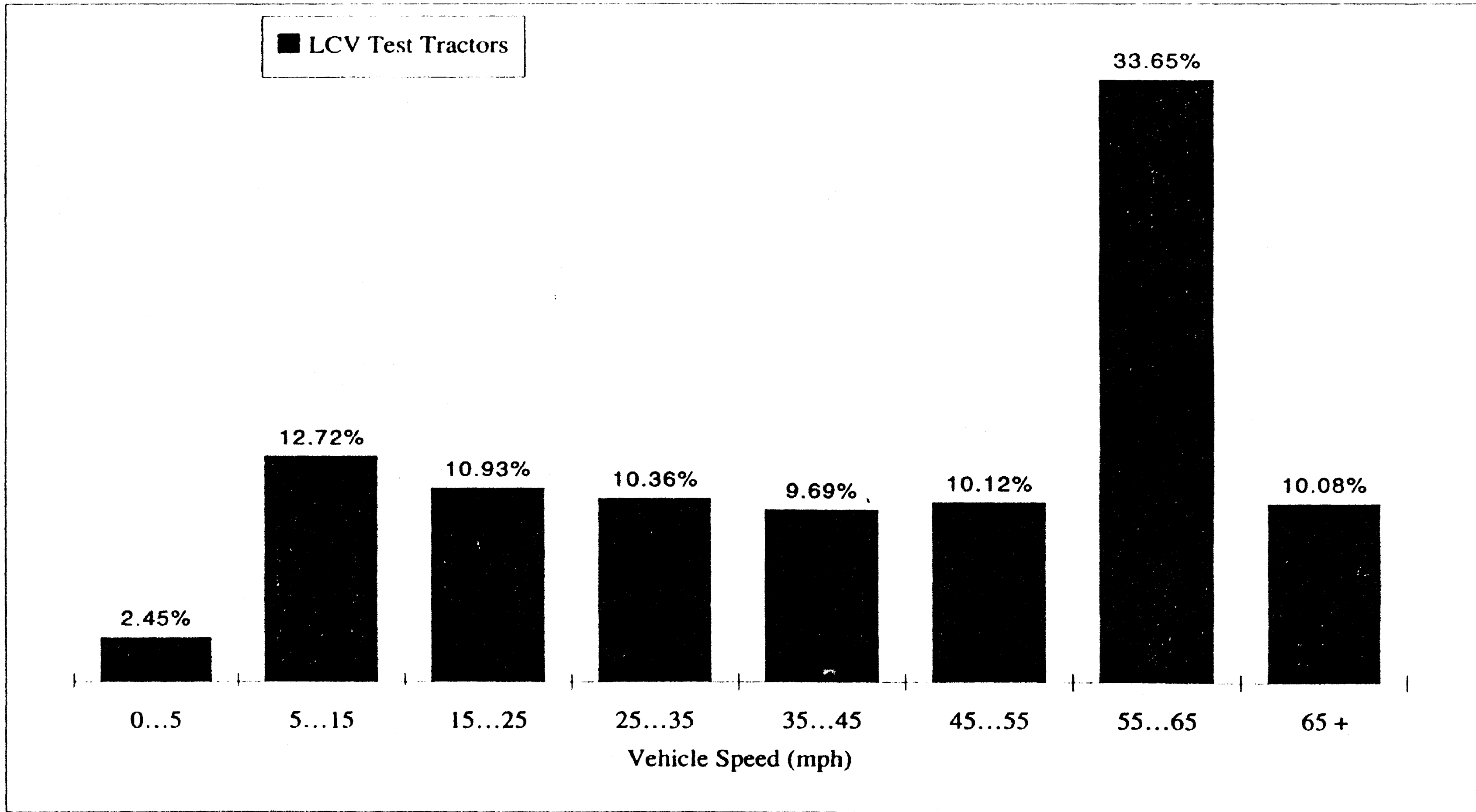

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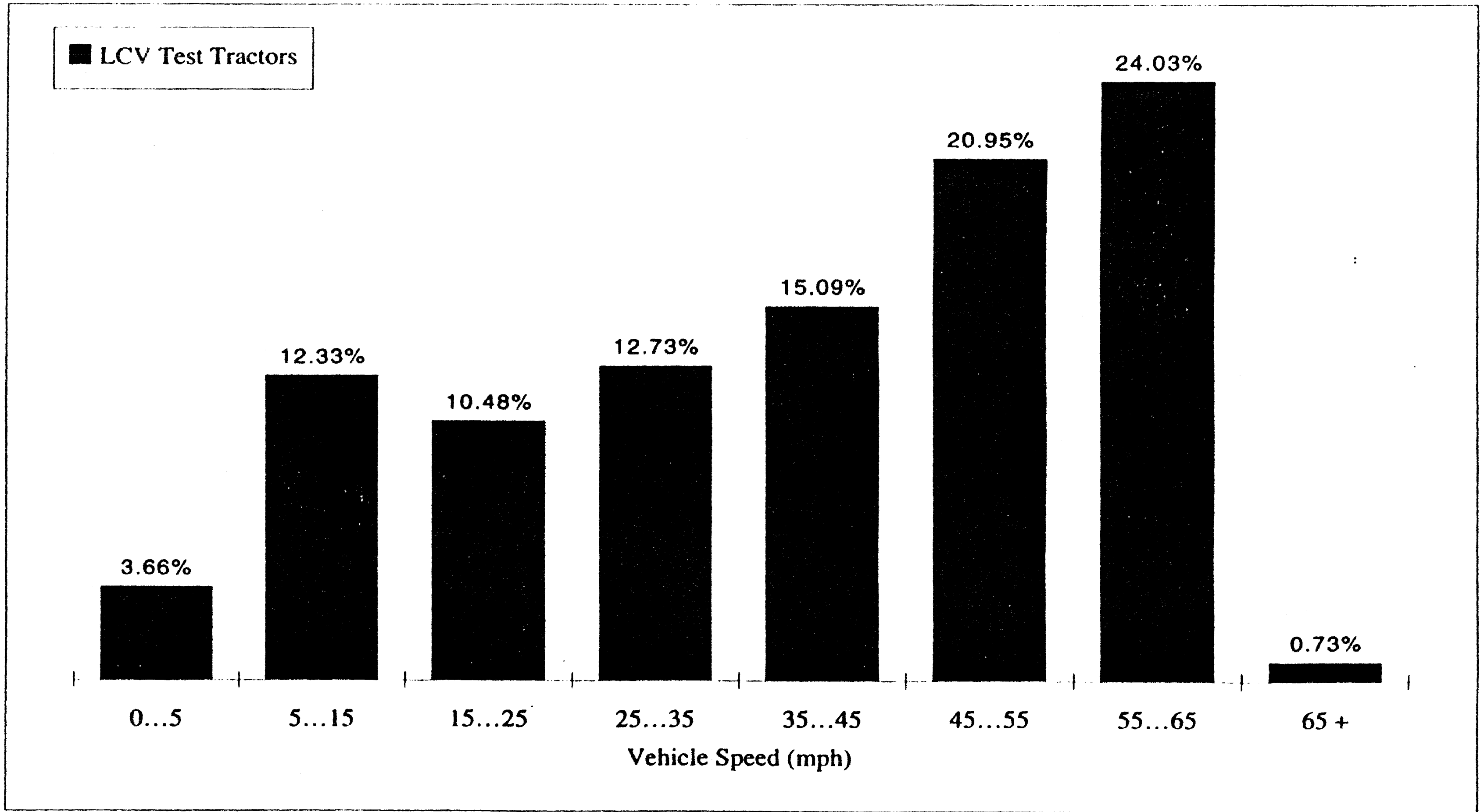

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Number of historgrams:	153	Percent of time braking:	3.08%	

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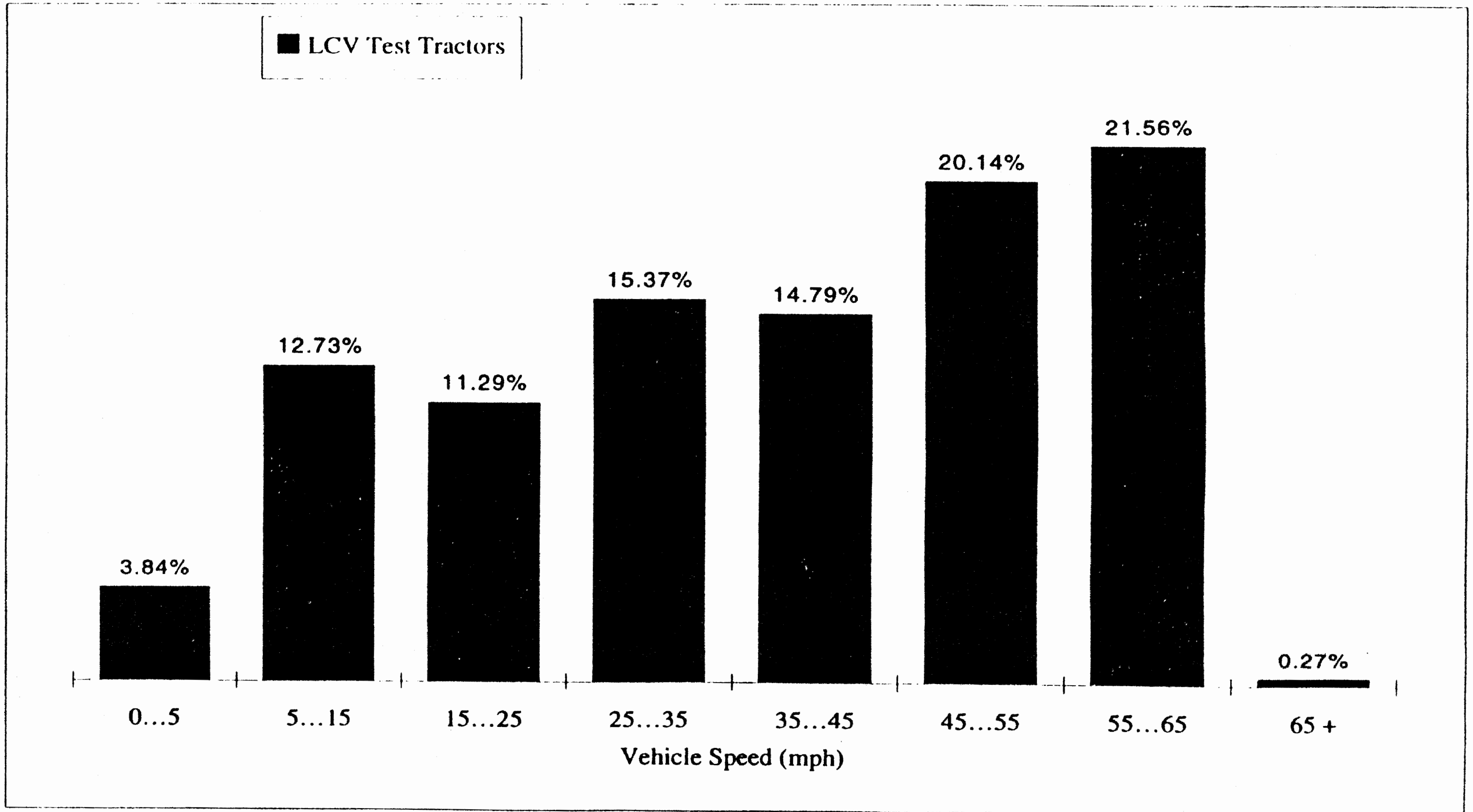

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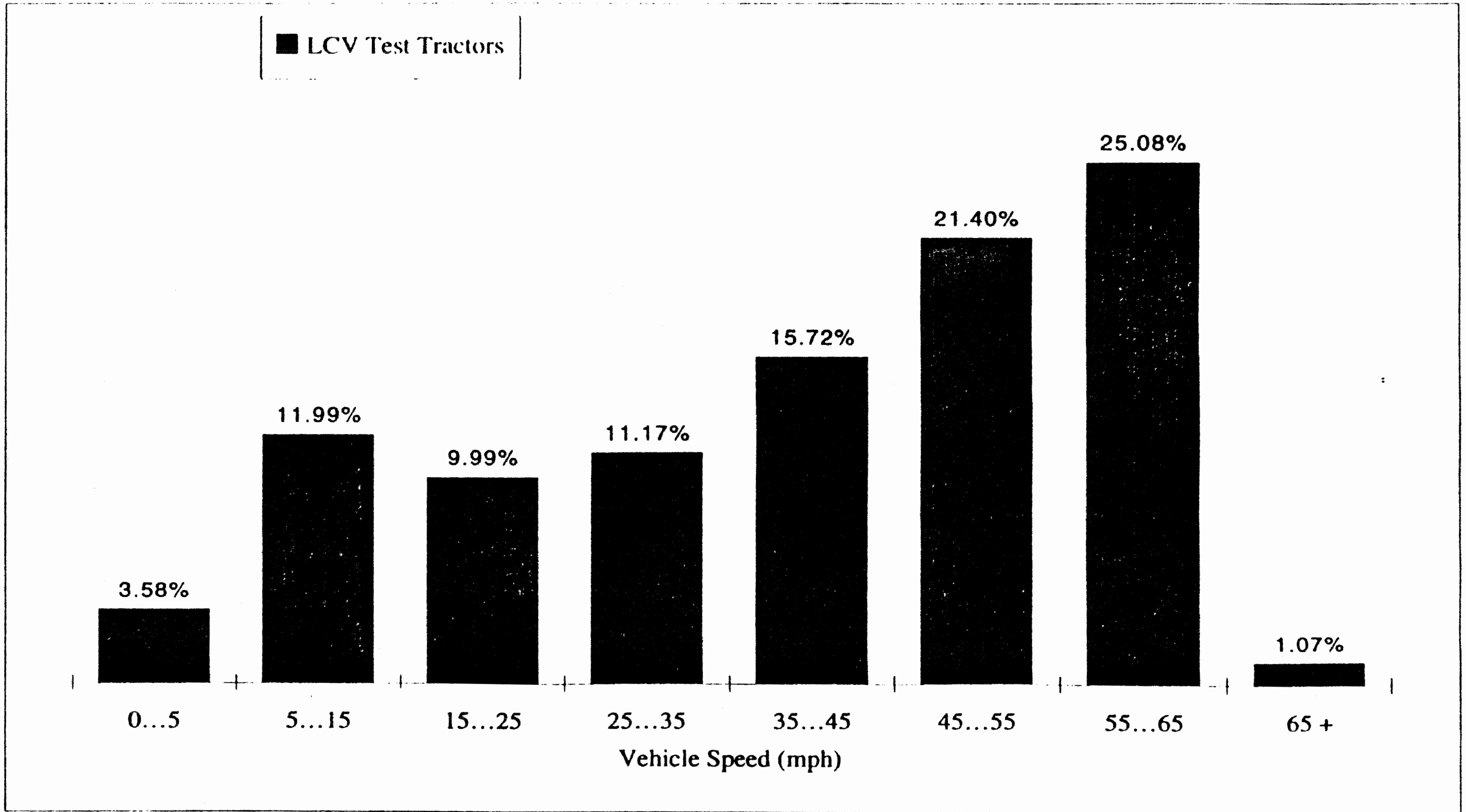

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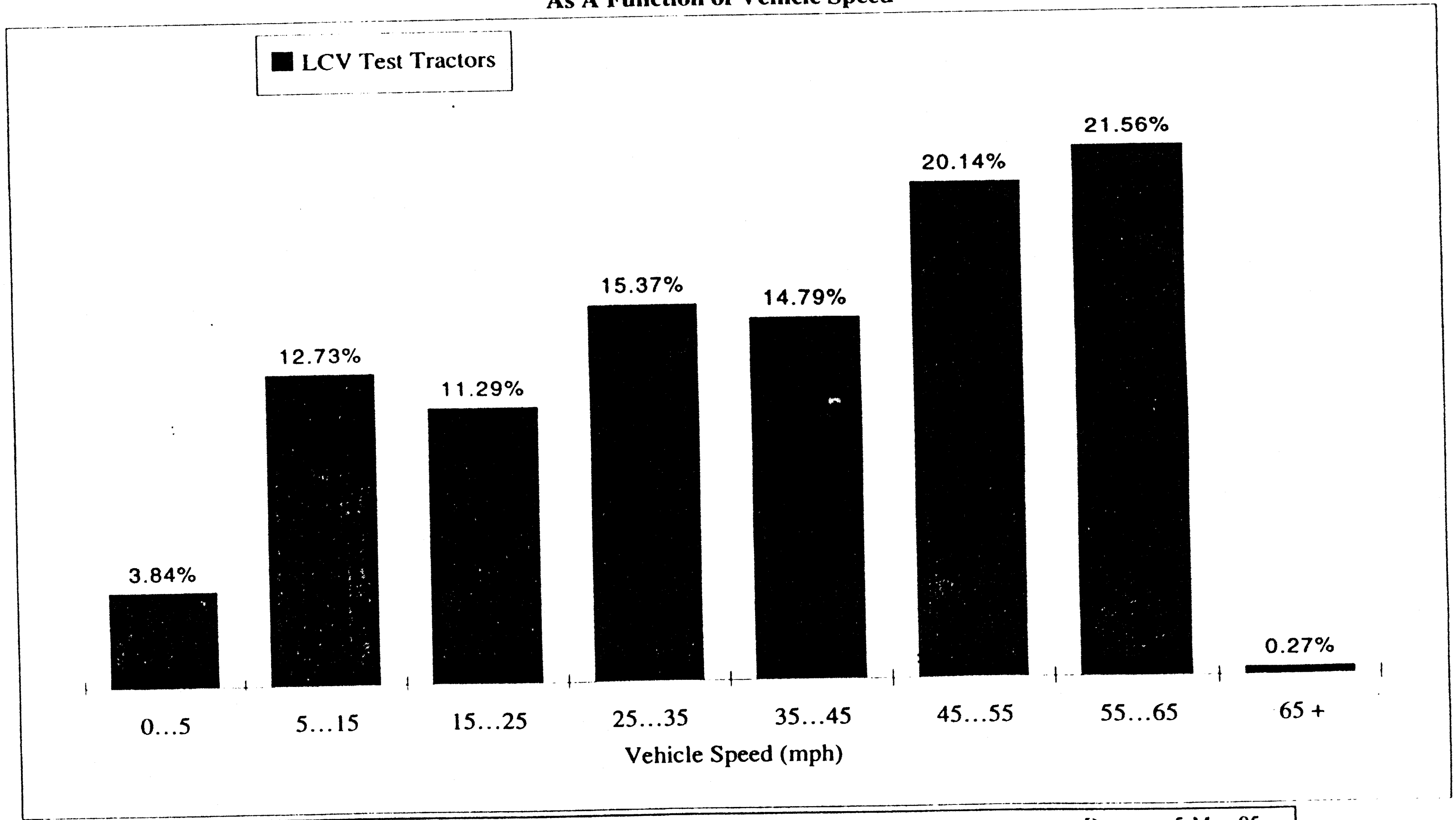

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Number of historgrams:	18	Percent of time braking:	2.32%

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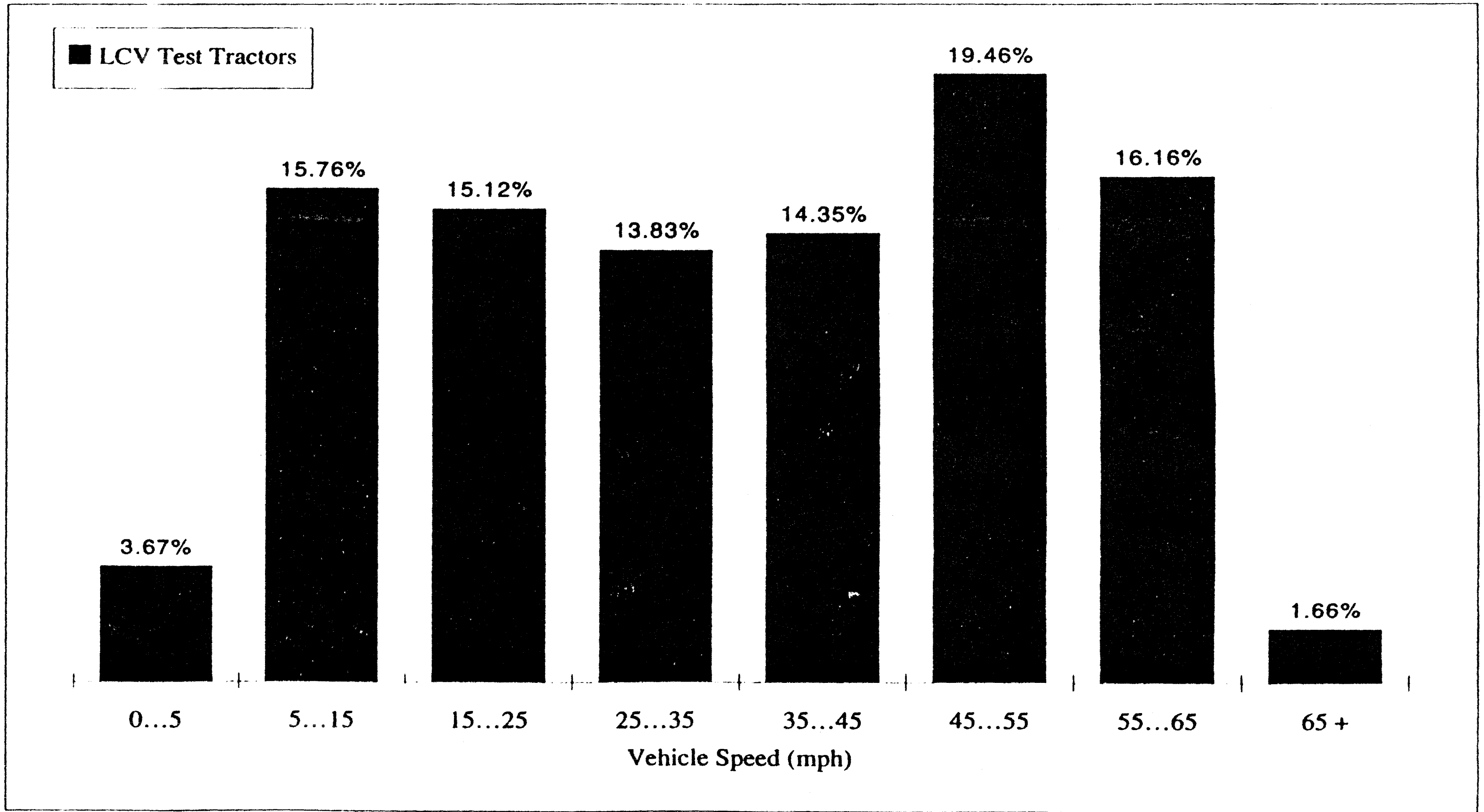

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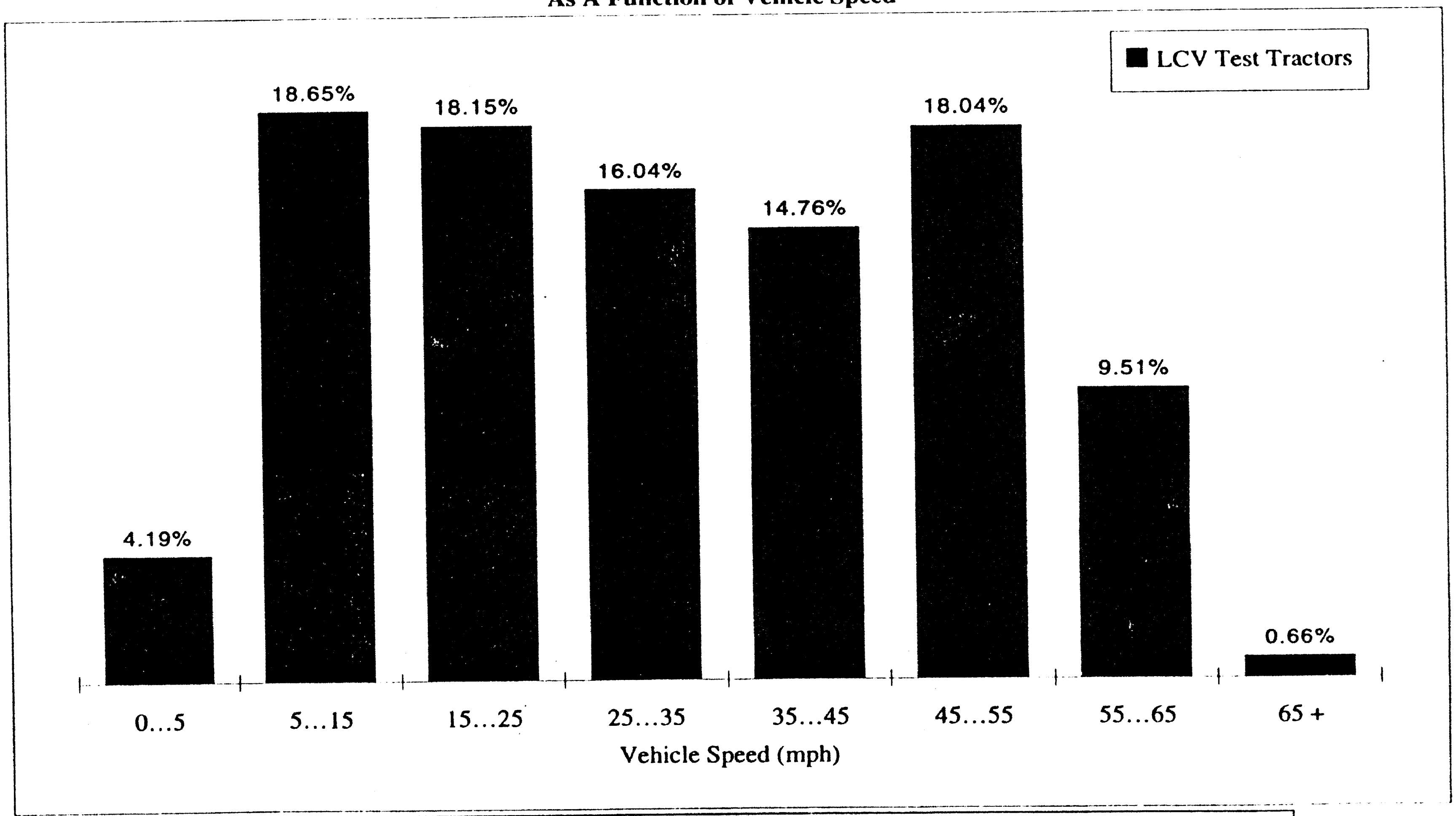

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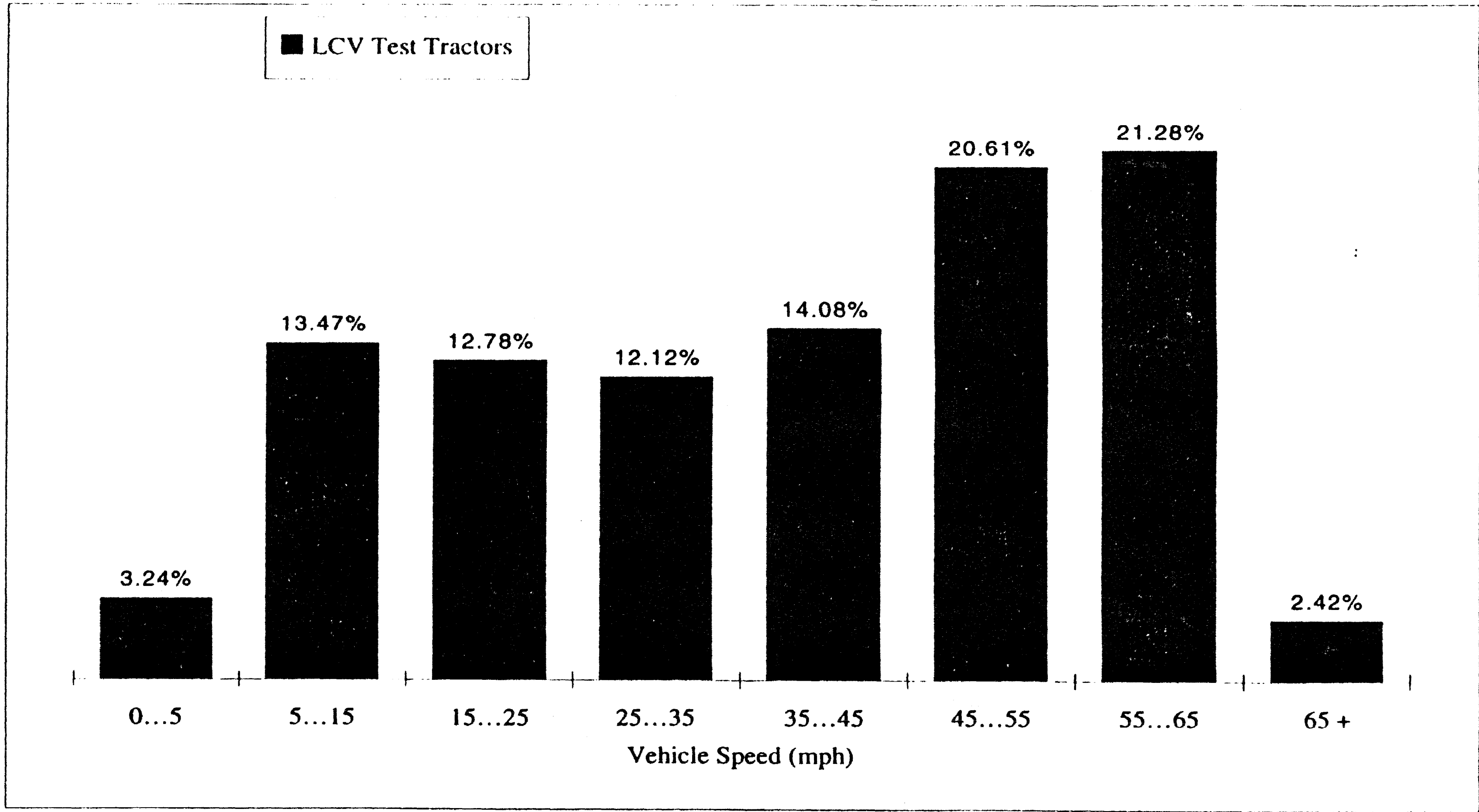

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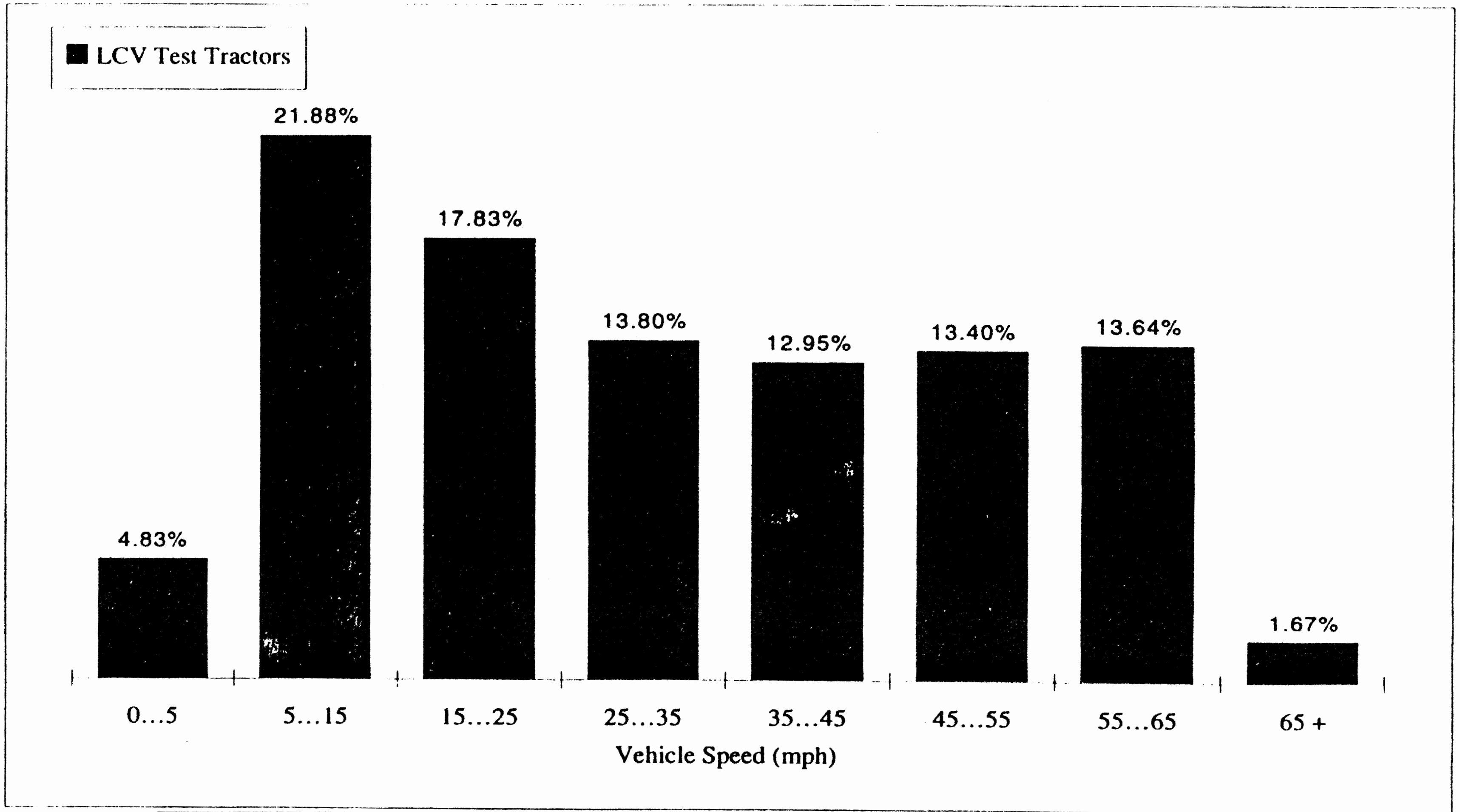

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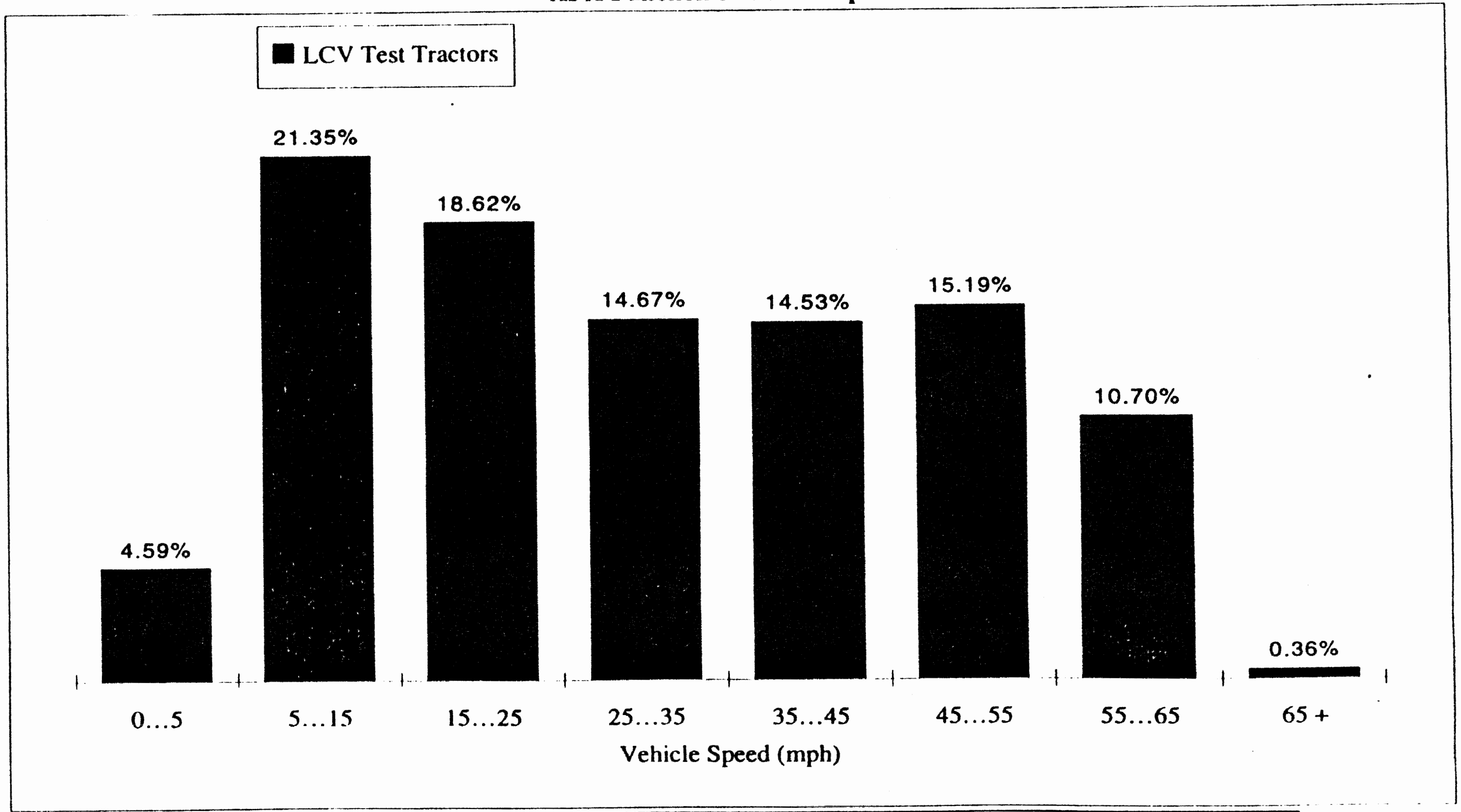

Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Reverse Rocky	Total braking time (hrs):	4
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Number of historgrams:	27	Percent of time braking:	2.21%

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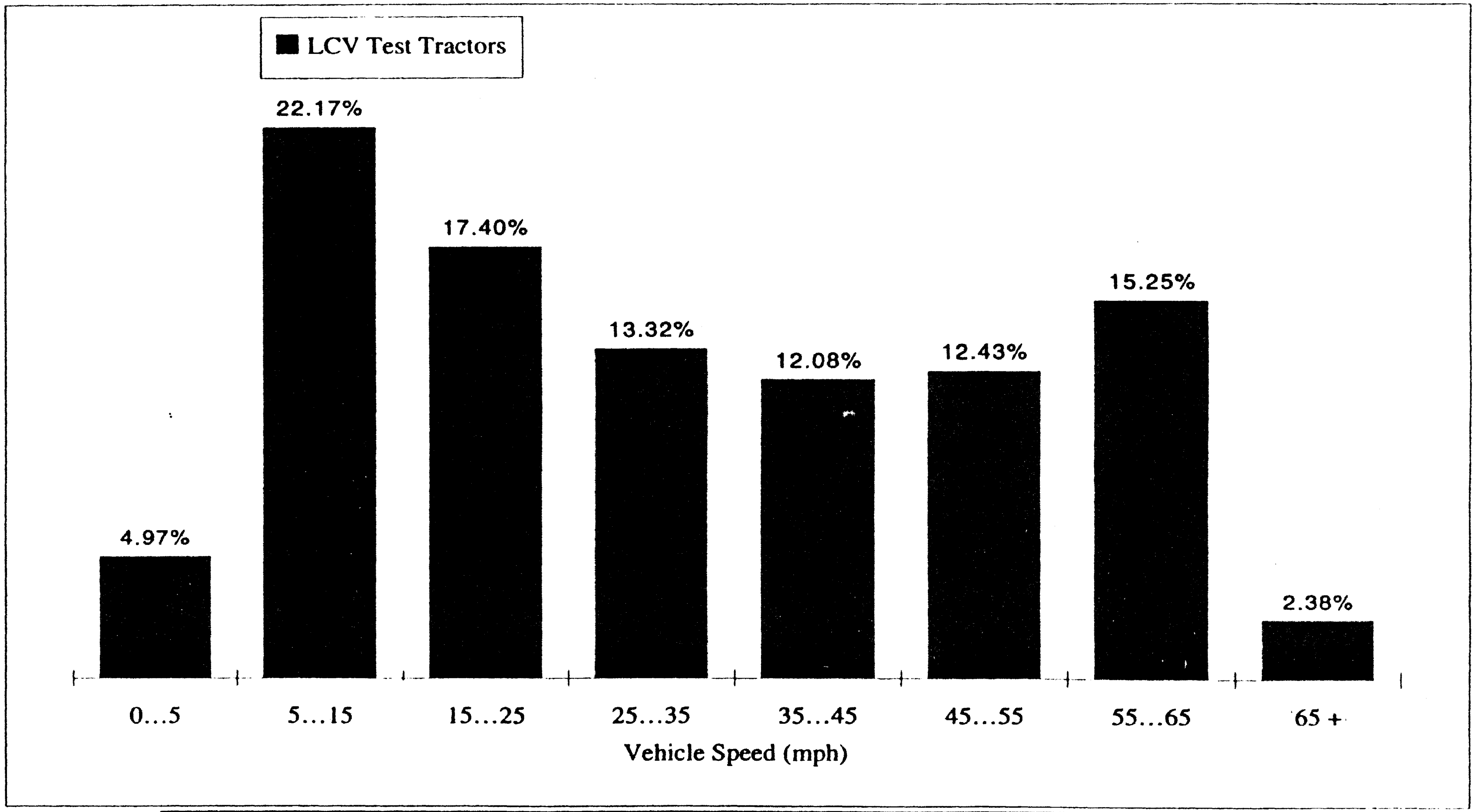


Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	Reverse Rocky	Total braking time (hrs):	7
Vehicle Load Condition:	Full	Total time (hrs):	243
Number of historgrams:	34	Percent of time braking:	3.01%

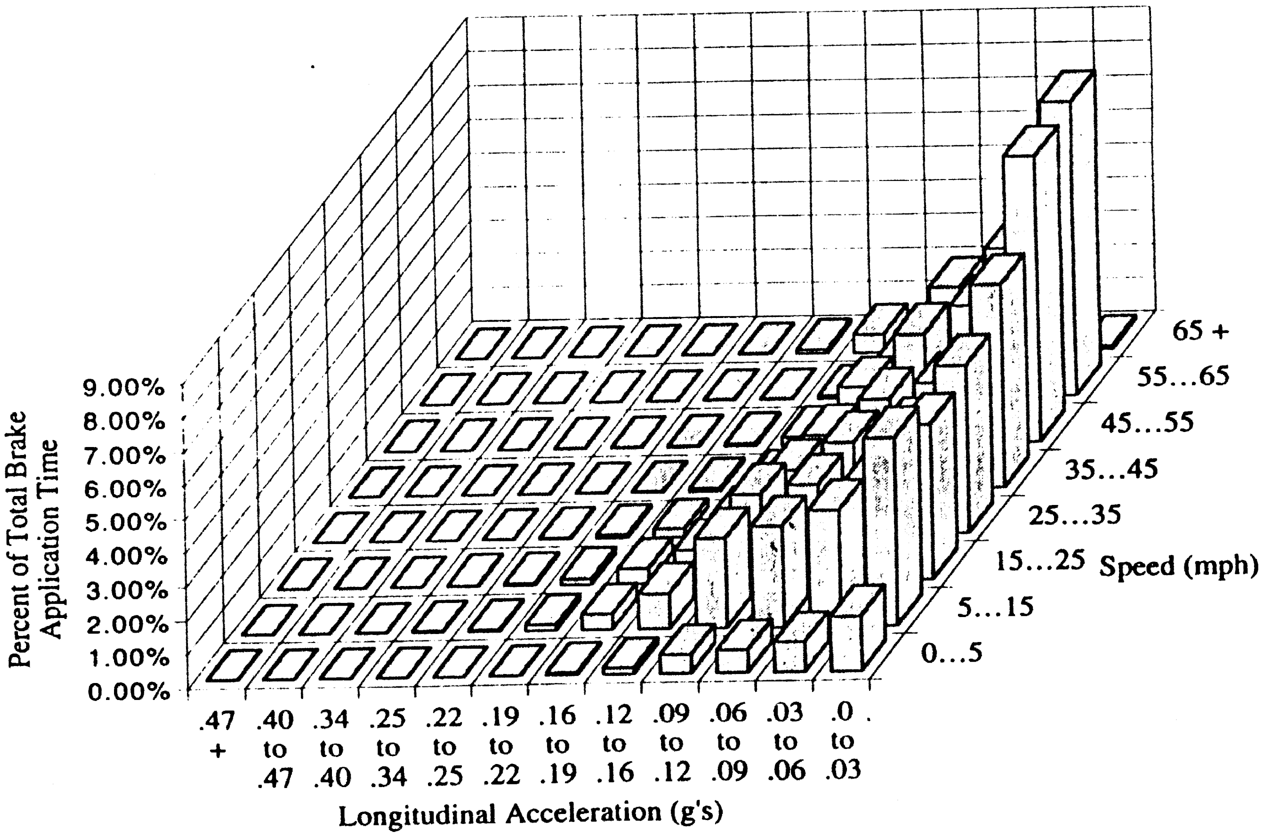
APPENDIX J

LONGITUDINAL ACCELERATION HISTOGRAMS

This appendix presents histograms of brake application time as functions of longitudinal acceleration and vehicle speed, segregated for different vehicle configurations and load conditions.

Table of Contents:

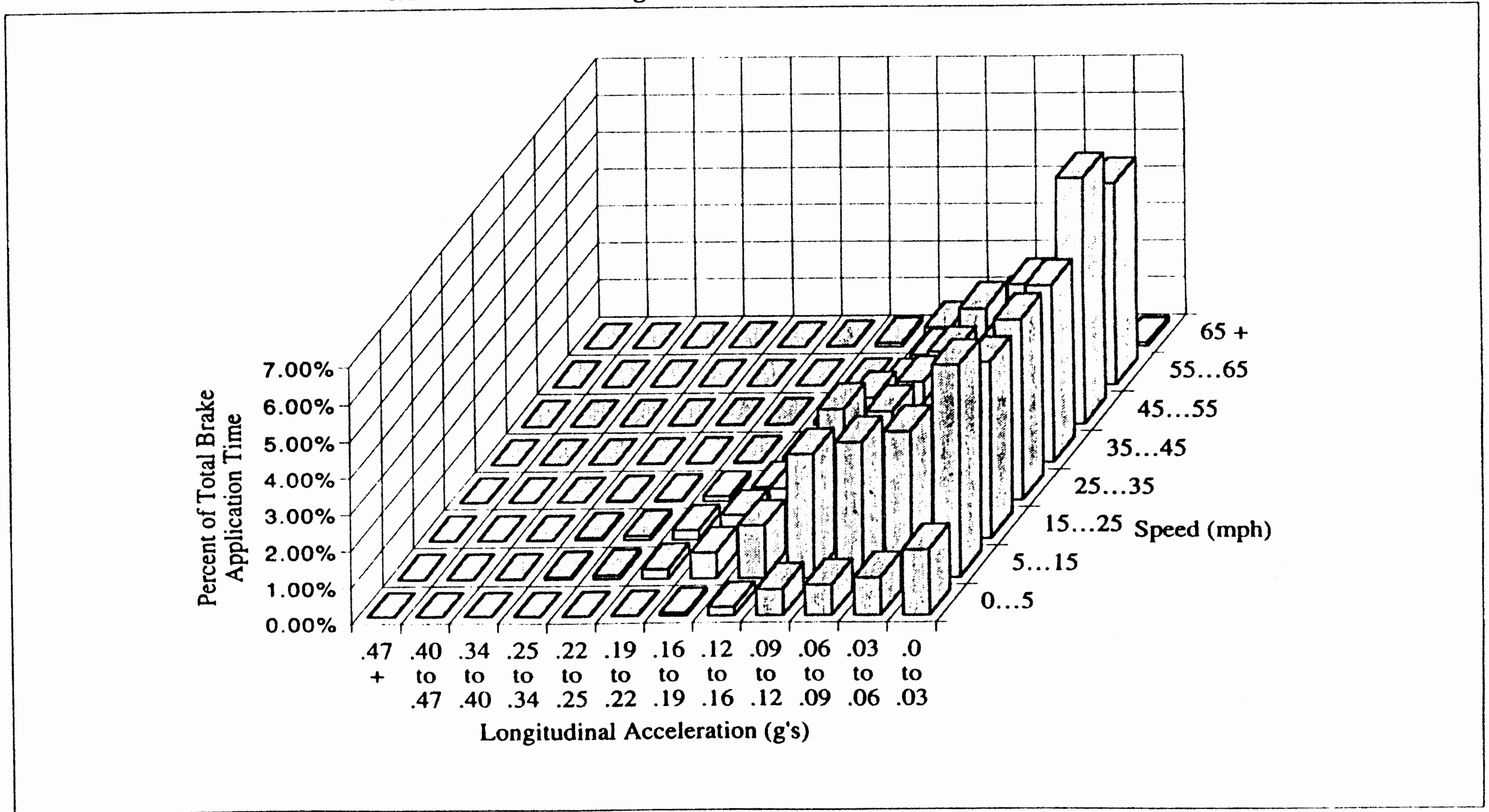
Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	179
Vehicle Load Condition:	All	Total time (hrs):	6088
Number of histograms:	759	Percent of time braking:	2.94%

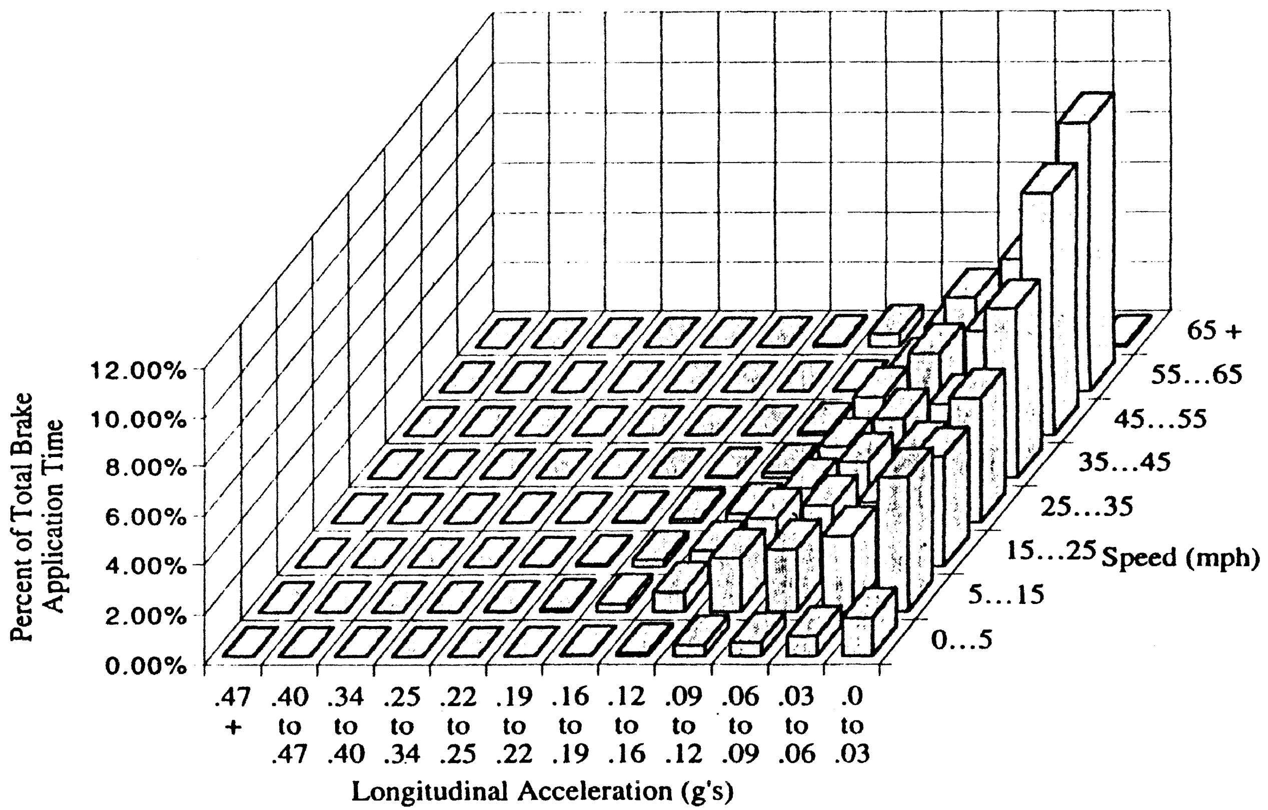
Distribution of Brake Application Time for the LCV Study Fleet

As A Function of Longitudinal Acceleration and Vehicle Speed



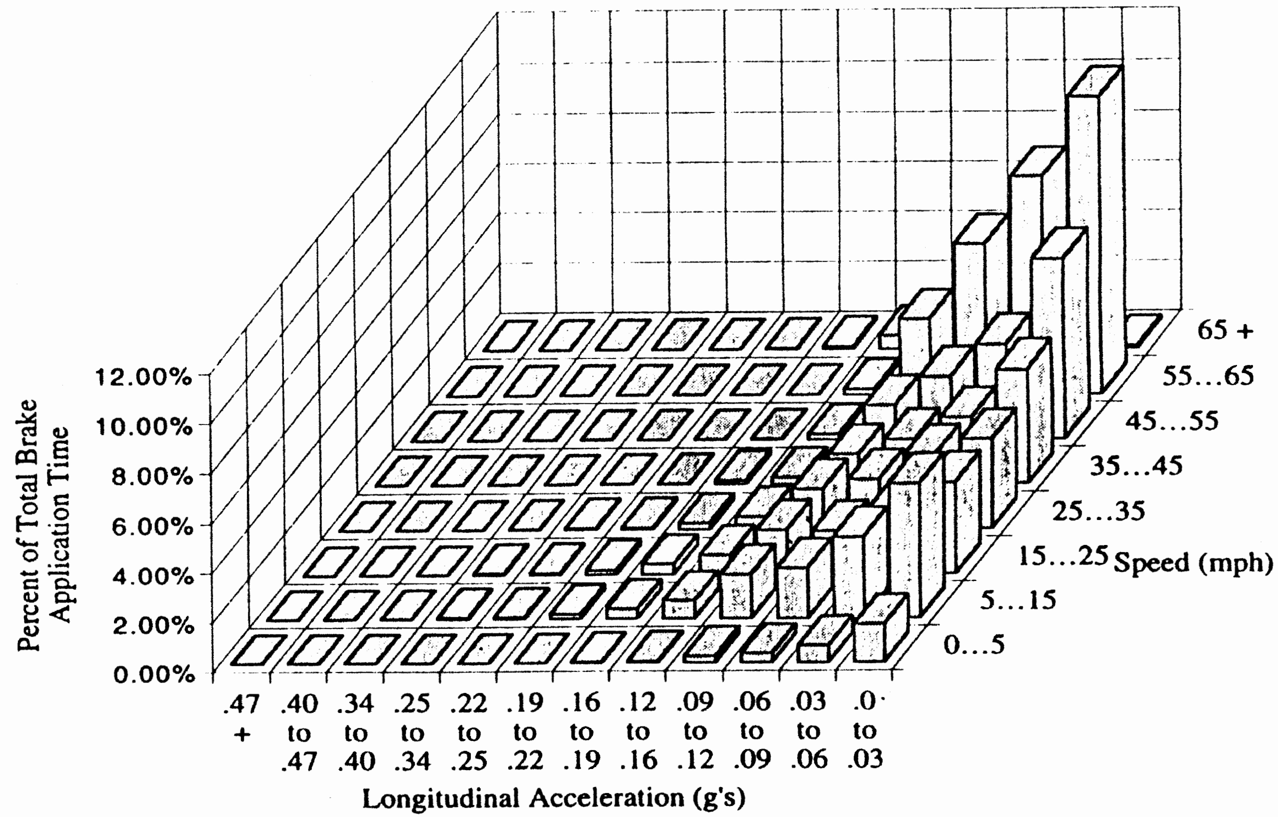
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	72
Vehicle Load Condition:	Empty	Total time (hrs):	2576
Number of historgrams:	317	Percent of time braking:	2.80%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



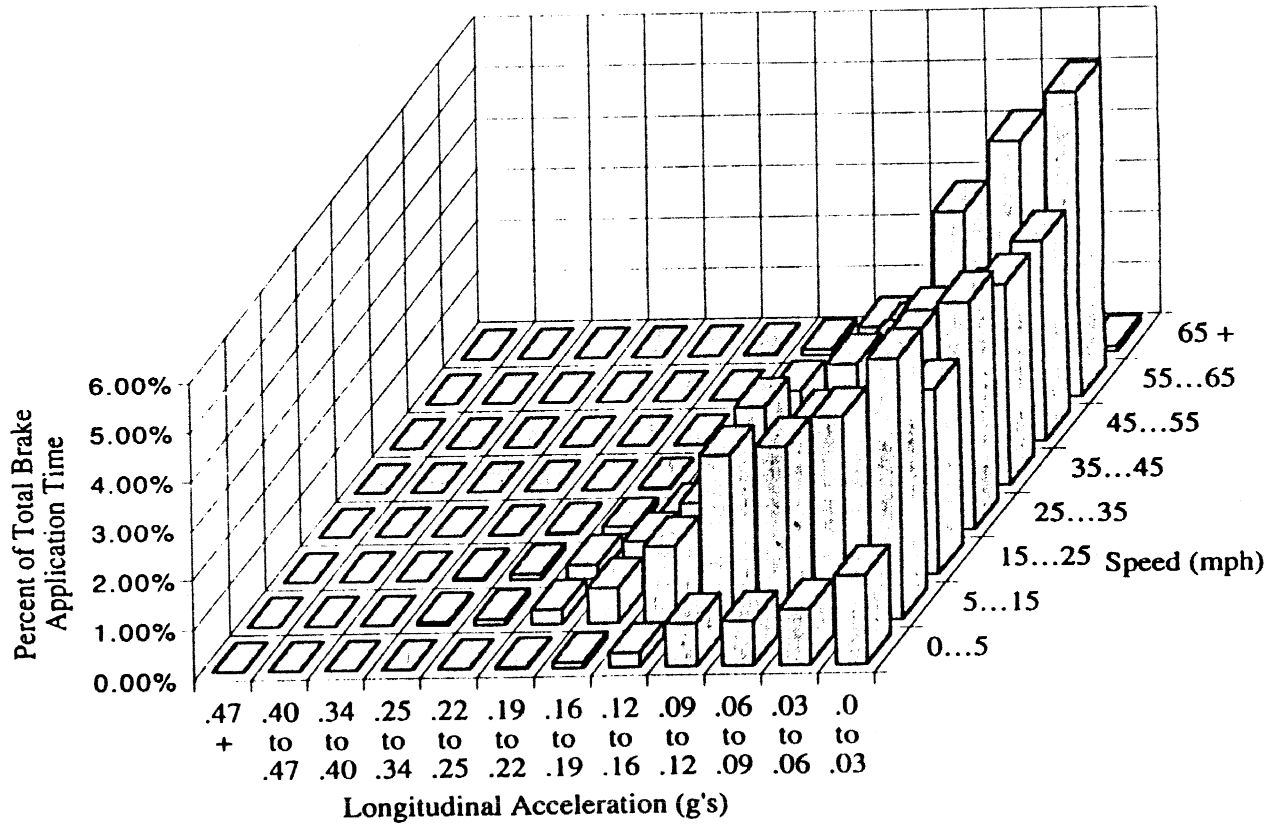
Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	101
Vehicle Load Condition:	Full	Total time (hrs):	3172
Number of historgrams:	394	Percent of time braking:	3.18%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



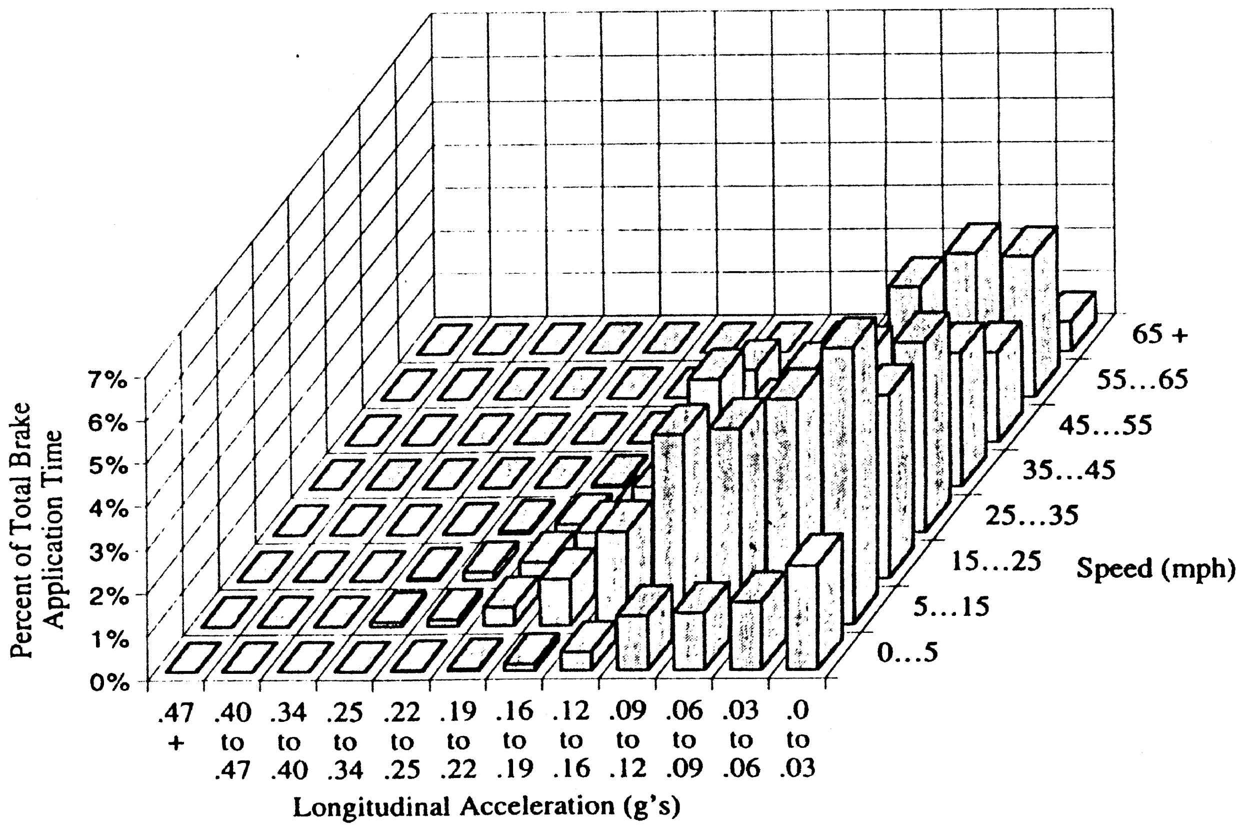
Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	6
Vehicle Load Condition:	Mixed	Total time (hrs):	340
Number of historgrams:	48	Percent of time braking:	1.80%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



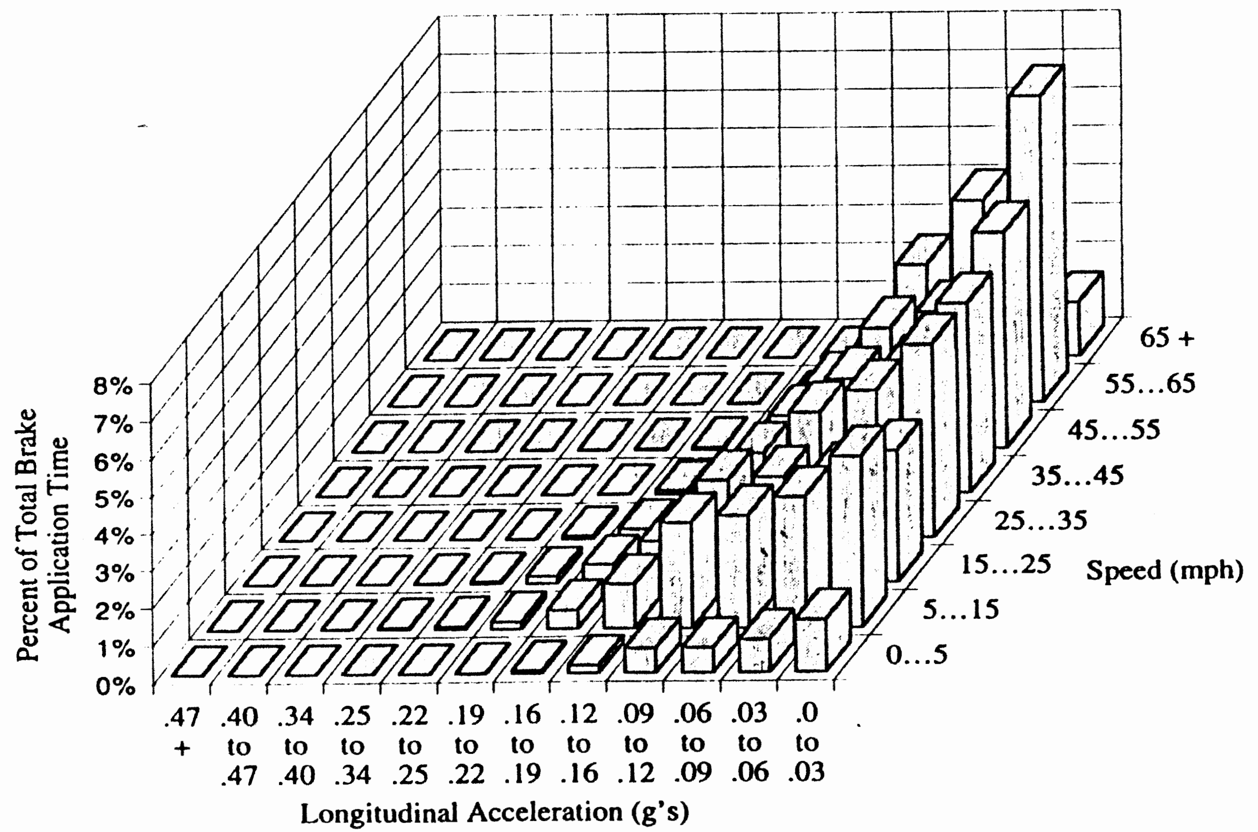
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Triple	Total braking time (hrs):	38
Vehicle Load Condition:	All	Total time (hrs):	1674
Number of historgrams:	197	Percent of time braking:	2.24%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



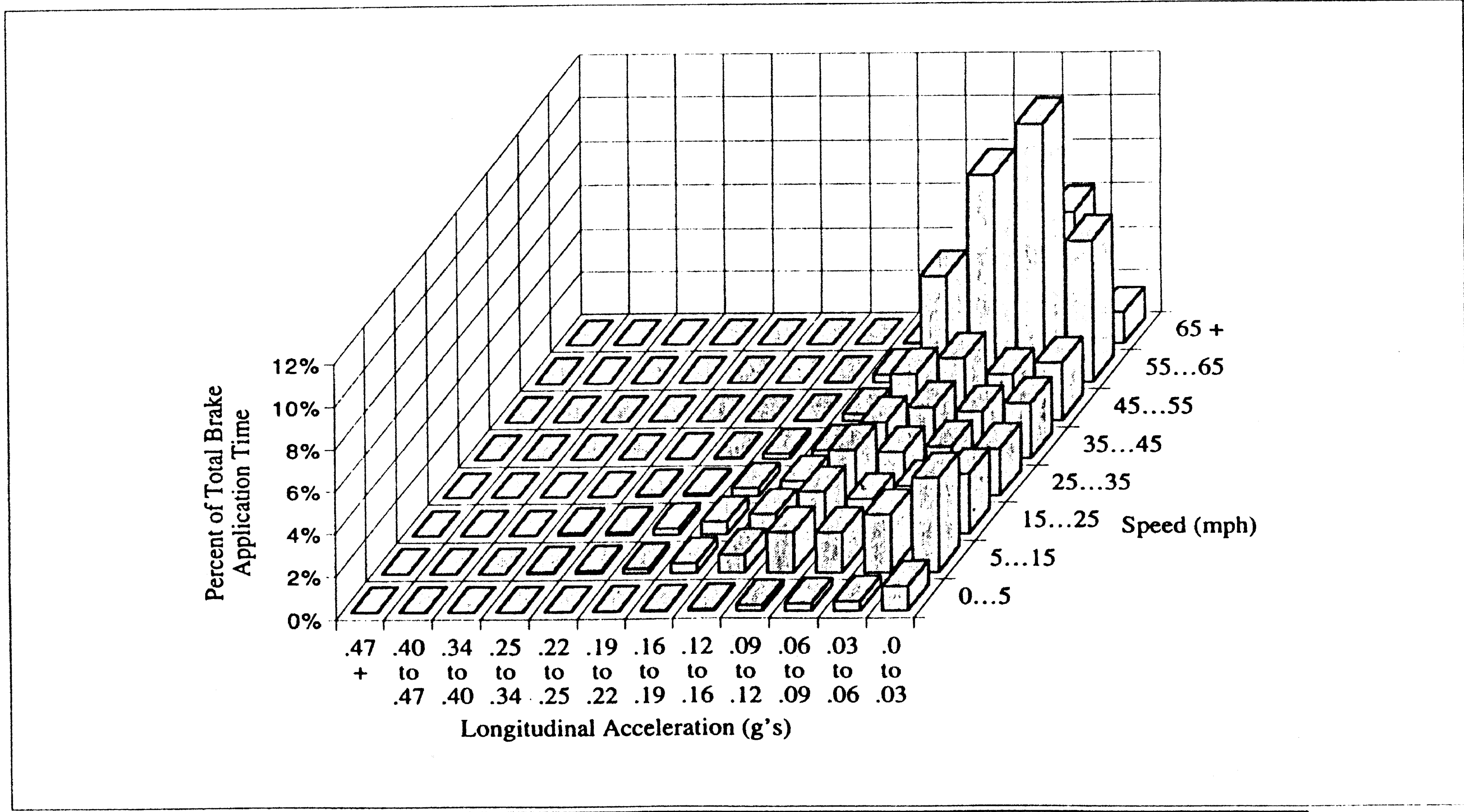
Results are based on the following:			Date: 10-May-95
Vehicle Configuration	Triple	Total braking time (hrs):	15
Vehicle Load Condition	Empty	Total time (hrs):	636
Number of historgrams:	73	Percent of time braking:	2.34%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



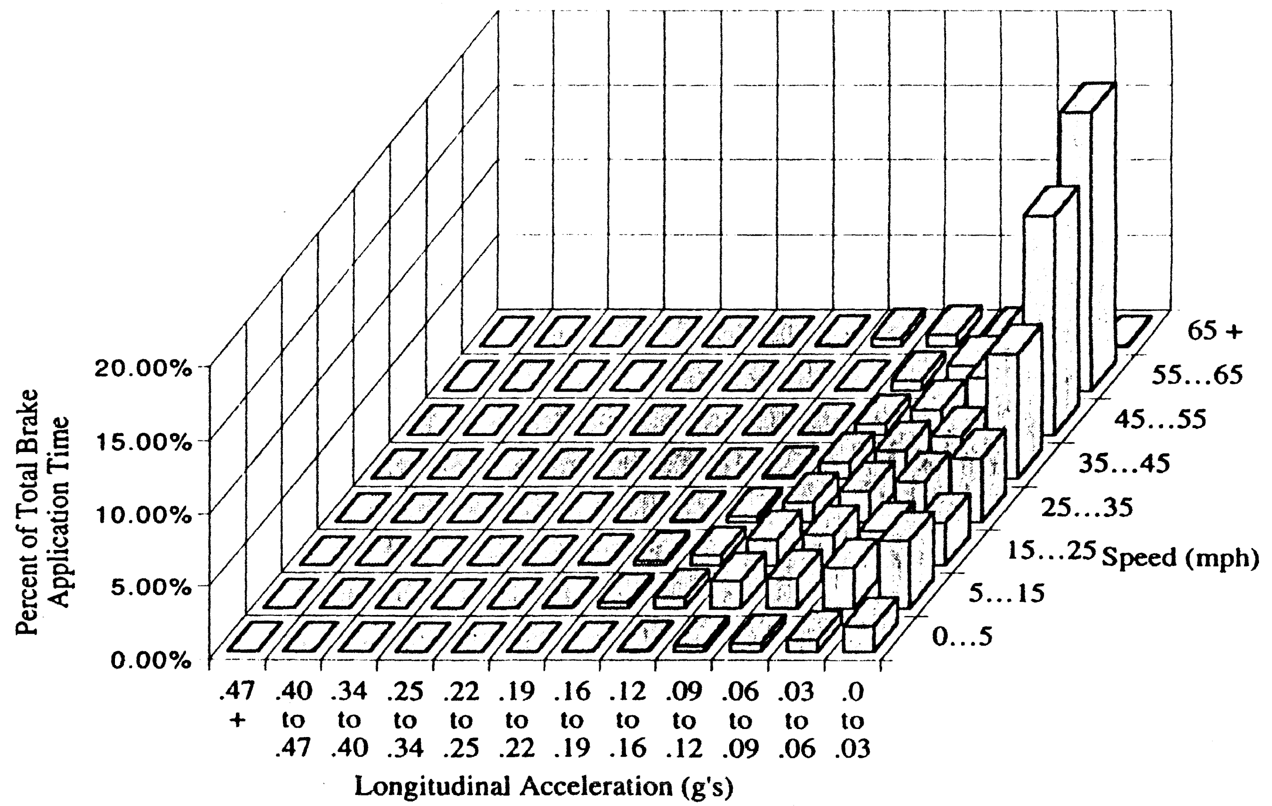
Results are based on the following:		Date:	10-May-95
Vehicle Configuration	Triple	Total braking time (hrs):	20
Vehicle Load Condition	Full	Total time (hrs):	831
Number of historgrams:	97	Percent of time braking:	2.35%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



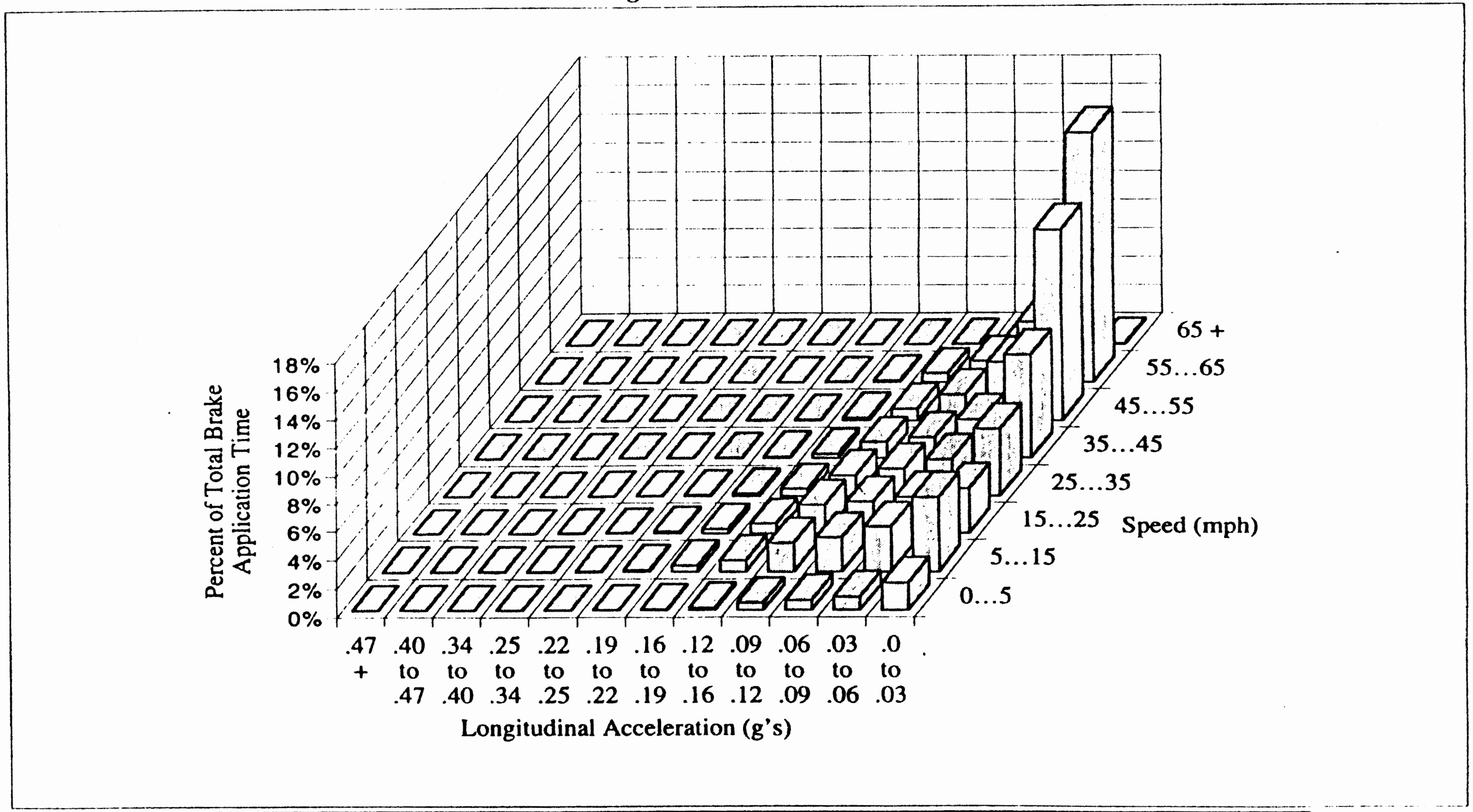
Results are based on the following:		Date:	10-May-95
Vehicle Configuration	Triple	Total braking time (hrs):	3
Vehicle Load Condition	Mixed	Total time (hrs):	207
Number of historgrams:	27	Percent of time braking:	1.50%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



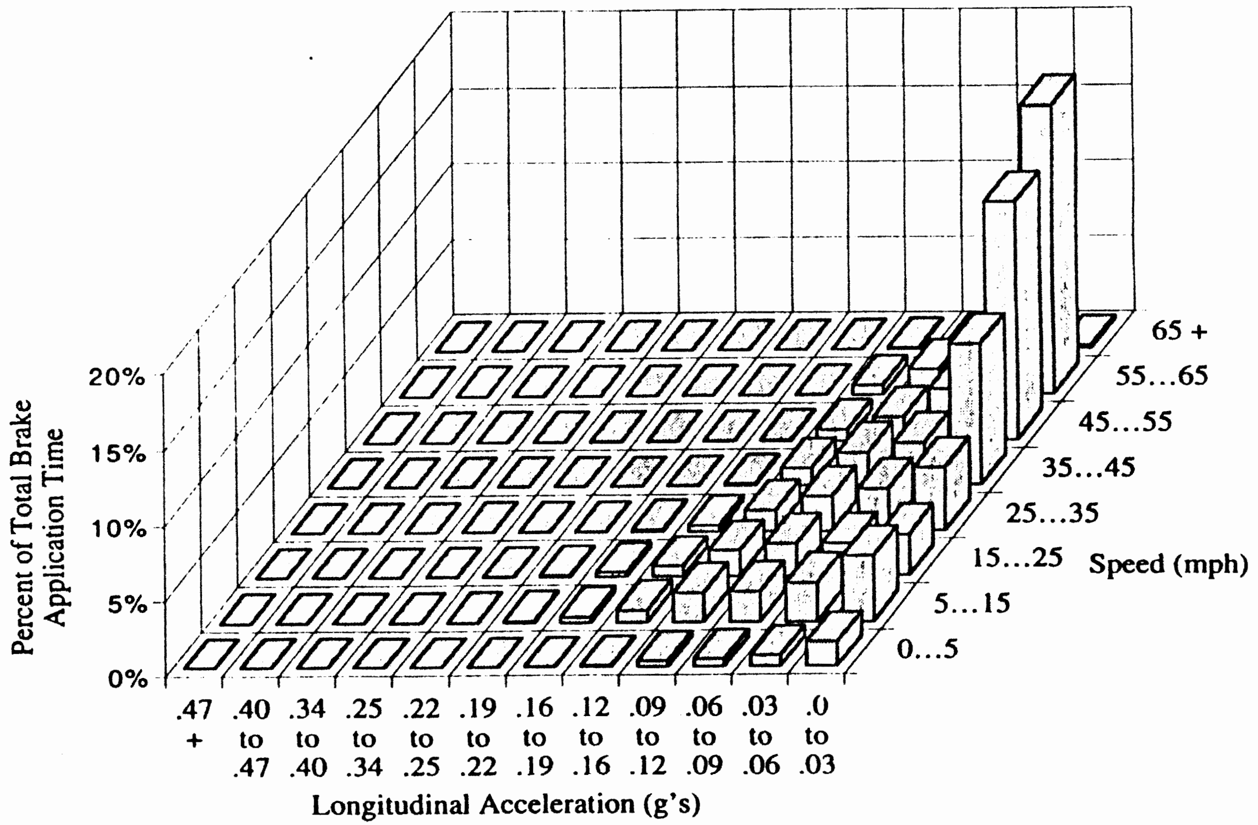
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Double	Total braking time (hrs):	29
Vehicle Load Condition:	All	Total time (hrs):	1034
Number of historgrams:	151	Percent of time braking:	2.80%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



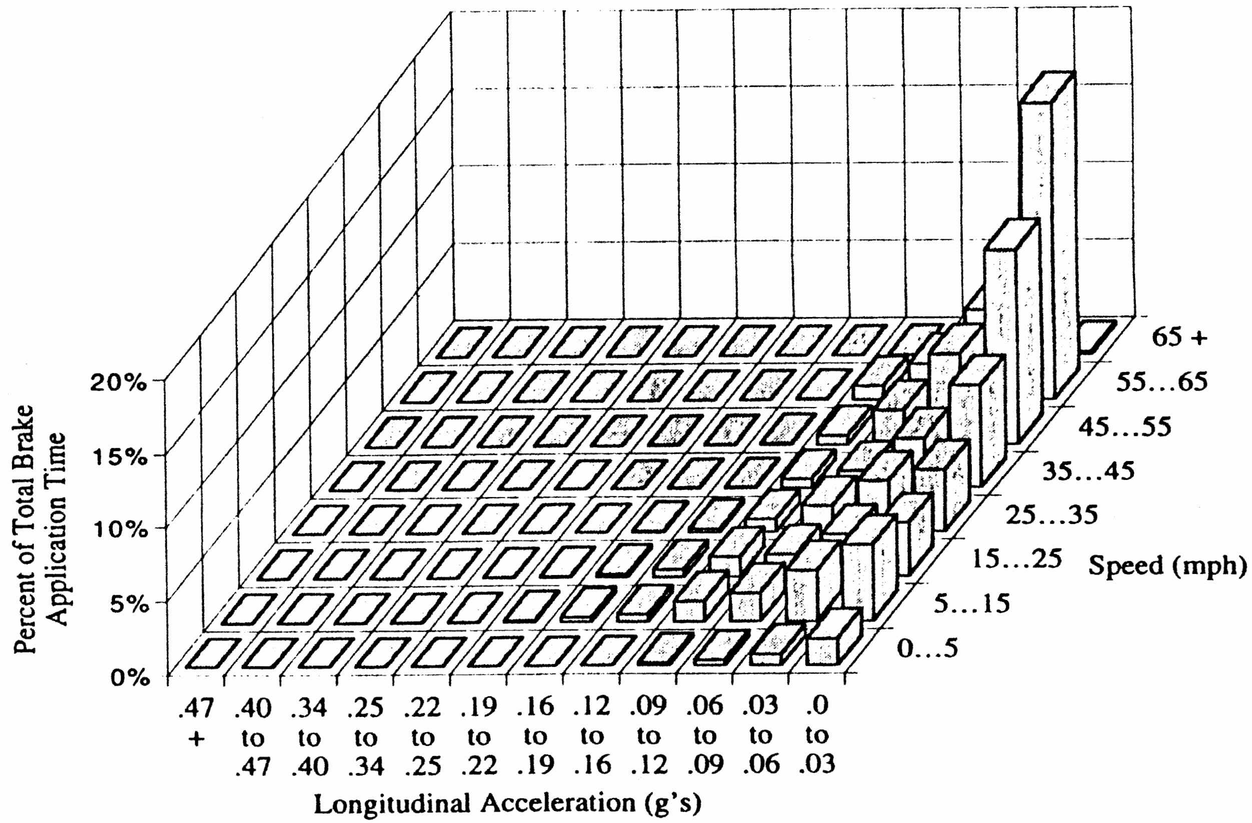
Results are based on the following:			Date: 10-May-95
Vehicle Configuration	Double	Total braking time (hrs):	9
Vehicle Load Condition	Empty	Total time (hrs):	385
Number of historgrams:	60	Percent of time braking:	2.37%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



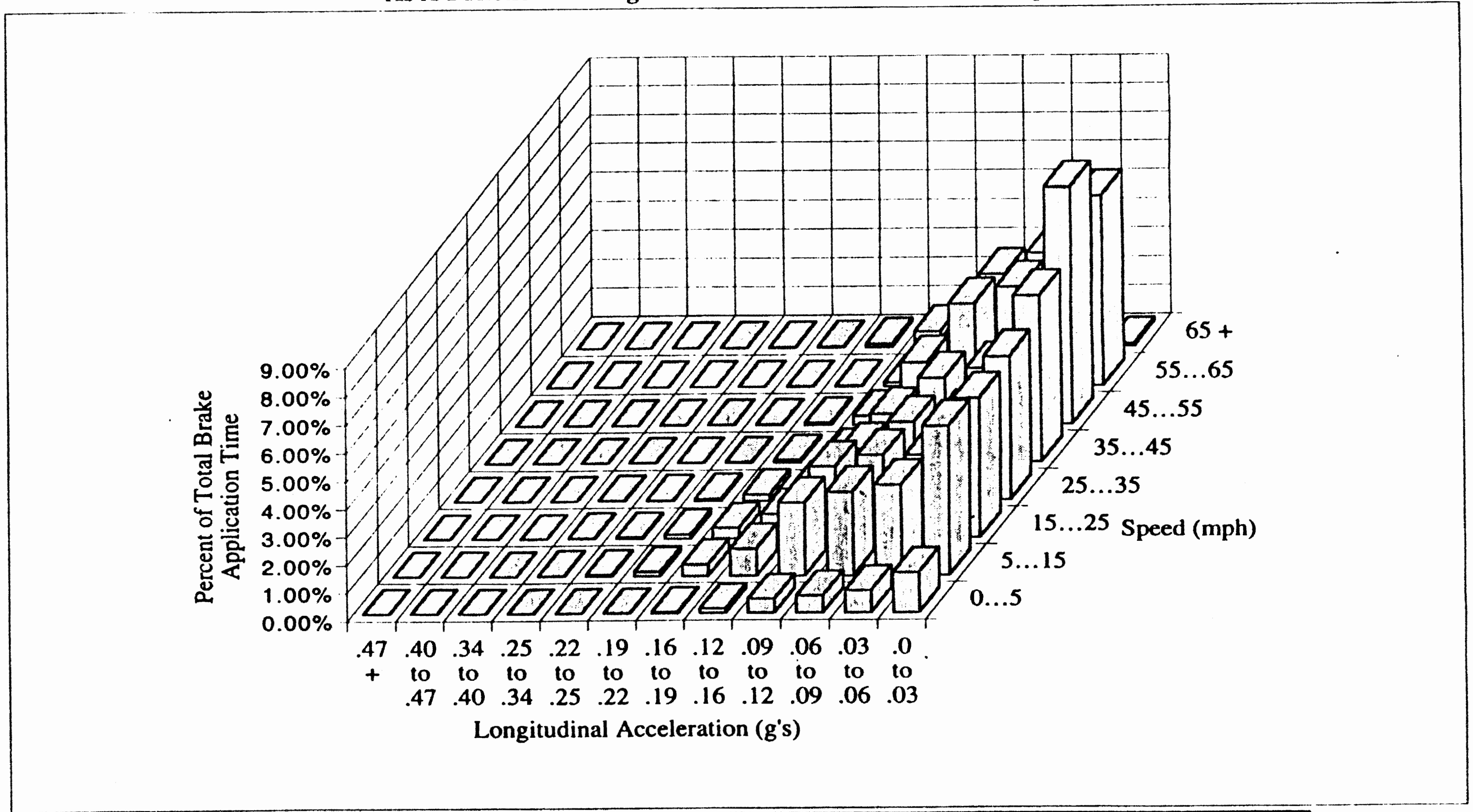
Results are based on the following:		Date:	10-May-95
Vehicle Configuration	Double	Total braking time (hrs):	17
Vehicle Load Condition	Full	Total time (hrs):	536
Number of historgrams:	73	Percent of time braking:	3.21%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



Results are based on the following:		Date:	10-May-95
Vehicle Configuration	Double	Total braking time (hrs):	3
Vehicle Load Condition	Mixed	Total time (hrs):	112
Number of historgrams:	18	Percent of time braking:	2.32%

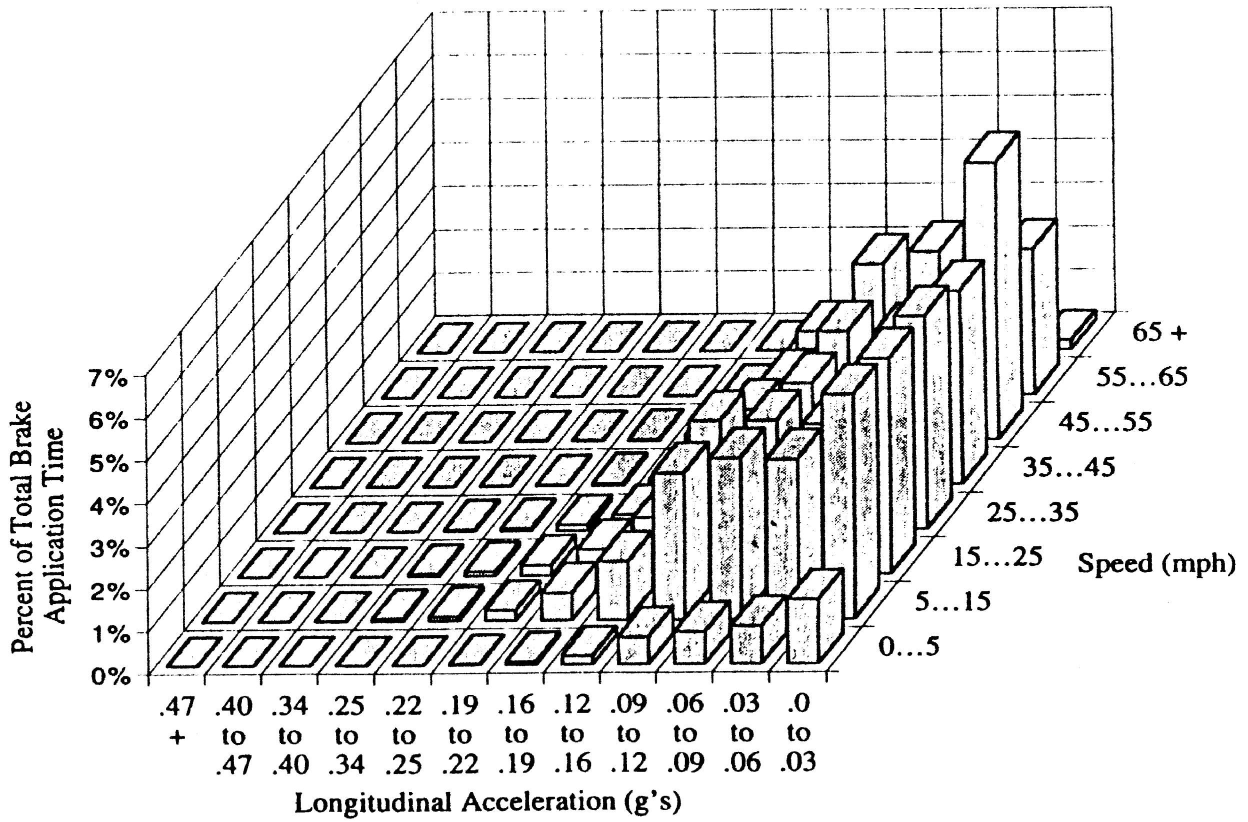
Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Rocky	Total braking time (hrs):	101
Vehicle Load Condition:	All	Total time (hrs):	2956
Number of historgrams:	350	Percent of time braking:	3.43%

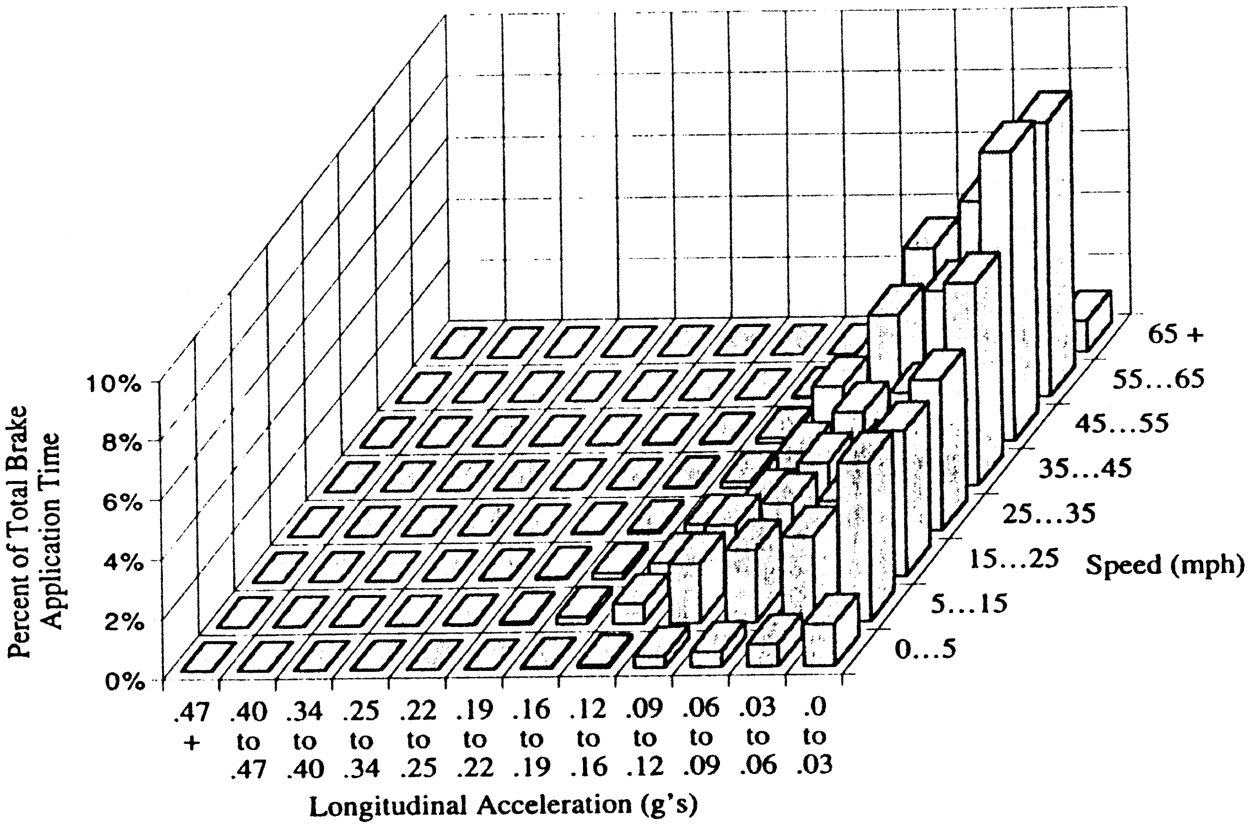
Distribution of Brake Application Time for the LCV Study Fleet

As A Function of Longitudinal Acceleration and Vehicle Speed



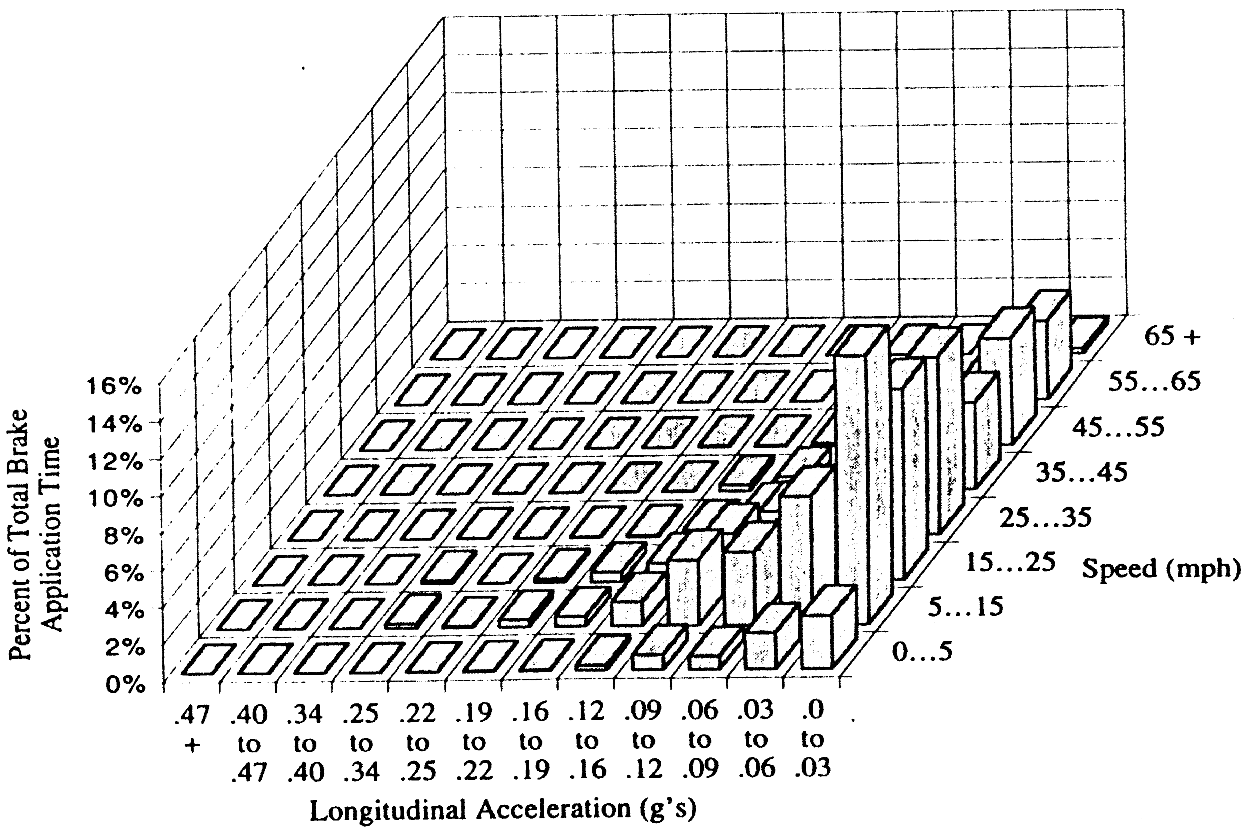
Results are based on the following:			Date: 10-May-95
Vehicle Configuration	Rocky	Total braking time (hrs):	44
Vehicle Load Condition	Empty	Total time (hrs):	1374
Number of historgrams:	157	Percent of time braking:	3.21%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



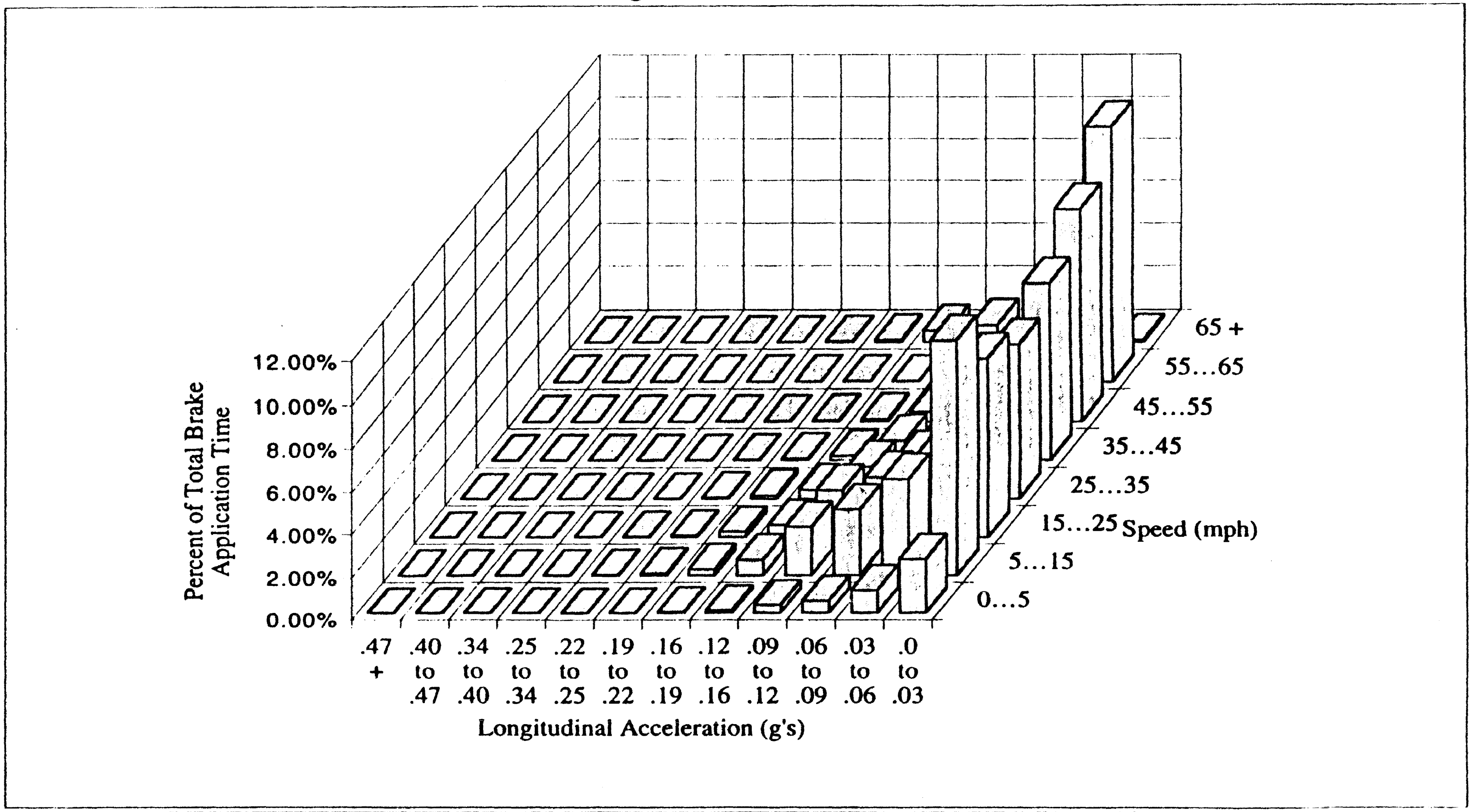
Results are based on the following:		Date:	10-May-95
Vehicle Configuration	Rocky	Total braking time (hrs):	57
Vehicle Load Condition	Full	Total time (hrs):	1562
Number of historgrams:	190	Percent of time braking:	3.63%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



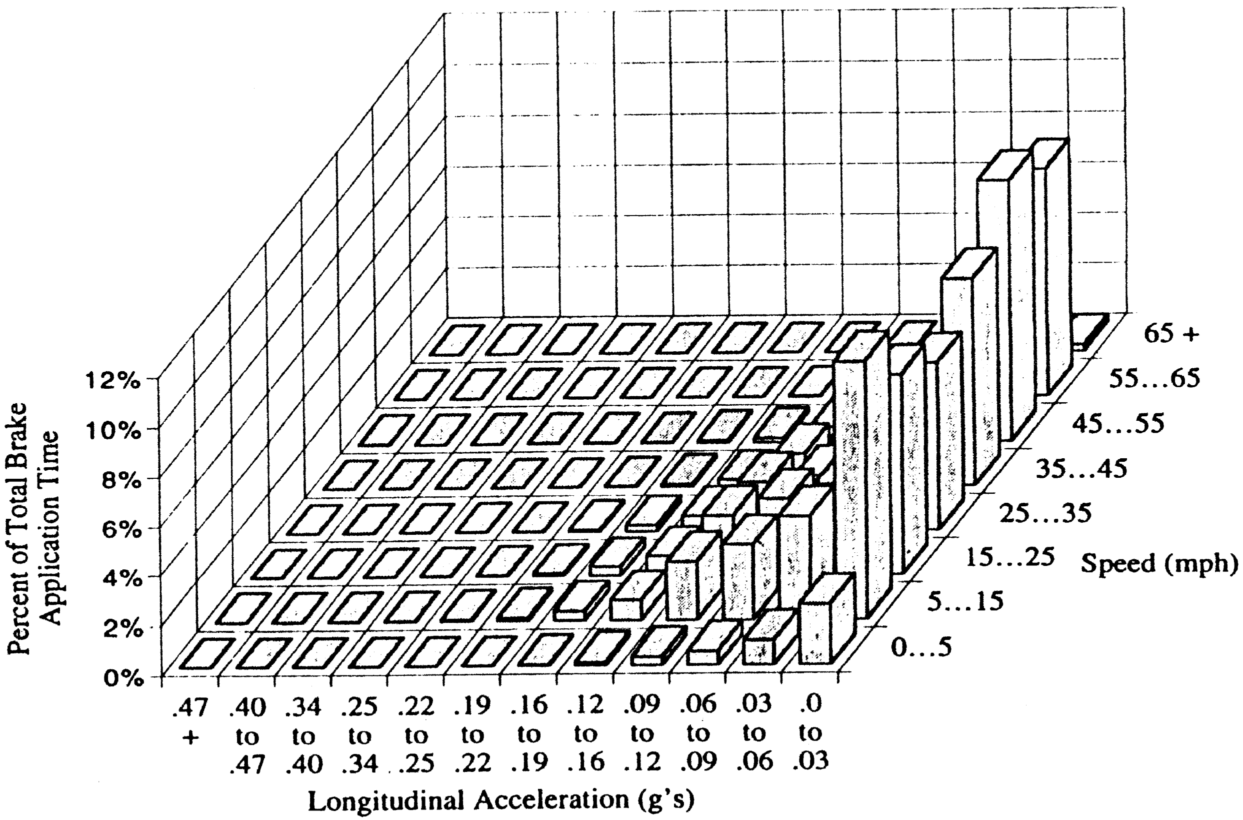
Results are based on the following:		Date:	10-May-95
Vehicle Configuration	Rocky	Total braking time (hrs):	0
Vehicle Load Condition	Mixed	Total time (hrs):	20
Number of historgrams:	3	Percent of time braking:	2.03%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



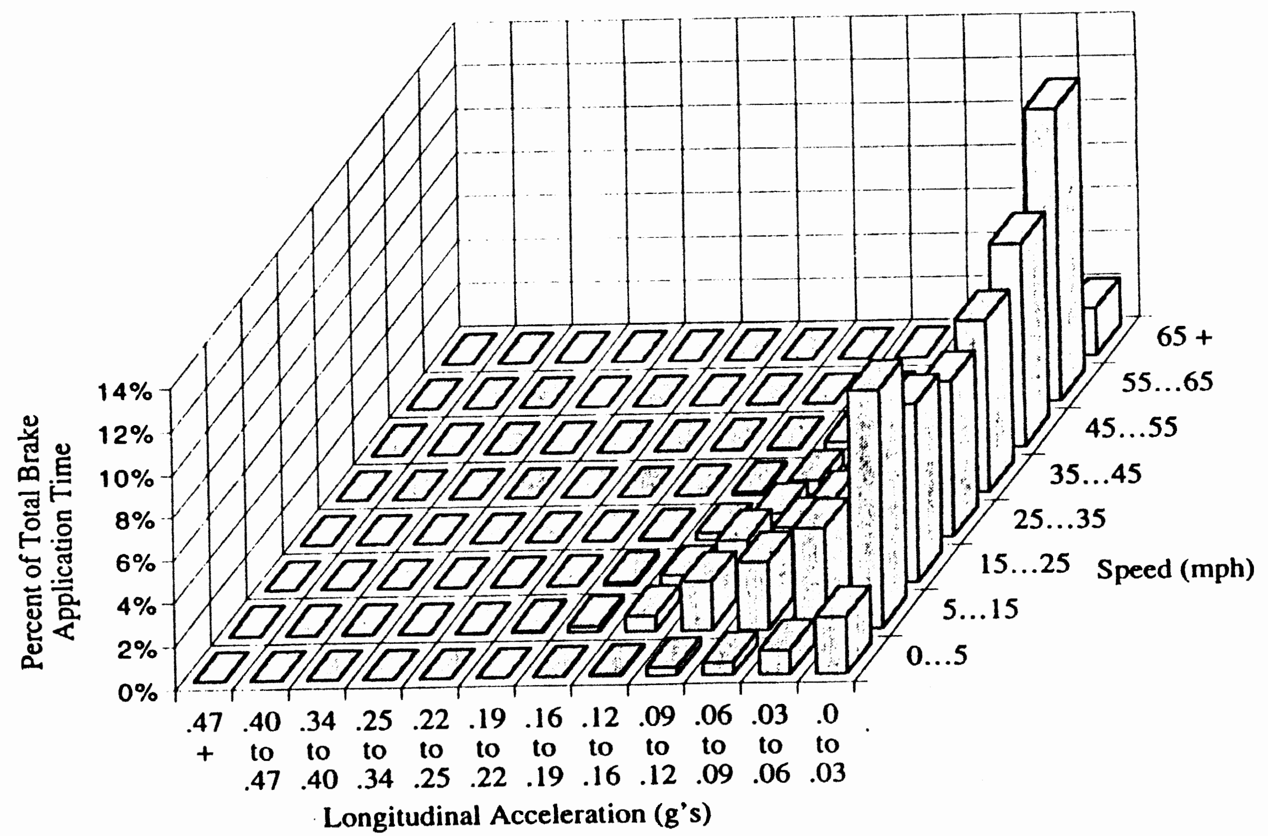
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Reverse	Total braking time (hrs):	11
Vehicle Load Condition:	All	Total time (hrs):	425
Number of historgrams:	61	Percent of time braking:	2.67%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



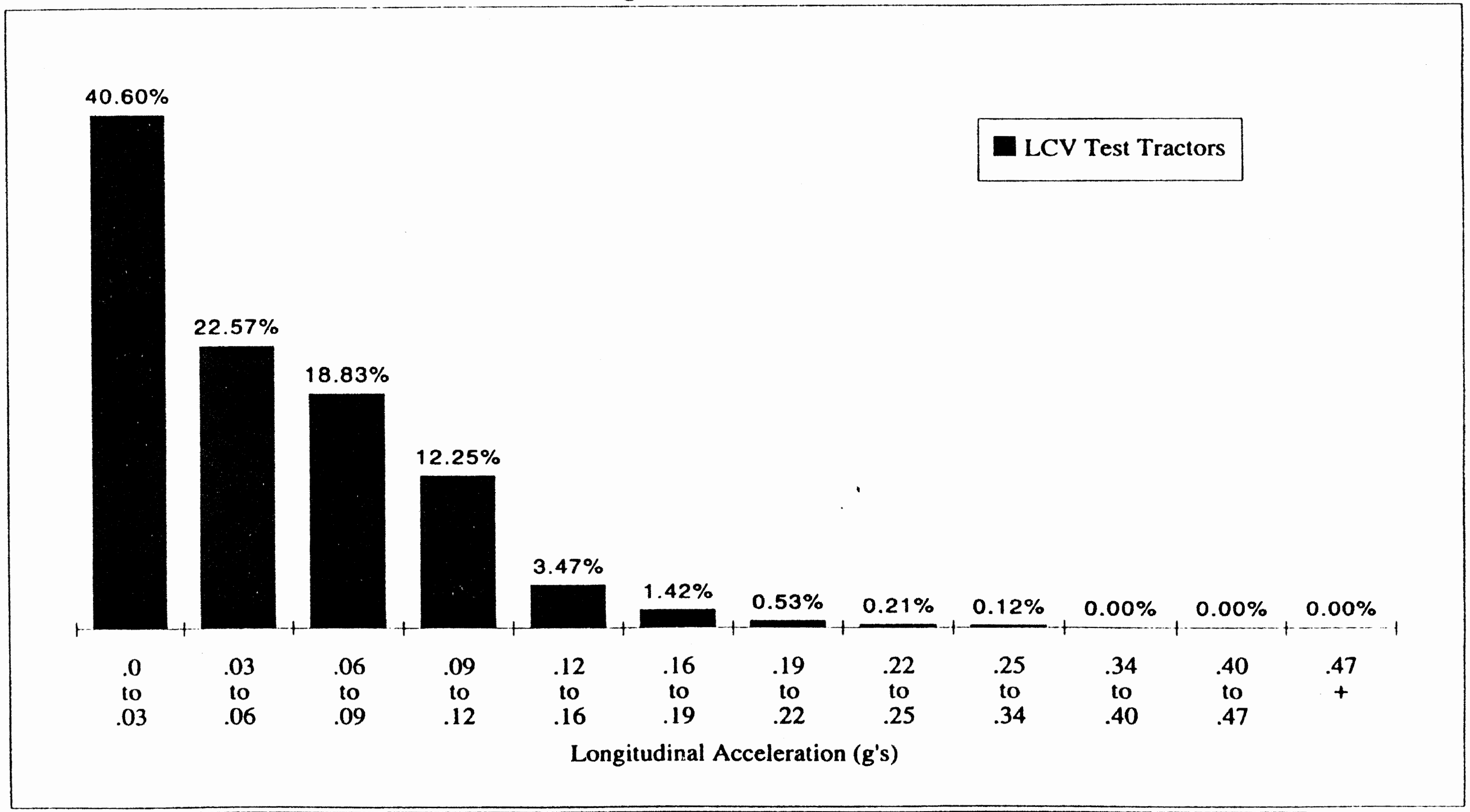
Results are based on the following:			Date: 10-May-95
Vehicle Configuration	Reverse	Total braking time (hrs):	4
Vehicle Load Condition	Empty	Total time (hrs):	181
Number of historgrams:	27	Percent of time braking:	2.21%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



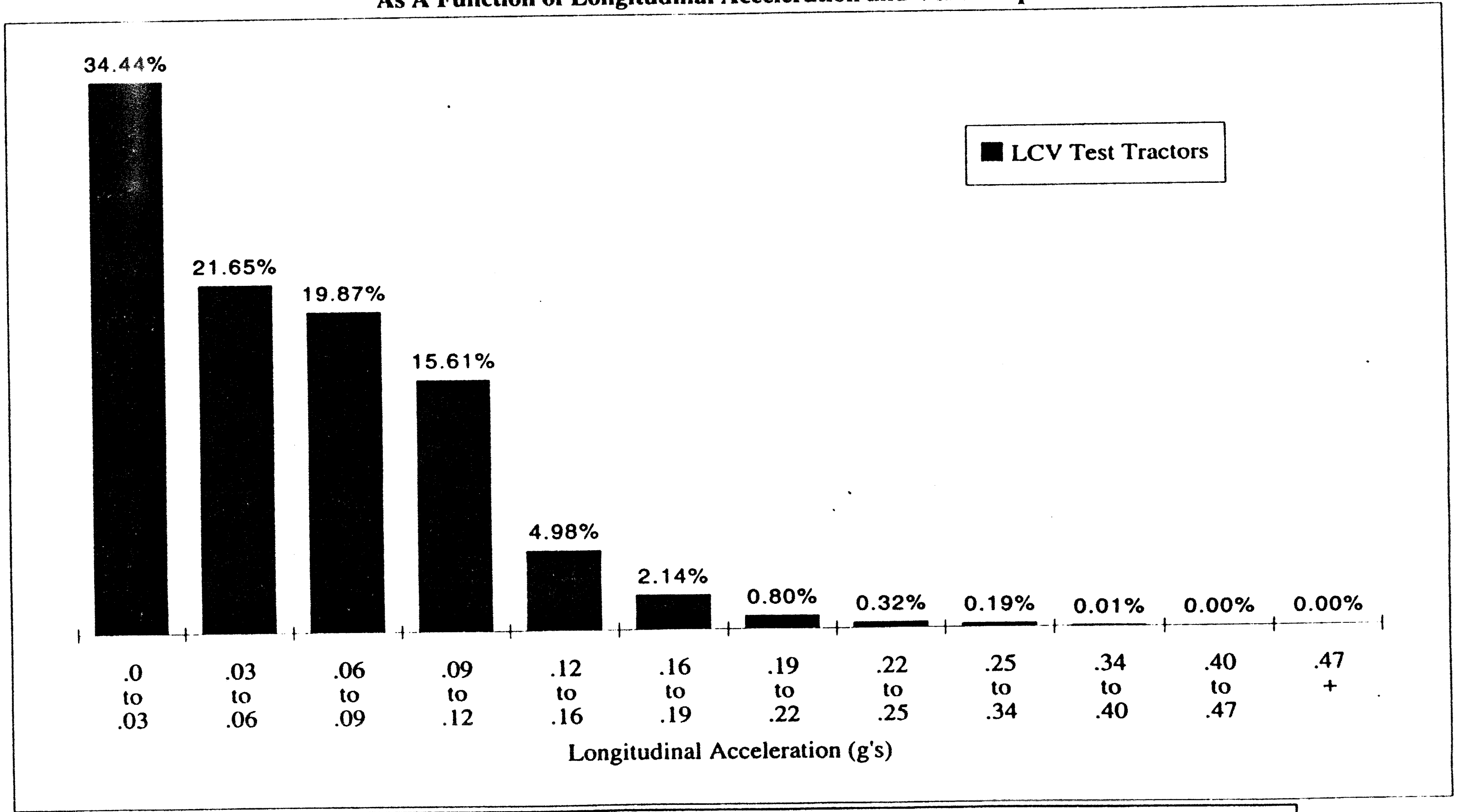
Results are based on the following:			Date: 10-May-95
Vehicle Configuration	Reverse	Total braking time (hrs):	7
Vehicle Load Condition	Full	Total time (hrs):	243
Number of historgrams:	34	Percent of time braking:	3.01%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



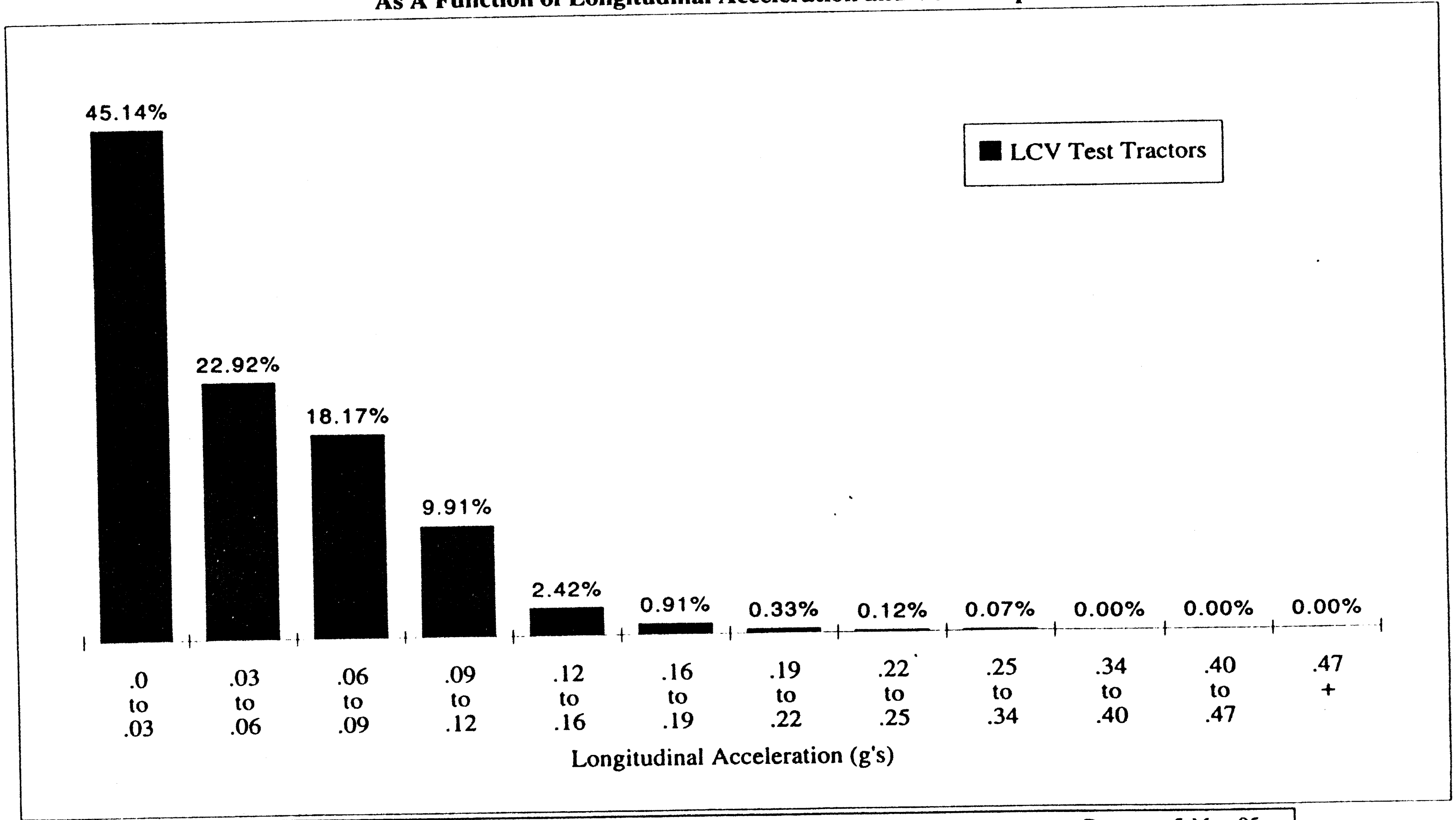
Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	179
Vehicle Load Condition:	All	Total time (hrs):	6088
Number of histograms:	759	Percent of time braking:	2.94%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	72
Vehicle Load Condition:	Empty	Total time (hrs):	2576
Number of historgrams:	317	Percent of time braking:	2.80%

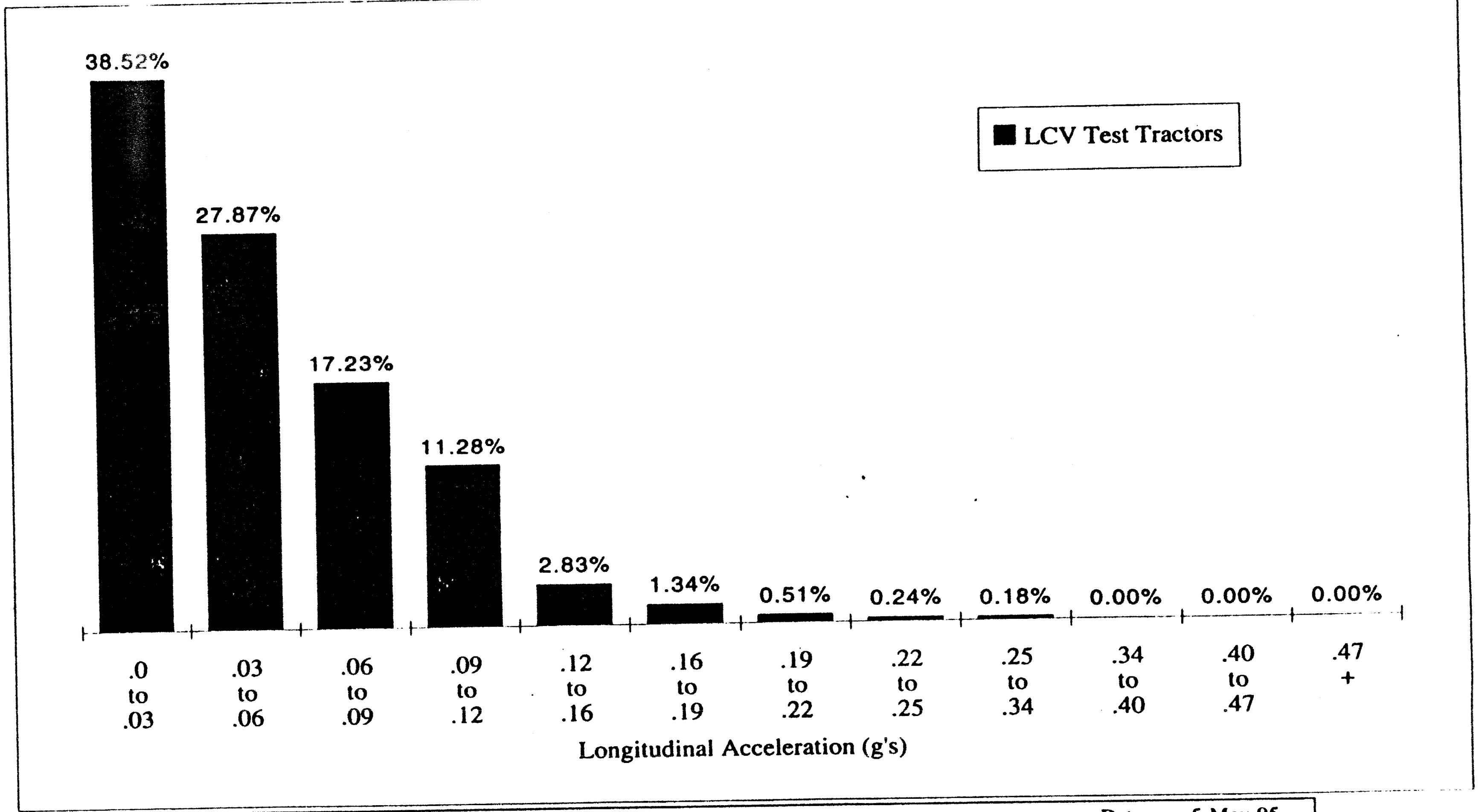
Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	101
Vehicle Load Condition:	Full	Total time (hrs):	3172
Number of historgrams:	394	Percent of time braking:	3.18%

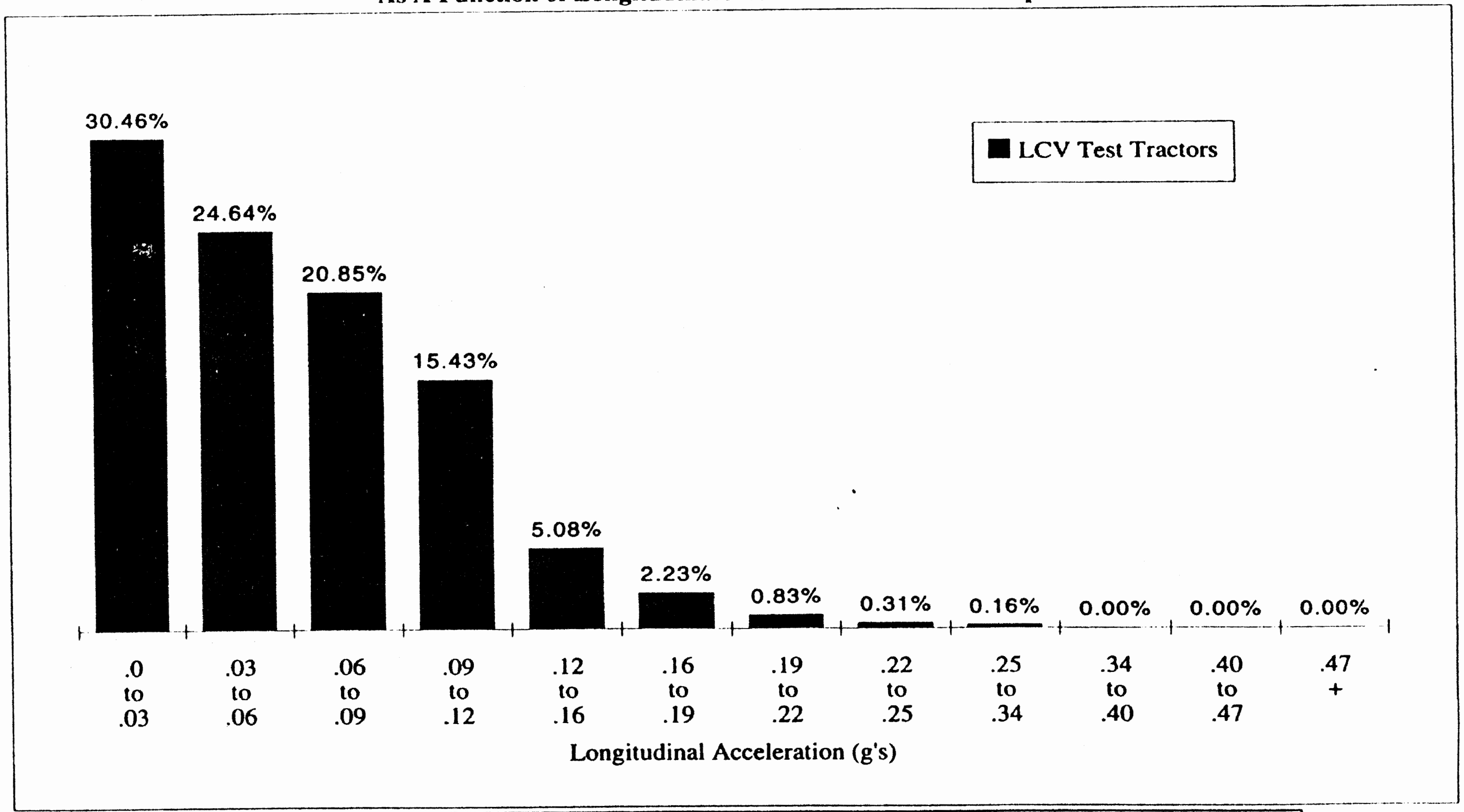
Distribution of Brake Application Time for the LCV Study Fleet

As A Function of Longitudinal Acceleration and Vehicle Speed



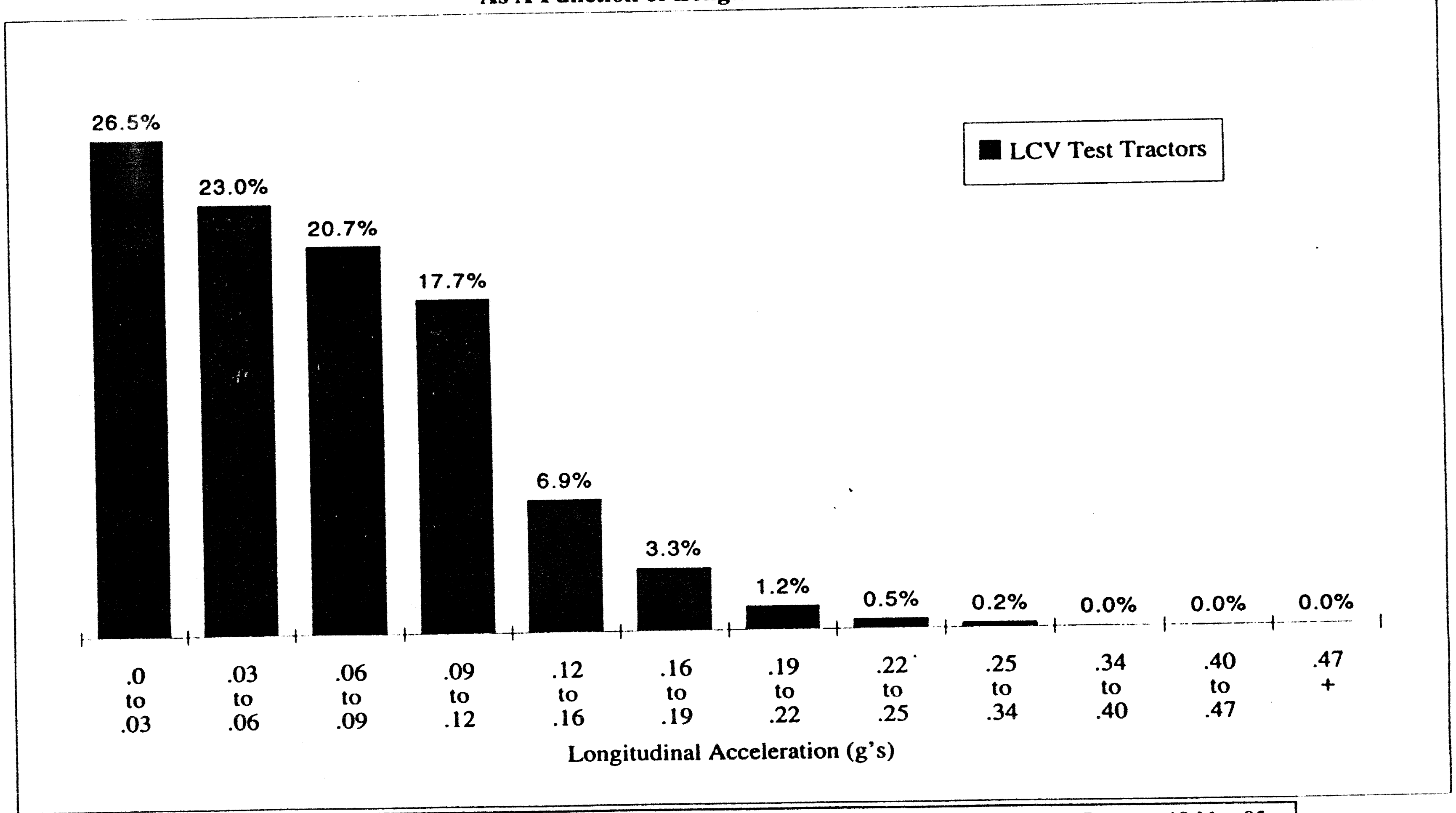
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	All	Total braking time (hrs):	6
Vehicle Load Condition:	Mixed	Total time (hrs):	340
Number of historgrams:	48	Percent of time braking:	1.80%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



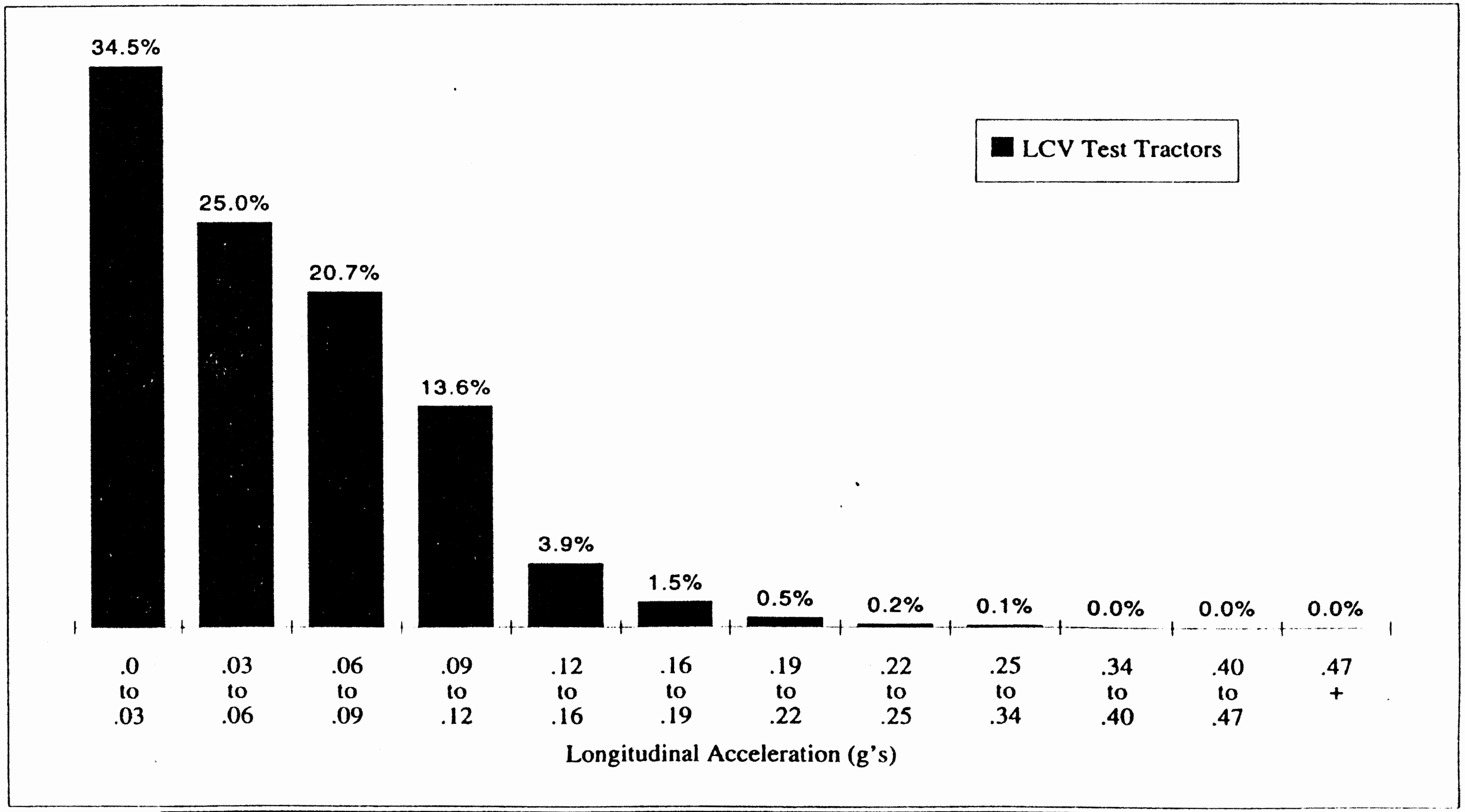
Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	Triple	Total braking time (hrs):	38
Vehicle Load Condition:	All	Total time (hrs):	1674
Number of historgrams:	197	Percent of time braking:	2.24%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration



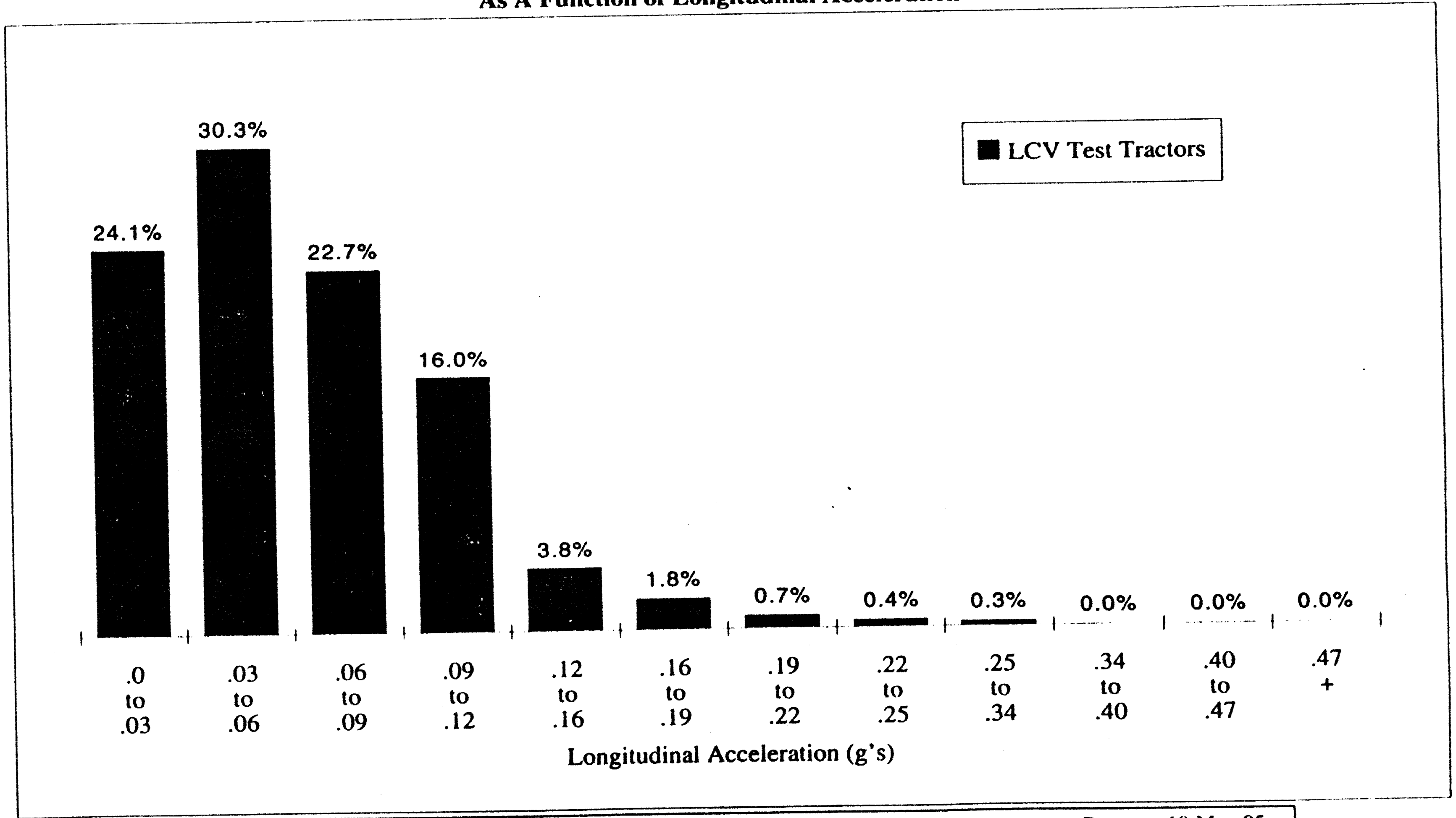
Results are based on the following:			Date: 10-May-95
Vehicle Configuration	Triple	Total braking time (hrs):	15
Vehicle Load Condition	Empty	Total time (hrs):	636
Number of historgrams:	73	Percent of time braking:	2.34%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration



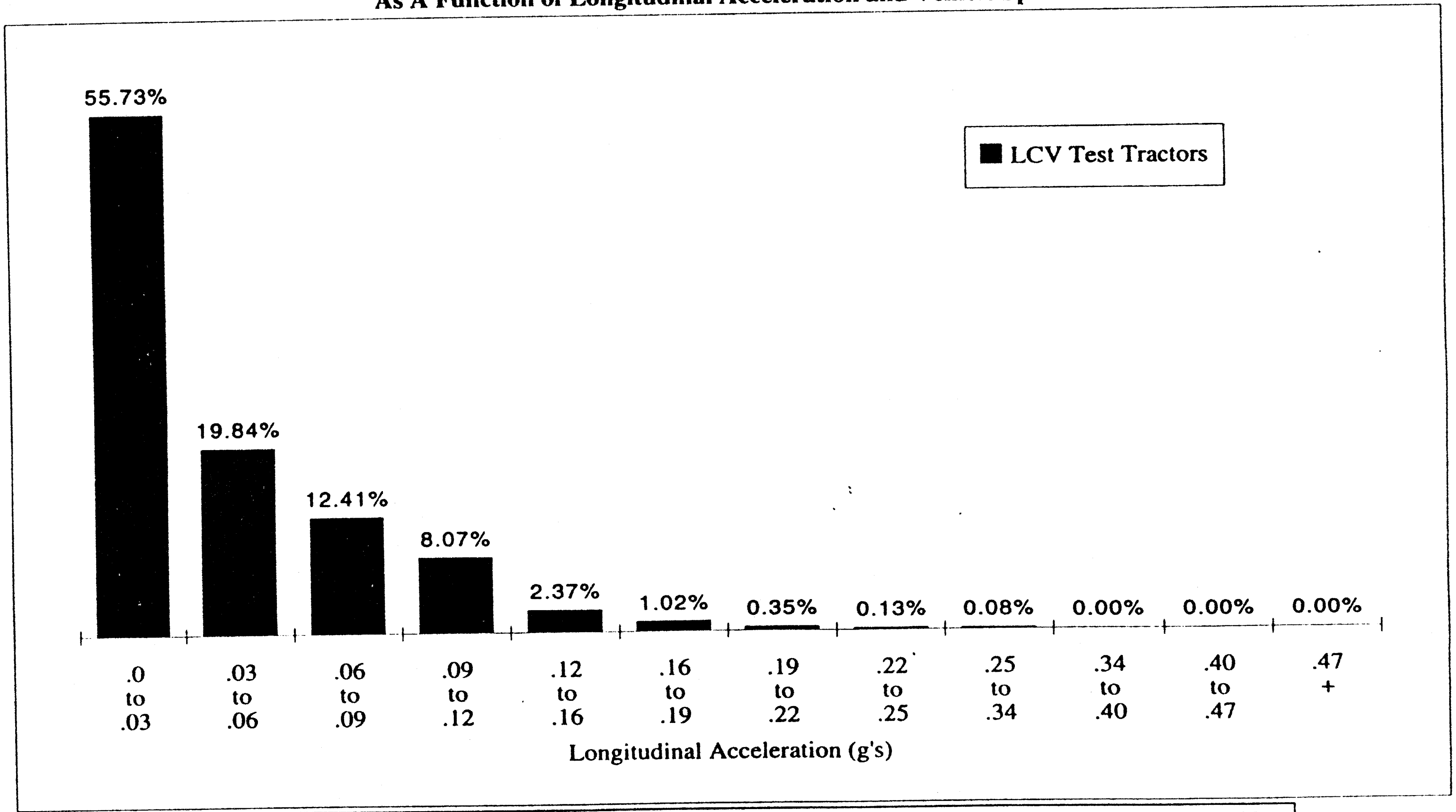
Results are based on the following:		Date:	10-May-95
Vehicle Configuration	Triple	Total braking time (hrs):	20
Vehicle Load Condition	Full	Total time (hrs):	831
Number of historgrams:	97	Percent of time braking:	2.35%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration



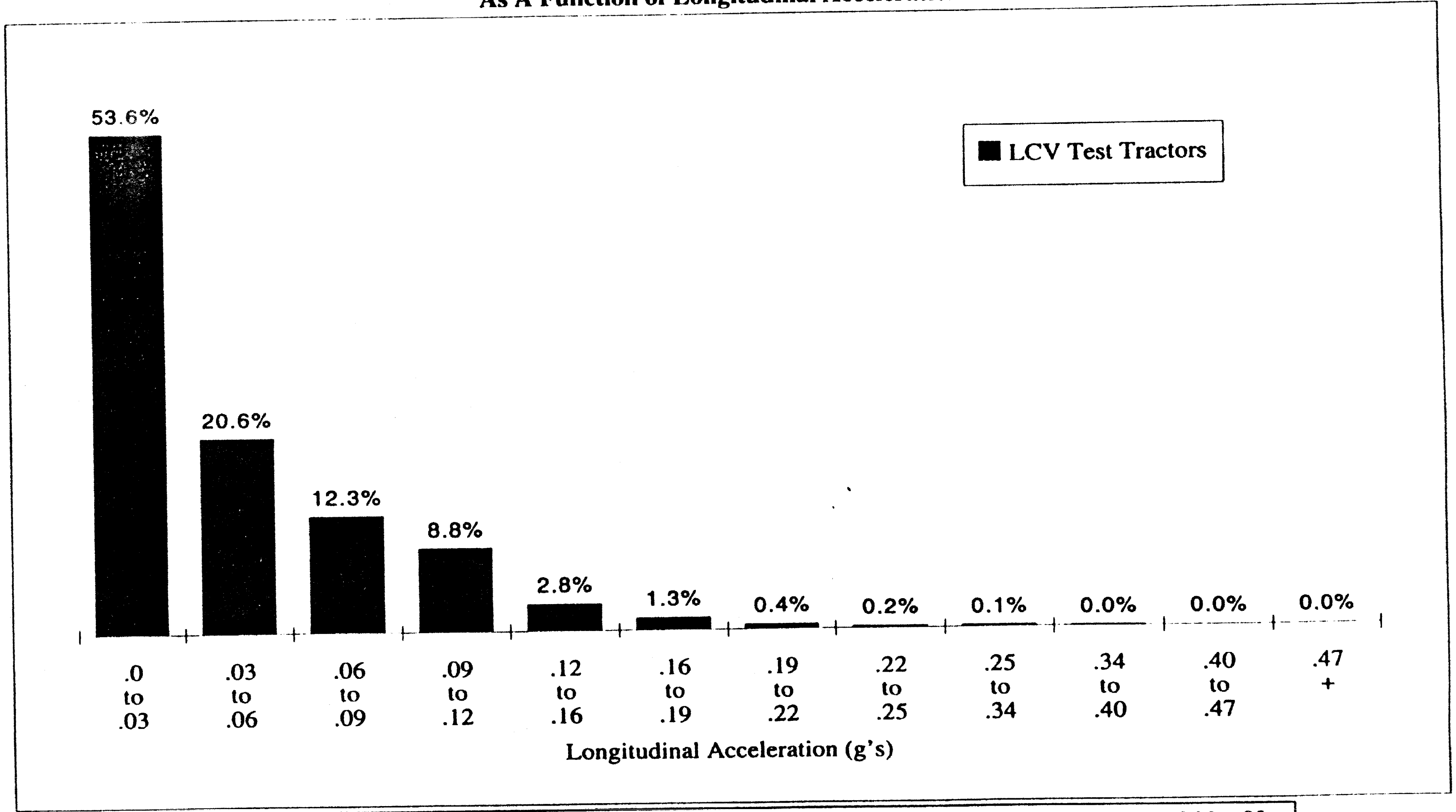
Results are based on the following:			Date: 10-May-95
Vehicle Configuration	Triple	Total braking time (hrs):	3
Vehicle Load Condition	Mixed	Total time (hrs):	207
Number of historgrams:	27	Percent of time braking:	1.50%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



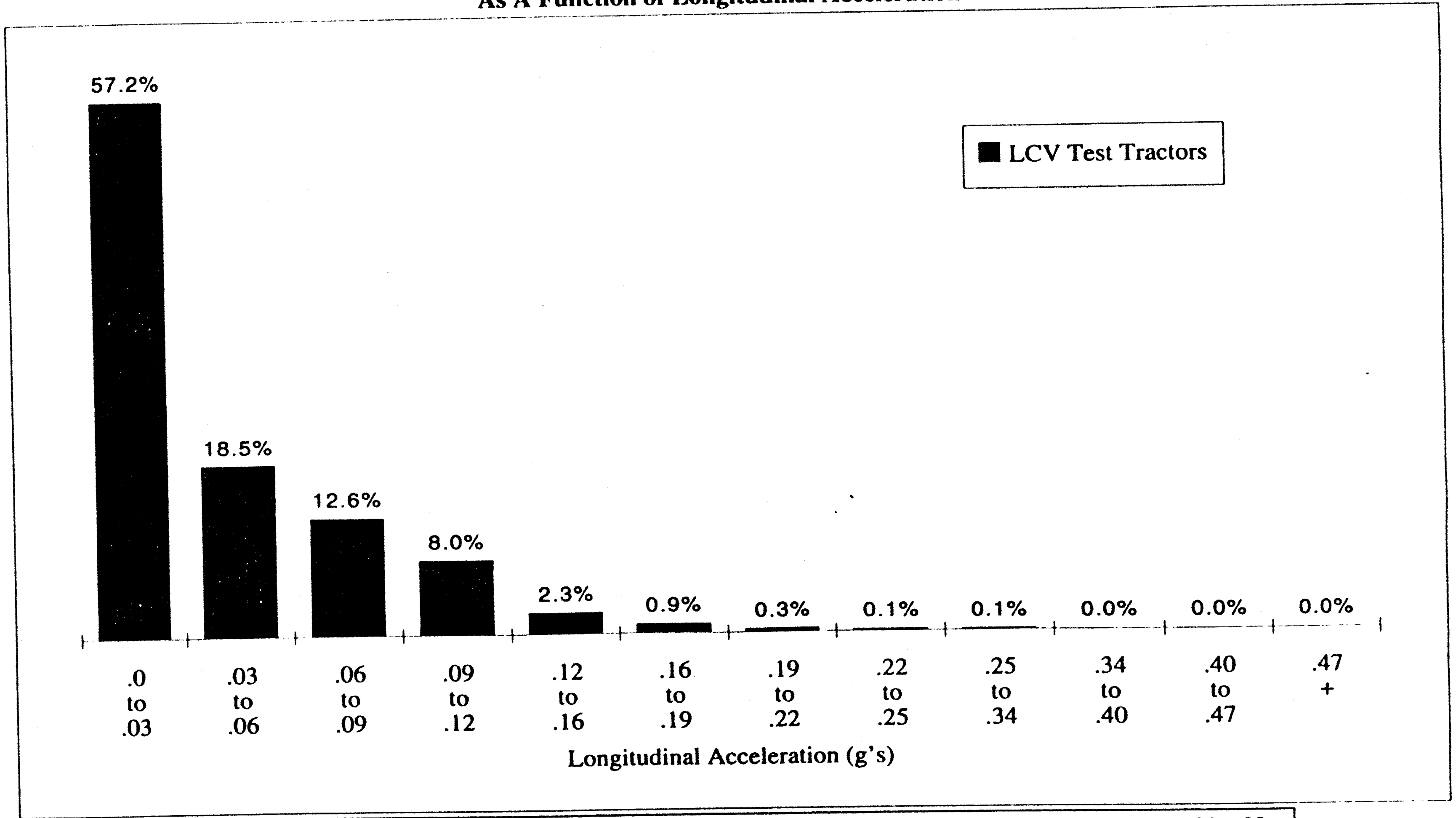
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Double	Total braking time (hrs):	29
Vehicle Load Condition:	All	Total time (hrs):	1034
Number of historgrams:	151	Percent of time braking:	2.80%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration



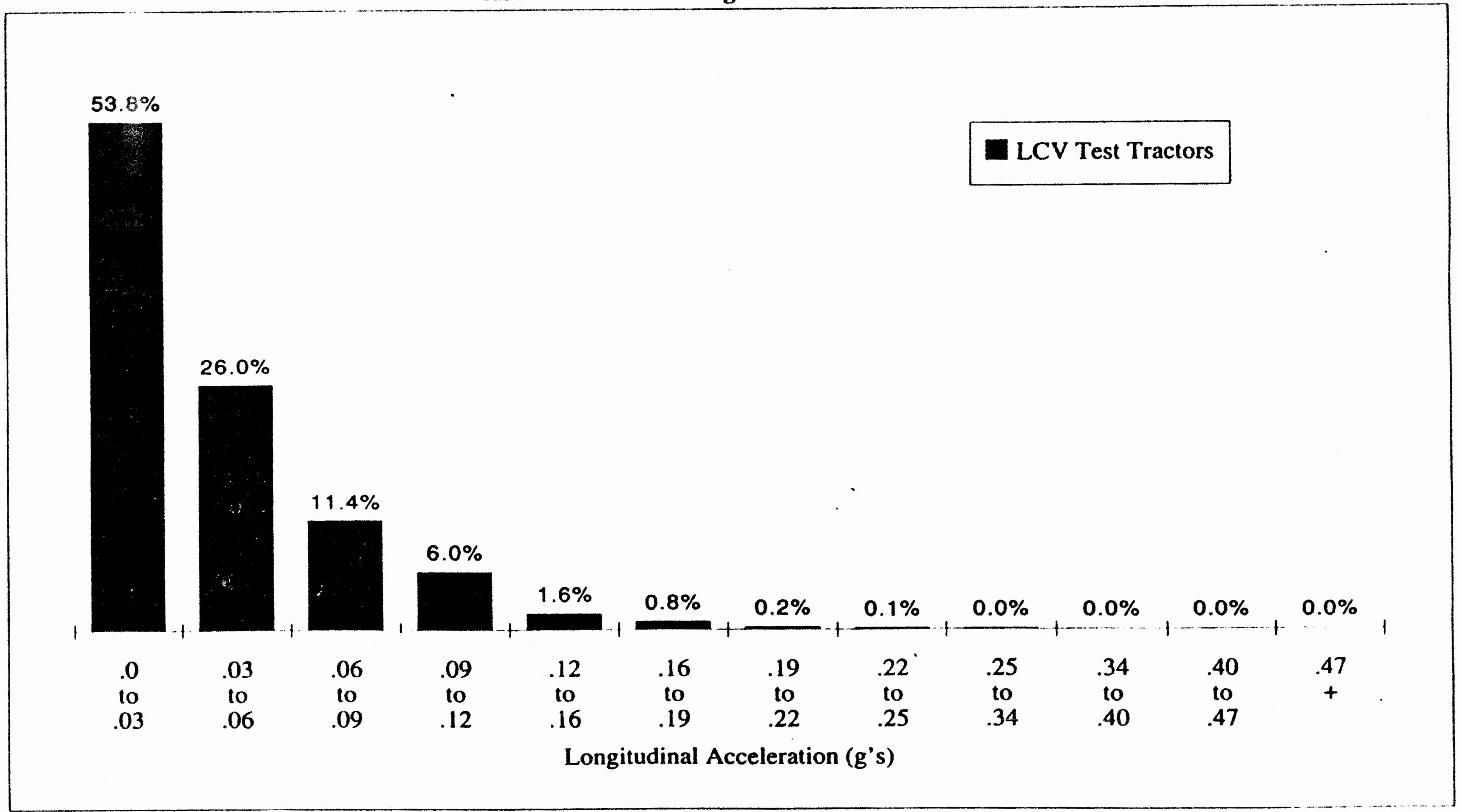
Results are based on the following:		Date:	10-May-95
Vehicle Configuration	Double	Total braking time (hrs):	9
Vehicle Load Condition	Empty	Total time (hrs):	385
Number of historgrams:	60	Percent of time braking:	2.37%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration



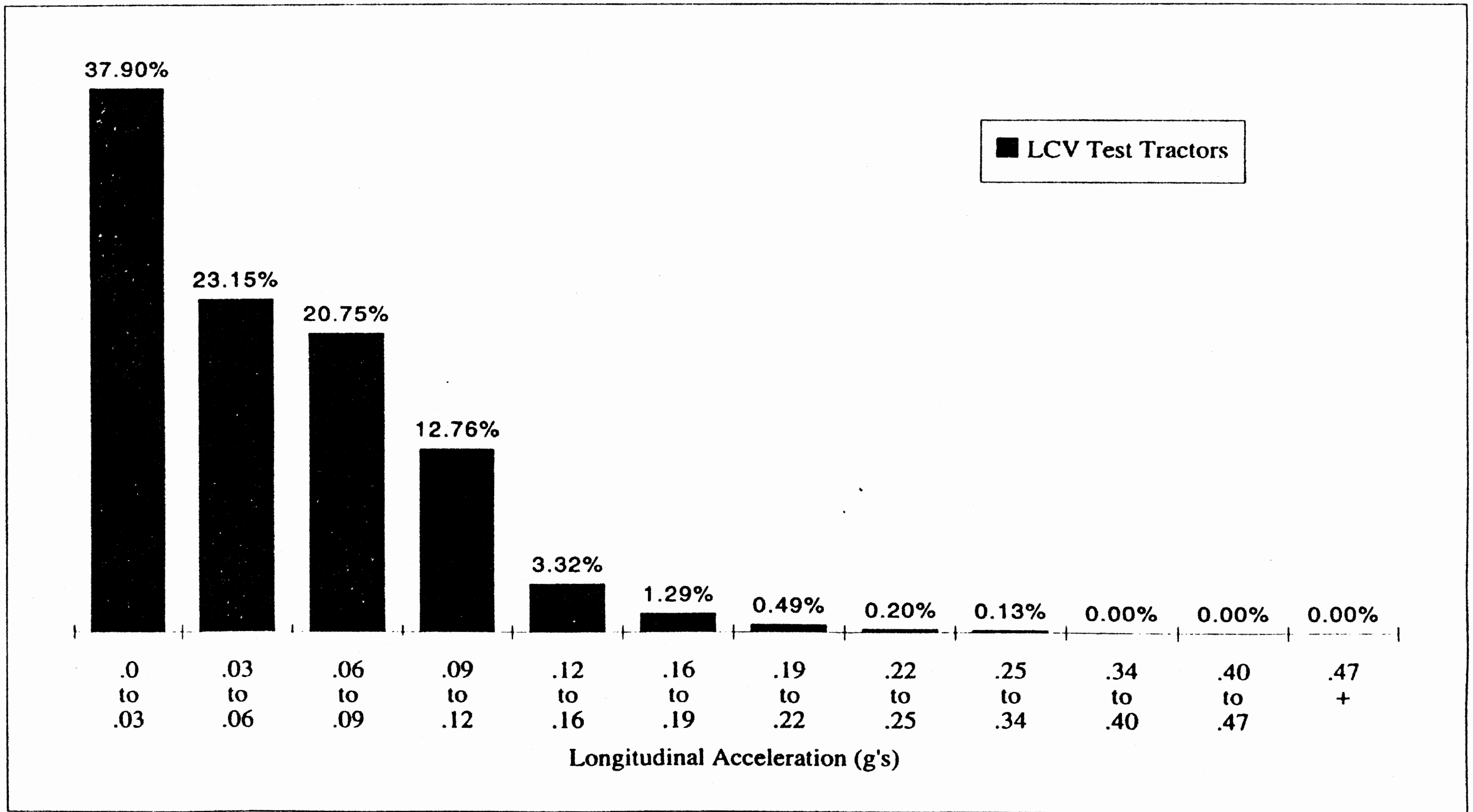
Results are based on the following:		Date:	10-May-95
Vehicle Configuration	Double	Total braking time (hrs):	17
Vehicle Load Condition	Full	Total time (hrs):	536
Number of historgrams:	73	Percent of time braking:	3.21%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration



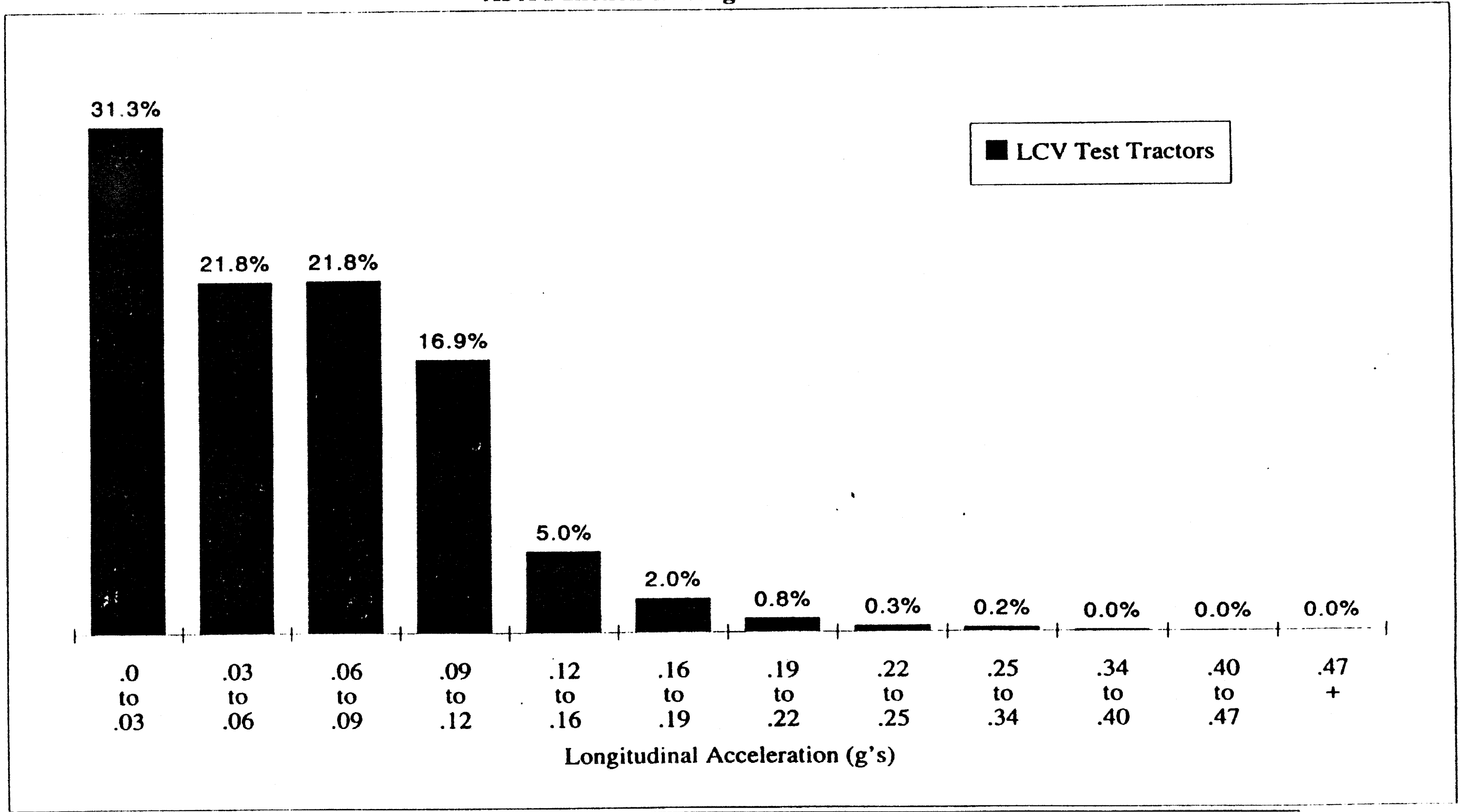
Results are based on the following:		Date:	10-May-95
Vehicle Configuration	Double	Total braking time (hrs):	3
Vehicle Load Condition	Mixed	Total time (hrs):	112
Number of historgrams:	18	Percent of time braking:	2.32%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



Results are based on the following:			Date: 5-May-95
Vehicle Configuration:	Rocky	Total braking time (hrs):	101
Vehicle Load Condition:	All	Total time (hrs):	2956
Number of historgrams:	350	Percent of time braking:	3.43%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration



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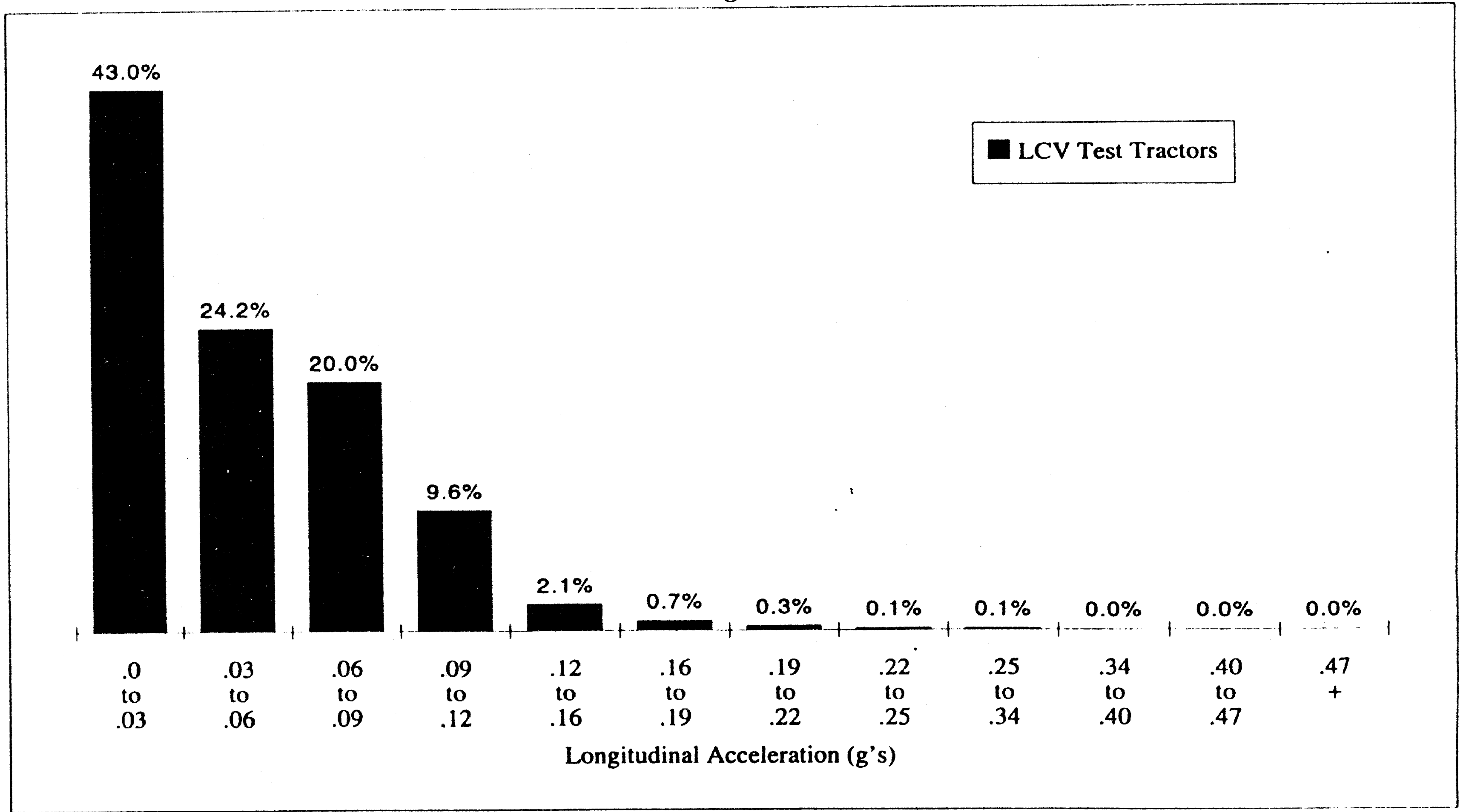
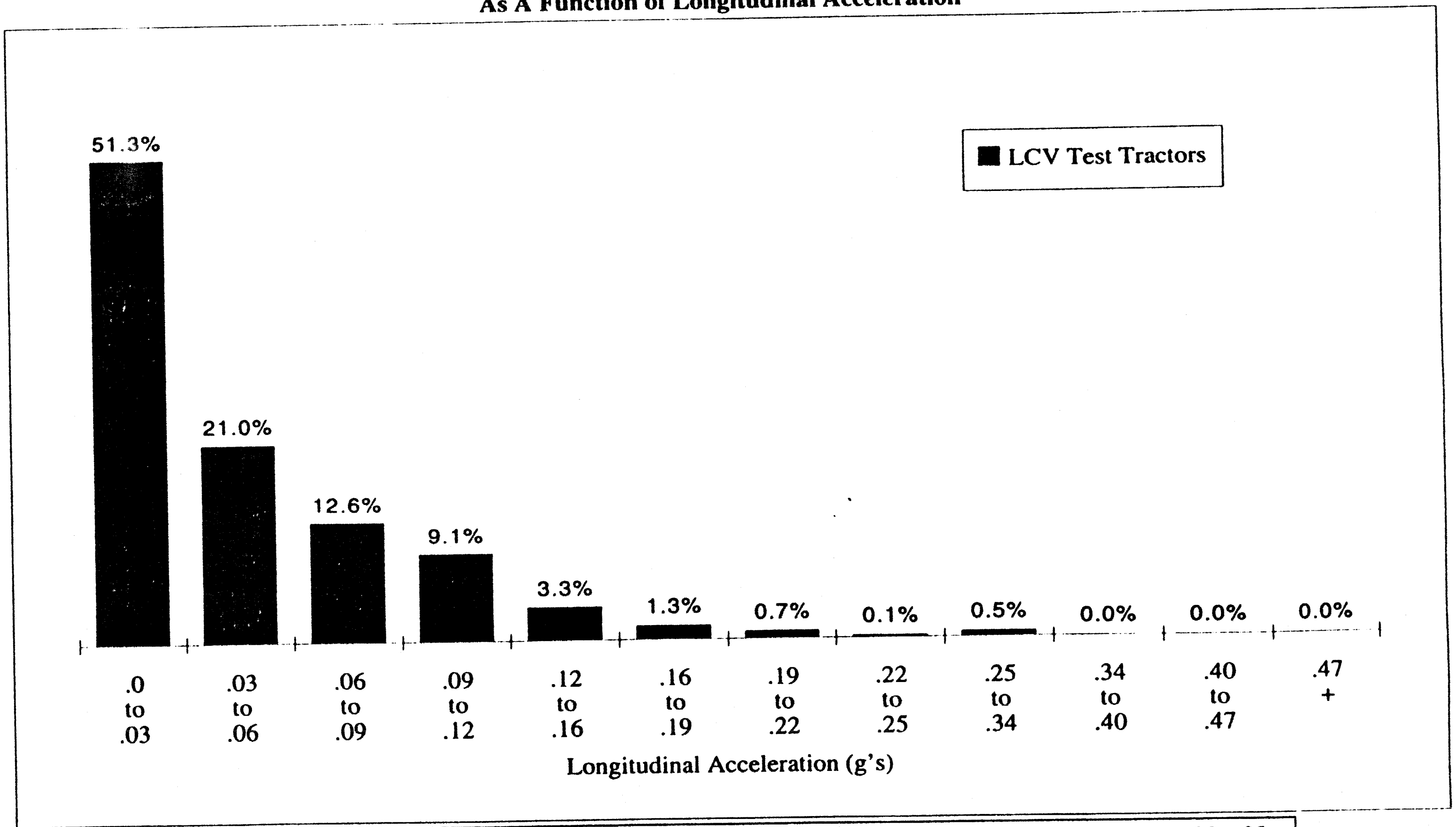
Vehicle Load Condition	Empty	Total time (hrs):	1374
Number of historgrams:	157	Percent of time braking:	3.21%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration



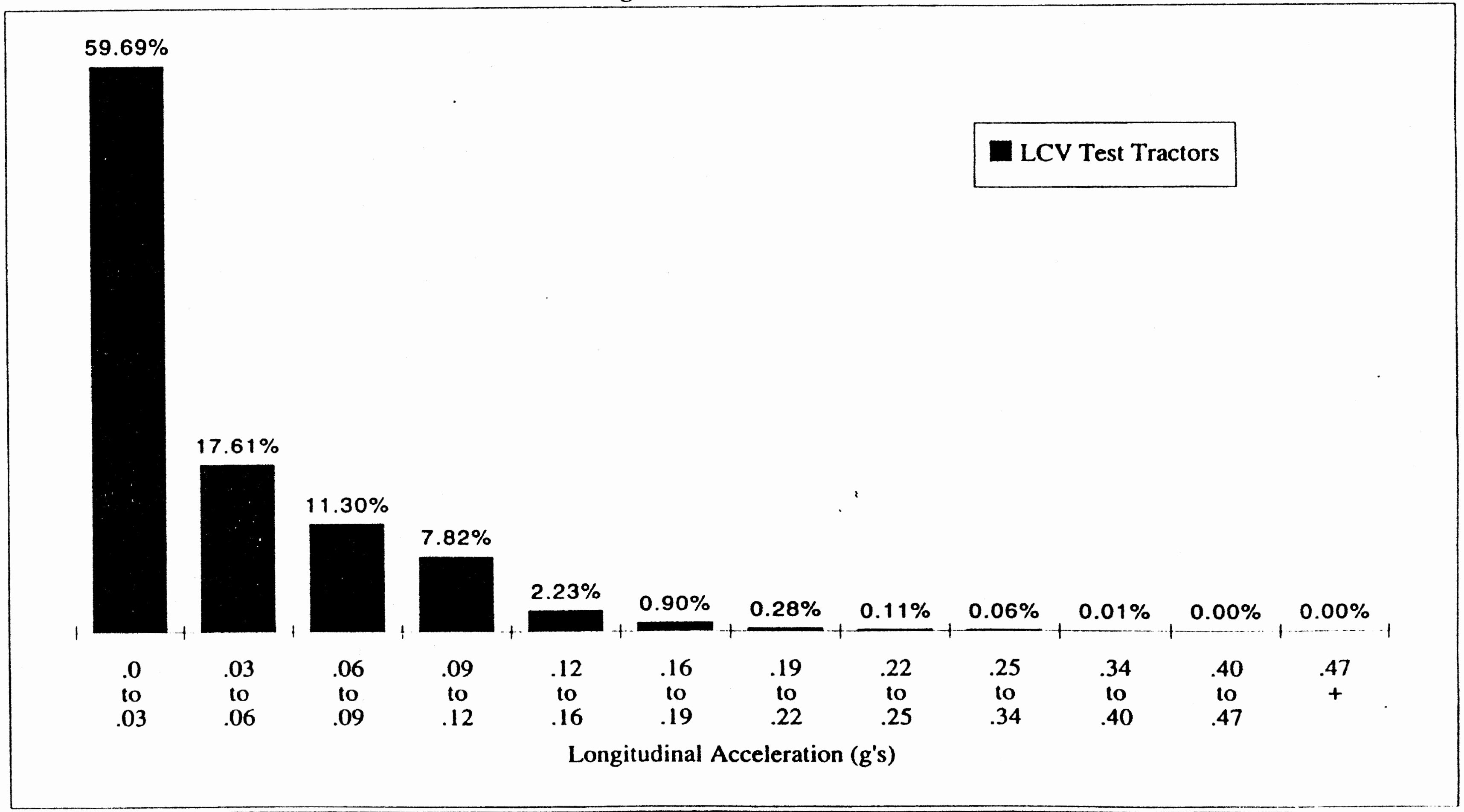
Results are based on the following:		Date:	10-May-95
Vehicle Configuration	Rocky	Total braking time (hrs):	57
Vehicle Load Condition	Full	Total time (hrs):	1562
Number of historgrams:	190	Percent of time braking:	3.63%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration



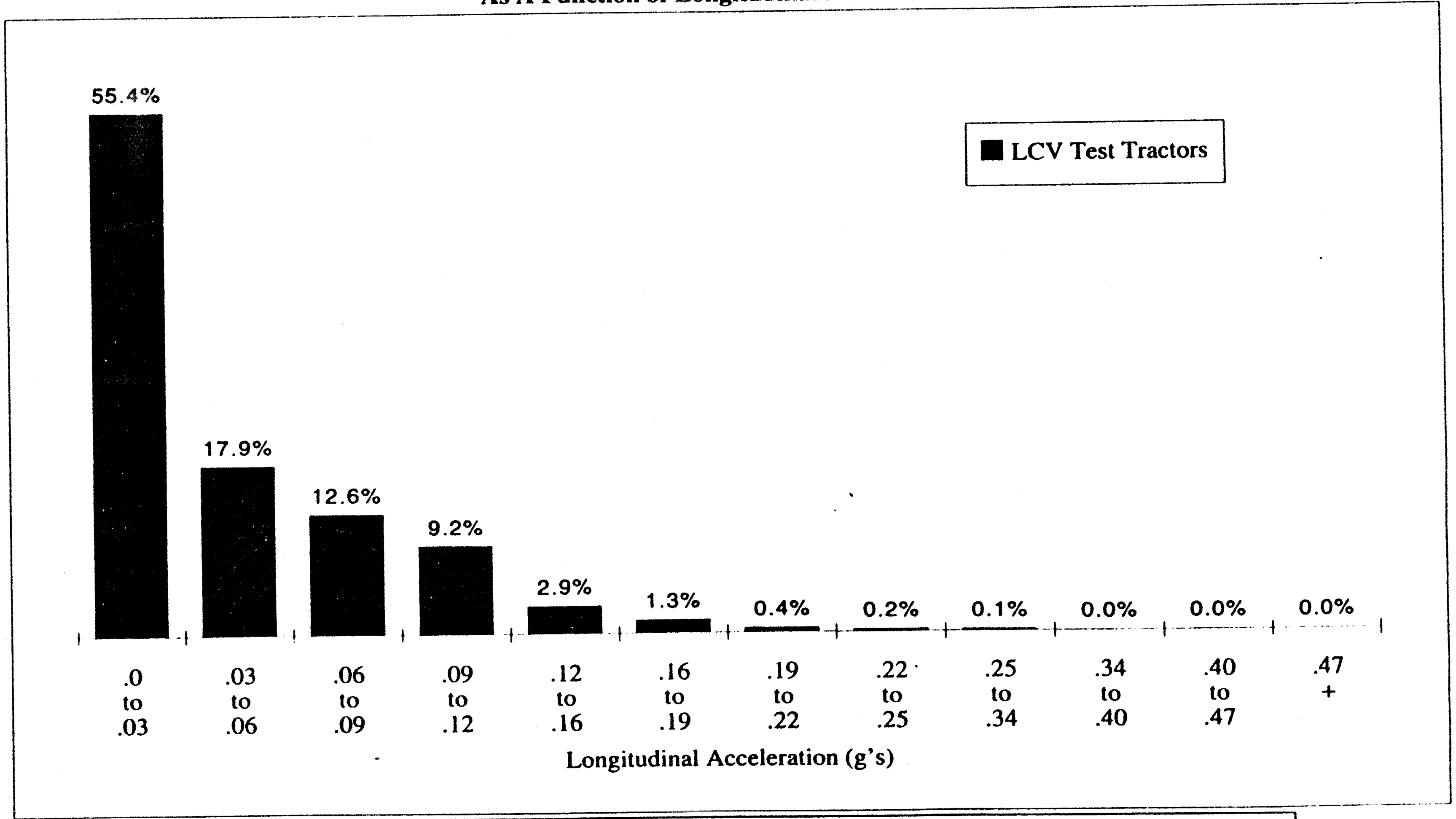
Results are based on the following:			Date: 10-May-95
Vehicle Configuration	Rocky	Total braking time (hrs):	0
Vehicle Load Condition	Mixed	Total time (hrs):	20
Number of historgrams:	3	Percent of time braking:	2.03%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration and Vehicle Speed



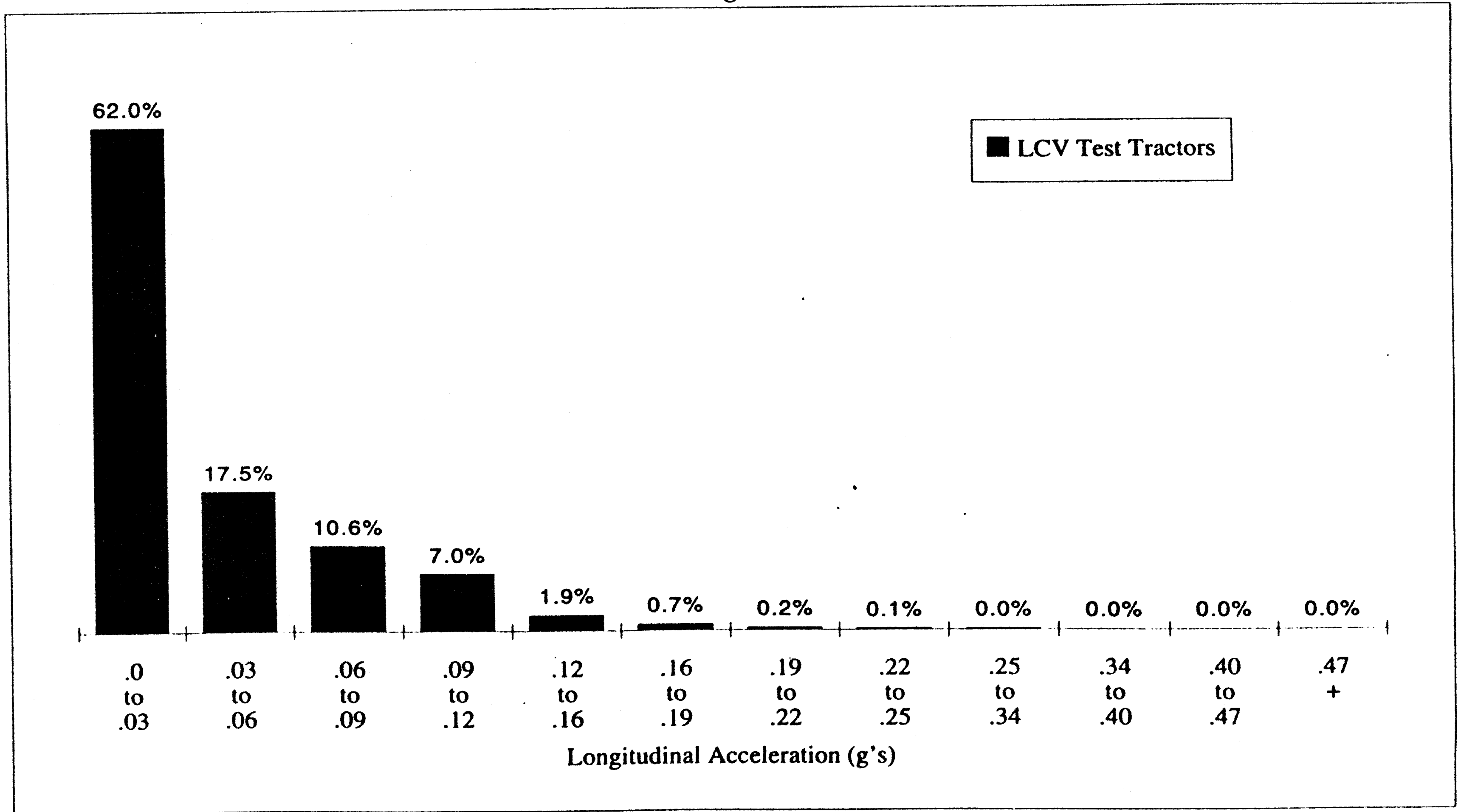
Results are based on the following:		Date:	5-May-95
Vehicle Configuration:	Reverse	Total braking time (hrs):	11
Vehicle Load Condition:	All	Total time (hrs):	425
Number of historgrams:	61	Percent of time braking:	2.67%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration



Results are based on the following:		Date:	10-May-95
Vehicle Configuration	Reverse	Total braking time (hrs):	4
Vehicle Load Condition	Empty	Total time (hrs):	181
Number of historgrams:	27	Percent of time braking:	2.21%

Distribution of Brake Application Time for the LCV Study Fleet
As A Function of Longitudinal Acceleration



Results are based on the following:		Date:	10-May-95
Vehicle Configuration	Reverse	Total braking time (hrs):	7
Vehicle Load Condition	Full	Total time (hrs):	243
Number of historgrams:	34	Percent of time braking:	3.01%

APPENDIX K

MAINTENANCE COSTS FOR TRAILERS AND TRACTORS, AND STANDARDIZED LABOR RATES AND PARTS COSTS

Maintenance Costs For Trailers And Tractors

This report uses a rate of $9.05 per 100 miles as the estimate of the total maintenance costs for tractors (excluding ABS). This rate is composed of $7.80 per 100 miles for the maintenance of all systems other than tires and $1.25 per 100 miles for the cost of tires. The former of these two rates was quoted by Skeydel in reference [26] and is said to be an industry-wide average for the year 1990. (This figure does *not* include the costs of tires, fuels, or lubricants.) The figure of $1.25 per 100 miles for tire costs is the average for tire costs for 280 tractors in a previous NHTSA field study on ABS.[2]

The estimate of the total maintenance costs for trailers (excluding ABS) which has been used in this report is $2.582 per 100 miles. This figure comes from a variety of sources including the historical maintenance records of trailers of the fleets participating in this study. Table K-1 reviews the costs of various maintenance systems as revealed by all of these sources.

The sources for the data of table K-1, by the columns headings, are:

- Semitrailer - The previous NHTSA study involving 50 semitrailers which tracked the maintenance cost of four semitrailer systems.[3][1]
- Historical - The historical records of 18 single axle and 6 tandem axle van trailers in operation between Jan. 1988 and Oct. 1993. During that time, these units traveled a combined distance of 4.5 million miles and had 464 repairs for the systems listed in the table.
- LTL Fleet - The average trailer costs for an LTL carrier operating 12,000 linehaul trailers of various ages in service between 1987 and 1992.[2]
- Go-West - From an article of this periodical which showed costs per mile for a large fleet of linehaul trailers from 1990 and 1992.[27]

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[1] Figure 3.8 "Comparison of Repair/Replacement Maintenance Costs for the 50 ABS Equipped Semitrailers by System Needing Work", Page 3-20.

[2] Data supplied by Robert Deierlein, in private correspondence with UMTRI. Mr. Deierlein is a consultant to the trucking industry.

Table K-1. Summary of trailer system maintenance costs derived from four different sources (dollars per 100 miles)

Trailer System	*Semitrailer*	*Historical*	*LTL*†	*Go-West*†	*Average*
Suspension		0.055	0.108	0.165	0.109
Wheels	0.220	0.120	0.107	0.150	0.149
Frame	0.232	0.232	0.199	0.265	0.232
Electrical	0.220	0.082	0.251	0.325	0.219
Brakes	0.450	0.342	0.457	0.470	0.430
Tires	0.710	0.561			0.635
Body, Door, Trim		0.250	1.047	1.125	0.807
Total					2.582

† Non-standardized parts and labor costs.

Note: All sources did not provide data for all categories. Where data was not available, the cell has been intentionally left blank.

Standardized Labor Rate And Parts Costs

Standardized labor rates and parts costs were used in the cost analyses of this report whenever possible. These standard costs were used instead of the fleets' own accounting charges, since accounting practices vary substantially among fleets. (For example, some account for small parts such as bulbs, screws, etc. by individual job and some consider them as an overhead item.)

The standard labor rate used was $35 per hour. The standardized parts costs are given in the following three tables.

Table K-2. Standardized costs for the tractors

Item	*Cost*	*Item*	*Cost*
STEER AXLE		***DRIVE AXLE***	
BRAKES		***BRAKES***	
Brake Lining per Wheel	$32.00	Brake Lining per Wheel	$30.00
Brake Shoes per Wheel	$32.00	Brake Shoes per Wheel	$30.00
Brake Drum	$105.00	Brake Drum	$105.00
Slack Adjuster	$115.00	Slack Adjuster	$48.00
Turn Brake Drum	$25.00		
		AIR SYSTEM	
AIR SYSTEM		Alcohol Kit	$6.00
Air Dryer	$60.00	Alcohol Fluid	$4.00
Dryer Dessicant	$50.00	Q/R Valve	$13.00
Q/R Valve	$19.00	Brake Hose	$12.00
Brake Hose	$23.00	Brake Chamber	$40.00
Service Chamber	$40.00	Proportioning Valve	$15.00
Relay Valve	$34.00		
Service/Spring Chamber	$43.00	***WHEELS***	
		Bearing Assembly per Wheel	$15.00
WHEELS		Seal	$20.00
Bearing Assembly per Wheel	$40.00	Wheel Stud	$5.00
Seal	$20.00	Wheel Steel	$90.00
Wheel Stud	$3.00	Wheel Aluminum	$300.00
Wheel Steel	$90.00	Cap Gasket	$1.00
Wheel Aluminum	$300.00	Oil Cap	$16.00
		Cup	$15.00
TIRES			
Used Tire	$75.00	***TIRES***	
Retread Tire	$150.00	Used Tire	$75.00
New Tire	$300.00	Retread Tire	$175.00
		New Tire	$300.00
ELECTRICAL			
Alternator Rebuilt	$130.00	***ELECTRICAL***	
Alternator New	$240.00	Gauge Oil Air Water	$30.00
Belt	$5.00	Gauge Speedo Tach	$70.00
Battery	$70.00	Sender	$20.00
Fuse	$1.00	Bulb	$3.00
Circuit Breaker	$3.00	Interior Assembly	$8.00
Light Cord/Pigtail	$25.00	Exterior Specialty	$4.00
Cord Ends	$5.00	Fog Light Bulb	$5.00
Blower/Heater Motor	$50.00	Tail Light Assembly	$6.00
Wiper Motor	$60.00	Head Light	$8.00
Starter Rebuilt	$125.00	Turn Signal Assembly	$35.00
Starter New	$250.00	Toggle Switch	$3.00
		Headlight/Foglight	$6.00
		Dimmer Switch	$20.00
		Turn Signal Switch	$50.00
Standard Labor Rate/Hour	$35.00	Standard Labor Rate/Hour	$35.00

Table K-3. Standardized costs for the trailers

Item	*Cost*	*Item*	*Cost*
BRAKES		***ELECTRICAL***	
Brake Combo	$50.00	Housing	$25.00
Piggy Back Air Can	$35.00	Reflector	$2.00
Air Handle Control Valve	$30.00		
Glad Hand	$25.00		
Quick Release Valve	$14.00	***SUSPENSION***	
Coupler	$3.00		
		Air Bag	$160.00
		Air Ride Levelling Valve	$50.00
BODY		Spacers	$12.00
		U-Bolts	$5.00
Pintle Hitch	$350.00		
Kick Rails	$140.00	***WHEELS***	
Deck Plate	$90.00		
Anti-Dive Stiff Leg	$90.00	Race	$25.00
Door Seal	$60.00	Bearing	$15.00
Top Rail	$55.00	Seal	$15.00
Door Bottom Panel	$50.00	Hub Cap	$8.00
Door Latch / Catch	$45.00	Side Flaps (10 ft)	$1.00
Intermediate Door Panel	$30.00	Gasket	$1.00
Pintle Hook Diaphragm	$20.00		
Door Bottom Roller	$5.00		
Pintle Hook Thimble	$5.00	***MISCELLANEOUS***	
Rear Door Handle	$3.00		
Door Hinge Rollers	$2.00	Max Security Lock	$45.00
Door Hinge	$1.00	Paint	$20.00
		Anti Spray/Hula Skirt	$20.00
		Door Placard	$15.00
COUPLING		Registration Pouch	$14.00
		Cable Drum	$10.00
Torque Arm	$35.00	Skirt Retainer	$7.00
		Standard Labor Rate/Hour	$35.00

Table K-4. Standardized costs for the dollies

Item	*Cost*	*Item*	*Cost*
BRAKES		***FRAME***	
Slack adjuster (auto)	$110.00	Dolly Leg Assembly	$200.00
Chamber (spring brake)	$95.00	New Premier Dolly Jack	$200.00
Drum	$85.00	Outer Tube Assembly - Dolly Jack	$70.00
Air Tank	$75.00	Caster & Wheel Assembly	$40.00
Bendix Valve C-Dolly	$60.00	Dolly Wheel	$30.00
Relay Valve	$60.00	Crank Shaft Screw Dolly	$25.00
Slack adjuster (manual)	$50.00	Caster	$20.00
Chamber (service)	$40.00	Half-Nut in Landing leg	$12.00
Brake Reline (one wheel)	$40.00	Arm	$10.00
Air Handle Control Valve	$30.00	Landing Gear Handle Spring	$3.00
Hose/Air line	$25.00		
Brake Shoes	$20.00	***STEERING***	
Brake Seal	$15.00	Plunger	$60.00
Quick Release Valve	$14.00	Dampner Can/Chamber Housing	$25.00
In-Line Filter	$10.00	Stabilizer Can for steering	$25.00
Glad Hand	$8.00	Damper Boots	$15.00
Kits	$8.00	Diaphragm	$3.00
Cable Drain or Drain valve	$6.00		
Brake Boots C-Dolly	$6.00	***TIRES***	
Hose Tender	$3.00	New Tire	$275.00
Brake Gaskets	$1.00	Recap outright	$150.00
		Recap w/casting	$90.00
COUPLING		Caps	$75.00
5th Wheel Kit	$175.00	Section Repair	$50.00
Safety Chain Assembly	$65.00	Repair	$4.00
Clevis Assembly	$22.00		
Coupler	$20.00	***WHEELS***	
5th wheel Assembly	$20.00	Steel	$85.00
Clevis Clip	$20.00	Ball Bearing (one wheel)	$40.00
5th wheel Release Handle	$15.00	Hubometer	$40.00
5th wheel Shaft	$10.00	Mud Flap Bracket Kit - Dolly	$30.00
Clevis Pin, & Roll Pin	$10.00	Mud Flap Straight Arm Kit	$20.00
Safety Chain Hook	$10.00	Mud Flap Bracket	$20.00
Clevis Pin Hook Spring	$8.00	Wheel Seal	$15.00
Lock Guard	$7.00	Mud Flap Assembly	$15.00
Safety Clip	$5.00	Mud Flap Angle Arm (Hanger)	$10.00
Clevis Pin Retainer	$4.00	Mud Flap	$8.00
Latch Kit	$3.00	Oil/Hub Cap	$8.00
		Hub Cap Window	$3.00
ELECTRICAL		Hub Cap Kit	$3.00
7way Harness	$70.00		
Brake Lite Switch	$25.00	***MISCELLANEOUS***	
7way Wire (10 ft)	$10.00	Quarter Fender	$50.00
Junction Box	$11.00	License Box	$14.00
7way Socket/Plug	$8.00	Registration Box	$14.00
Light Assembly or Kit	$6.00		
Bulb, Sealed beam	$3.00		
Circuit Breaker	$2.00		
Lens	$2.00	Standard Labor Rate/Hour	$35.00

APPENDIX L

LATERAL STABILITY PERFORMANCE DATA

This appendix presents twenty tables containing the results of analyses of the lateral stability of the study vehicles while using A-dollies and C-dollies. Tables L-1 through L-16 present the measured values of rearward amplification as a function of frequency. The data are given as functions of vehicle configuration, load condition, and speed for LCVs using both A-dollies and C-dollies, respectively. Indicated frequencies are the center frequency of the bandpass filter used in gathering power-spectral-density data (see appendix B).

Tables L-17 to L-20 present the lateral acceleration experience of the tractors and trailers of all the vehicles of the field study fleet while traveling at speeds equal to or greater than 45 mph . These are the data used to produce figures 41 through 46 in volume 1. These data are segregated by vehicle configuration, load condition, and type of dolly. Tables 21 through 30 present the same data further segregated by velocity. At this level, the data tend to be so sparse as to produce rather "noisy" graphs.

Table L-1. Rearward amplification of trailers: Fully loaded triples with the A-dollies

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.04E+0	1.07E+0	9.39E-1	1.03E+0	7.06E-1	2.53E-1
Trailer2	1.00E+0	1.27E+0	1.39E+0	1.47E+0	1.38E+0	6.36E-1	2.40E-1
Trailer3	1.00E+0	1.41E+0	1.84E+0	2.22E+0	2.18E+0	1.07E+0	1.99E-1
45 to 55 mph							
Trailer1	1.00E+0	1.15E+0	1.21E+0	1.01E+0	9.84E-1	6.85E-1	2.72E-1
Trailer2	1.00E+0	1.54E+0	2.11E+0	1.95E+0	1.45E+0	7.84E-1	2.98E-1
Trailer3	1.00E+0	1.75E+0	2.89E+0	3.29E+0	2.69E+0	1.42E+0	2.79E-1
55 to 65 mph							
Trailer1	1.00E+0	1.22E+0	1.46E+0	1.15E+0	8.91E-1	6.08E-1	2.76E-1
Trailer2	1.00E+0	1.71E+0	2.57E+0	2.48E+0	1.73E+0	7.16E-1	2.57E-1
Trailer3	1.00E+0	2.08E+0	3.82E+0	4.77E+0	3.99E+0	1.66E+0	2.94E-1

Table L-2. Rearward amplification of trailers: Fully loaded triples with the C-dollies

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	9.54E-1	9.94E-1	8.22E-1	7.77E-1	6.89E-1	3.56E-1
Trailer2	1.00E+0	1.08E+0	1.16E+0	8.93E-1	6.42E-1	4.77E-1	1.86E-1
Trailer3	1.00E+0	1.27E+0	1.66E+0	1.53E+0	1.12E+0	5.11E-1	9.27E-2
45 to 55 mph							
Trailer1	1.00E+0	1.01E+0	9.59E-1	8.10E-1	7.33E-1	6.02E-1	3.34E-1
Trailer2	1.00E+0	1.19E+0	1.27E+0	1.05E+0	8.48E-1	5.90E-1	2.26E-1
Trailer3	1.00E+0	1.40E+0	2.02E+0	2.08E+0	1.75E+0	8.65E-1	1.30E-1
55 to 65 mph							
Trailer1	1.00E+0	1.00E+0	9.35E-1	7.79E-1	6.80E-1	5.12E-1	2.73E-1
Trailer2	1.00E+0	1.22E+0	1.30E+0	1.05E+0	8.14E-1	5.73E-1	2.32E-1
Trailer3	1.00E+0	1.45E+0	2.02E+0	2.19E+0	1.84E+0	1.02E+0	1.62E-1

Table L-3. Rearward amplification of trailers: Empty triples with the A-dollies

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.12E+0	1.16E+0	1.12E+0	1.03E+0	8.42E-1	3.17E-1
Trailer2	1.00E+0	1.33E+0	1.63E+0	1.72E+0	1.65E+0	1.41E+0	4.85E-1
Trailer3	1.00E+0	1.58E+0	2.13E+0	2.58E+0	2.38E+0	1.98E+0	4.53E-1
45 to 55 mph							
Trailer1	1.00E+0	1.05E+0	1.16E+0	1.22E+0	9.62E-1	7.10E-1	3.23E-1
Trailer2	1.00E+0	1.27E+0	1.95E+0	2.40E+0	1.93E+0	1.19E+0	5.31E-1
Trailer3	1.00E+0	1.52E+0	2.65E+0	4.17E+0	4.12E+0	1.91E+0	4.34E-1
55 to 65 mph							
Trailer1	1.00E+0	1.10E+0	1.25E+0	1.45E+0	1.21E+0	8.24E-1	3.09E-1
Trailer2	1.00E+0	1.39E+0	2.27E+0	3.28E+0	2.81E+0	1.37E+0	4.33E-1
Trailer3	1.00E+0	1.65E+0	3.35E+0	6.74E+0	7.12E+0	2.57E+0	4.21E-1

Table L-4. Rearward amplification of trailers: Empty triples with the C-dollies

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.04E+0	1.15E+0	1.01E+0	9.26E-1	7.26E-1	2.77E-1
Trailer2	1.00E+0	1.08E+0	1.27E+0	1.08E+0	8.52E-1	5.67E-1	1.80E-1
Trailer3	1.00E+0	1.29E+0	1.62E+0	1.51E+0	1.08E+0	6.05E-1	1.06E-1
45 to 55 mph							
Trailer1	1.00E+0	1.07E+0	1.19E+0	9.89E-1	8.53E-1	6.58E-1	3.11E-1
Trailer2	1.00E+0	1.18E+0	1.46E+0	1.31E+0	1.02E+0	6.90E-1	2.26E-1
Trailer3	1.00E+0	1.45E+0	2.02E+0	2.07E+0	1.76E+0	9.88E-1	1.80E-1
55 to 65 mph							
Trailer1	1.00E+0	1.05E+0	1.15E+0	9.78E-1	8.40E-1	6.01E-1	2.55E-1
Trailer2	1.00E+0	1.21E+0	1.54E+0	1.34E+0	1.06E+0	7.28E-1	2.28E-1
Trailer3	1.00E+0	1.49E+0	2.22E+0	2.26E+0	2.16E+0	1.30E+0	2.14E-1

Table L-5. Rearward amplification of trailers: Fully loaded western doubles with the A-dolly

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.09E+0	1.22E+0	1.20E+0	1.27E+0	8.63E-1	3.78E-1
Trailer2	1.00E+0	1.33E+0	1.72E+0	1.90E+0	2.02E+0	1.16E+0	3.57E-1
45 to 55 mph							
Trailer1	1.00E+0	1.17E+0	1.20E+0	1.21E+0	1.29E+0	8.07E-1	3.89E-1
Trailer2	1.00E+0	1.41E+0	1.76E+0	1.97E+0	2.34E+0	1.30E+0	4.88E-1
55 to 65 mph							
Trailer1	1.00E+0	1.17E+0	1.12E+0	1.06E+0	1.18E+0	8.19E-1	3.84E-1
Trailer2	1.00E+0	1.44E+0	1.83E+0	1.93E+0	2.12E+0	1.32E+0	5.10E-1

Table L-6. Rearward amplification of trailers: Fully loaded western doubles with the C-dolly

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.01E+0	1.02E+0	9.52E-1	9.62E-1	8.22E-1	3.53E-1
Trailer2	1.00E+0	1.15E+0	1.41E+0	1.46E+0	1.42E+0	9.07E-1	2.76E-1
45 to 55 mph							
Trailer1	1.00E+0	1.03E+0	9.78E-1	8.75E-1	8.59E-1	6.60E-1	3.35E-1
Trailer2	1.00E+0	1.25E+0	1.46E+0	1.57E+0	1.58E+0	1.06E+0	3.90E-1
55 to 65 mph							
Trailer1	1.00E+0	1.03E+0	9.78E-1	8.75E-1	8.59E-1	6.60E-1	3.35E-1
Trailer2	1.00E+0	1.25E+0	1.46E+0	1.57E+0	1.58E+0	1.06E+0	3.90E-1

Table L-7. Rearward amplification of trailers: Empty western doubles with the A-dolly

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.07E+0	1.22E+0	1.21E+0	1.16E+0	8.79E-1	3.41E-1
Trailer2	1.00E+0	1.26E+0	1.59E+0	1.83E+0	1.89E+0	1.36E+0	4.19E-1
45 to 55 mph							
Trailer1	1.00E+0	1.08E+0	1.17E+0	1.11E+0	1.03E+0	7.31E-1	3.35E-1
Trailer2	1.00E+0	1.24E+0	1.57E+0	1.73E+0	1.74E+0	1.22E+0	4.19E-1
55 to 65 mph							
Trailer1	1.00E+0	1.10E+0	1.22E+0	1.24E+0	1.13E+0	7.76E-1	3.17E-1
Trailer2	1.00E+0	1.34E+0	1.73E+0	1.87E+0	1.93E+0	1.26E+0	4.39E-1

Table L-8. Rearward amplification of trailers: Empty western doubles with the C-dolly

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.00E+0	9.73E-1	9.13E-1	9.19E-1	6.54E-1	2.90E-1
Trailer2	1.00E+0	1.16E+0	1.39E+0	1.45E+0	1.43E+0	9.04E-1	2.75E-1
45 to 55 mph							
Trailer1	1.00E+0	1.01E+0	9.43E-1	9.37E-1	8.00E-1	6.14E-1	2.90E-1
Trailer2	1.00E+0	1.20E+0	1.34E+0	1.40E+0	1.44E+0	9.73E-1	3.26E-1
55 to 65 mph							
Trailer1	1.00E+0	9.95E-1	9.54E-1	9.36E-1	7.89E-1	5.63E-1	2.63E-1
Trailer2	1.00E+0	1.22E+0	1.43E+0	1.57E+0	1.51E+0	9.79E-1	3.21E-1

Table L-9. Rearward amplification of trailers: Fully loaded Rocky Mountain doubles with the A-dolly

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.03E+0	1.14E+0	1.09E+0	1.06E+0	9.17E-1	2.30E-1
Trailer2	1.00E+0	1.36E+0	1.92E+0	2.18E+0	2.86E+0	2.37E+0	3.86E-1
45 to 55 mph							
Trailer1	1.00E+0	1.02E+0	1.06E+0	9.17E-1	8.14E-1	9.41E-1	2.74E-1
Trailer2	1.00E+0	1.38E+0	1.90E+0	2.02E+0	1.94E+0	1.91E+0	4.13E-1
55 to 65 mph							
Trailer1	1.00E+0	1.08E+0	1.12E+0	1.00E+0	7.93E-1	9.13E-1	2.55E-1
Trailer2	1.00E+0	1.49E+0	2.23E+0	2.51E+0	2.09E+0	2.08E+0	3.84E-1

Table L-10. Rearward amplification of trailers: Fully loaded Rocky Mountain doubles with the C-dolly

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.00E+0	1.01E+0	9.84E-1	9.59E-1	7.83E-1	3.04E-1
Trailer2	1.00E+0	1.39E+0	1.88E+0	2.10E+0	1.85E+0	1.12E+0	2.28E-1
45 to 55 mph							
Trailer1	1.00E+0	9.91E-1	9.71E-1	8.98E-1	9.30E-1	8.93E-1	3.18E-1
Trailer2	1.00E+0	1.39E+0	1.91E+0	2.15E+0	2.15E+0	1.57E+0	3.55E-1
55 to 65 mph							
Trailer1	1.00E+0	1.01E+0	9.64E-1	8.78E-1	8.58E-1	8.43E-1	3.65E-1
Trailer2	1.00E+0	1.40E+0	1.90E+0	2.16E+0	2.11E+0	1.60E+0	4.57E-1

Table L-11. Rearward amplification of trailers: Empty Rocky Mountain doubles with the A-dolly

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.04E+0	1.02E+0	1.03E+0	1.01E+0	9.44E-1	2.94E-1
Trailer2	1.00E+0	1.27E+0	1.89E+0	2.32E+0	2.45E+0	2.39E+0	6.38E-1
45 to 55 mph							
Trailer1	1.00E+0	9.92E-1	1.01E+0	9.00E-1	8.86E-1	9.28E-1	3.44E-1
Trailer2	1.00E+0	1.27E+0	1.79E+0	2.08E+0	2.22E+0	1.89E+0	6.40E-1
55 to 65 mph							
Trailer1	1.00E+0	1.04E+0	1.09E+0	1.02E+0	9.92E-1	9.75E-1	3.17E-1
Trailer2	1.00E+0	1.37E+0	2.11E+0	2.63E+0	2.75E+0	2.05E+0	5.70E-1

Table L-12. Rearward amplification of trailers: Empty Rocky Mountain doubles with the C-dolly

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.02E+0	1.07E+0	1.01E+0	8.55E-1	7.30E-1	3.21E-1
Trailer2	1.00E+0	1.30E+0	1.60E+0	1.55E+0	1.35E+0	1.02E+0	2.74E-1
45 to 55 mph							
Trailer1	1.00E+0	9.97E-1	1.06E+0	9.38E-1	8.63E-1	7.10E-1	2.67E-1
Trailer2	1.00E+0	1.36E+0	1.80E+0	1.96E+0	2.03E+0	1.57E+0	4.15E-1
55 to 65 mph							
Trailer1	1.00E+0	9.87E-1	9.76E-1	9.14E-1	8.17E-1	7.10E-1	2.77E-1
Trailer2	1.00E+0	1.35E+0	1.83E+0	2.17E+0	2.18E+0	1.91E+0	5.22E-1

Table L-13. Rearward amplification of trailers: Fully loaded reverse Rocky Mountain doubles with the A-dolly

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.14E+0	1.32E+0	1.22E+0	1.31E+0	1.24E+0	4.22E-1
Trailer2	1.00E+0	1.21E+0	1.51E+0	1.54E+0	1.51E+0	1.14E+0	2.70E-1
45 to 55 mph							
Trailer1	1.00E+0	1.19E+0	1.21E+0	9.86E-1	9.79E-1	1.37E+0	3.11E-1
Trailer2	1.00E+0	1.35E+0	1.66E+0	1.43E+0	1.36E+0	1.26E+0	3.04E-1
55 to 65 mph							
Trailer1	1.00E+0	1.27E+0	1.39E+0	1.21E+0	9.76E-1	9.96E-1	2.93E-1
Trailer2	1.00E+0	1.47E+0	1.96E+0	1.80E+0	1.47E+0	1.42E+0	3.05E-1

Table L-14. Rearward amplification of trailers: Fully loaded reverse Rocky Mountain doubles with the C-dolly

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	9.84E-1	1.12E+0	1.05E+0	1.05E+0	8.73E-1	4.18E-1
Trailer2	1.00E+0	1.08E+0	1.42E+0	1.36E+0	1.18E+0	7.75E-1	3.40E-1
45 to 55 mph							
Trailer1	1.00E+0	1.04E+0	1.05E+0	1.02E+0	8.91E-1	9.13E-1	3.81E-1
Trailer2	1.00E+0	1.20E+0	1.52E+0	1.18E+0	1.30E+0	8.96E-1	3.70E-1
55 to 65 mph							
Trailer1	1.00E+0	1.04E+0	1.03E+0	9.30E-1	7.23E-1	5.85E-1	2.73E-1
Trailer2	1.00E+0	1.38E+0	1.52E+0	1.18E+0	1.17E+0	8.05E-1	3.12E-1

Table L-15. Rearward amplification of trailers: Empty reverse Rocky Mountain doubles with the A-dolly

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.09E+0	1.29E+0	1.23E+0	1.27E+0	1.07E+0	3.55E-1
Trailer2	1.00E+0	1.25E+0	1.53E+0	1.78E+0	1.63E+0	1.57E+0	3.24E-1
45 to 55 mph							
Trailer1	1.00E+0	1.06E+0	1.23E+0	1.11E+0	1.15E+0	1.15E+0	3.51E-1
Trailer2	1.00E+0	1.29E+0	1.78E+0	1.93E+0	1.95E+0	1.83E+0	4.86E-1
55 to 65 mph							
Trailer1	1.00E+0	1.11E+0	1.30E+0	1.33E+0	1.20E+0	1.15E+0	2.98E-1
Trailer2	1.00E+0	1.38E+0	2.06E+0	2.31E+0	2.24E+0	1.80E+0	4.53E-1

Table L-16. Rearward amplification of trailers: Empty reverse Rocky Mountain doubles with the C-dolly

Frequency	*0.25 Hz*	*0.29 Hz*	*0.33 Hz*	*0.40 Hz*	*0.50 Hz*	*0.67 Hz*	*1.00 Hz*
35 to 45 mph							
Trailer1	1.00E+0	1.03E+0	1.08E+0	1.08E+0	1.02E+0	9.38E-1	3.60E-1
Trailer2	1.00E+0	1.17E+0	1.40E+0	1.35E+0	1.13E+0	7.50E-1	2.19E-1
45 to 55 mph							
Trailer1	1.00E+0	1.01E+0	9.99E-1	8.58E-1	8.44E-1	7.24E-1	2.94E-1
Trailer2	1.00E+0	1.19E+0	1.49E+0	1.46E+0	1.38E+0	9.94E-1	3.36E-1
55 to 65 mph							
Trailer1	1.00E+0	1.02E+0	9.69E-1	8.99E-1	8.04E-1	6.21E-1	2.45E-1
Trailer2	1.00E+0	1.28E+0	1.53E+0	1.56E+0	1.38E+0	9.98E-1	3.62E-1

Table L-17. Cumulative lateral acceleration histogram data for triples for different load conditions and dolly types

Unit Position	*Total Time**	*Percentage of travel time spent above the indicated level of lateral acceleration for speeds greater than 45 mph*											
	Hours	*> 0.00 g's*	*> 0.03 g's*	*> 0.06 g's*	*> 0.09 g's*	*> 0.12 g's*	*> 0.16 g's*	*> 0.19 g's*	*> 0.22 g's*	*> 0.25 g's*	*> 0.34 g's*	*> 0.40 g's*	*> 0.47 g's*
						Empty, A-dolly							
Tractor	15.68	1.00E+2	1.62E+1	4.09E+0	2.08E+0	9.65E-1	3.24E-1	7.65E-2	6.46E-3	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer1	12.31	1.00E+2	1.30E+1	3.78E+0	1.78E+0	7.80E-1	2.99E-1	1.02E-1	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer2	15.59	1.00E+2	1.17E+1	4.05E+0	2.00E+0	8.82E-1	3.24E-1	1.31E-1	8.87E-3	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer3	13.71	1.00E+2	2.57E+1	8.85E+0	4.82E+0	2.50E+0	1.15E+0	2.51E-1	3.61E-2	2.19E-3	0.00E+0	0.00E+0	0.00E+0
						Empty, C-dolly							
Tractor	524.26	1.00E+2	1.61E+1	6.10E+0	3.47E+0	1.57E+0	7.49E-1	3.14E-1	1.46E-1	9.36E-2	8.00E-2	1.97E-2	0.00E+0
Trailer1	592.47	1.00E+2	1.03E+1	3.23E+0	1.73E+0	8.88E-1	3.95E-1	1.12E-1	2.83E-2	6.48E-3	9.19E-4	0.00E+0	0.00E+0
Trailer2	546.28	1.00E+2	1.09E+1	3.73E+0	2.03E+0	1.04E+0	4.20E-1	1.42E-1	5.62E-2	4.26E-2	9.13E-3	8.67E-4	0.00E+0
Trailer3	530.60	1.00E+2	9.02E+0	2.31E+0	1.10E+0	5.24E-1	2.09E-1	5.95E-2	7.53E-3	6.19E-4	0.00E+0	0.00E+0	0.00E+0
						Fully loaded, A-dolly							
Tractor	87.08	1.00E+2	9.45E+0	2.14E+0	7.59E-1	1.86E-1	5.26E-2	6.92E-3	5.10E-4	1.91E-4	0.00E+0	0.00E+0	0.00E+0
Trailer1	35.23	1.00E+2	7.15E+0	2.10E+0	8.38E-1	2.67E-1	8.82E-2	1.59E-2	1.97E-3	4.73E-4	0.00E+0	0.00E+0	0.00E+0
Trailer2	41.68	1.00E+2	9.22E+0	2.30E+0	9.69E-1	3.05E-1	9.44E-2	1.53E-2	3.47E-3	4.00E-4	0.00E+0	0.00E+0	0.00E+0
Trailer3	37.38	1.00E+2	9.83E+0	2.40E+0	1.00E+0	3.27E-1	1.06E-1	2.60E-2	3.86E-3	4.46E-4	0.00E+0	0.00E+0	0.00E+0
						Fully loaded, C-dolly							
Tractor	645.81	1.00E+2	8.56E+0	2.26E+0	1.04E+0	3.75E-1	1.78E-1	7.23E-2	2.02E-2	9.57E-3	8.09E-3	7.79E-3	4.82E-3
Trailer1	686.16	1.00E+2	7.47E+0	2.52E+0	1.20E+0	4.64E-1	2.15E-1	9.75E-2	4.51E-2	2.47E-2	2.38E-3	4.21E-4	0.00E+0
Trailer2	624.46	1.00E+2	6.20E+0	1.32E+0	5.14E-1	1.60E-1	6.30E-2	1.59E-2	2.53E-3	2.45E-4	4.45E-6	0.00E+0	0.00E+0
Trailer3	633.38	1.00E+2	7.00E+0	1.50E+0	5.70E-1	1.70E-1	5.82E-2	1.54E-2	2.38E-3	2.46E-4	0.00E+0	0.00E+0	0.00E+0
						Mixed load, A-dolly							
Tractor	23.69	1.00E+2	8.03E+0	2.36E+0	1.08E+0	3.76E-1	1.49E-1	4.56E-2	7.04E-3	2.35E-4	0.00E+0	0.00E+0	0.00E+0
Trailer1	23.64	1.00E+2	1.96E+1	2.87E+0	1.31E+0	4.47E-1	2.07E-1	7.13E-2	1.75E-2	7.05E-4	0.00E+0	0.00E+0	0.00E+0
Trailer2	22.94	1.00E+2	8.56E+0	2.63E+0	1.22E+0	4.29E-1	1.94E-1	6.62E-2	1.68E-2	4.84E-4	0.00E+0	0.00E+0	0.00E+0
Trailer3	13.20	1.00E+2	5.96E+0	1.98E+0	7.60E-1	2.23E-1	1.00E-1	3.73E-2	1.12E-2	4.21E-4	0.00E+0	0.00E+0	0.00E+0
						Mixed load, C-dolly							
Tractor	175.04	1.00E+2	5.64E+0	2.21E+0	1.01E+0	3.29E-1	1.22E-1	2.16E-2	1.21E-3	3.17E-5	0.00E+0	0.00E+0	0.00E+0
Trailer1	158.01	1.00E+2	1.02E+1	2.37E+0	1.04E+0	3.46E-1	1.21E-1	2.68E-2	2.88E-3	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer2	166.17	1.00E+2	1.26E+1	2.10E+0	8.94E-1	2.61E-1	6.74E-2	8.16E-3	1.50E-4	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer3	177.19	1.00E+2	1.14E+1	2.53E+0	1.03E+0	3.04E-1	8.56E-2	1.26E-2	1.93E-3	5.96E-4	1.57E-5	0.00E+0	0.00E+0

* Total travel time of all vehicle units in a given category that contributed to these results

Table L-18. Cumulative lateral acceleration histogram data for Western doubles for different load conditions and dolly types

Unit Position	*Total Time**	*Percentage of travel time spent above the indicated level of lateral acceleration for speeds greater than 45 mph*											
	Hours	*> 0.00 g's*	*> 0.03 g's*	*> 0.06 g's*	*> 0.09 g's*	*> 0.12 g's*	*> 0.16 g's*	*> 0.19 g's*	*> 0.22 g's*	*> 0.25 g's*	*> 0.34 g's*	*> 0.40 g's*	*> 0.47 g's*
						Empty, A-dolly							
Tractor	86.24	1.16E+1	2.30E+0	9.47E-1	3.10E-1	9.56E-2	1.67E-2	5.12E-3	1.29E-3	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer1	76.31	1.16E+1	2.40E+0	1.06E+0	4.05E-1	1.62E-1	4.51E-2	7.35E-3	1.42E-3	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer2	78.23	1.70E+1	2.69E+0	1.16E+0	4.32E-1	1.67E-1	4.35E-2	8.70E-3	1.81E-3	0.00E+0	0.00E+0	0.00E+0	0.00E+0
						Empty, C-dolly							
Tractor	320.65	1.06E+1	2.19E+0	9.16E-1	3.05E-1	1.23E-1	4.03E-2	7.07E-3	3.98E-4	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer1	296.38	9.28E+0	2.21E+0	9.33E-1	3.11E-1	1.26E-1	3.77E-2	6.66E-3	5.53E-4	6.56E-5	9.37E-6	0.00E+0	0.00E+0
Trailer2	305.05	8.78E+0	2.10E+0	8.50E-1	2.73E-1	1.02E-1	2.91E-2	5.96E-3	3.37E-4	0.00E+0	0.00E+0	0.00E+0	0.00E+0
						Fully loaded, A-dolly							
Tractor	189.82	9.66E+0	1.83E+0	7.51E-1	2.37E-1	7.15E-2	1.42E-2	2.17E-3	1.61E-4	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer1	178.56	1.41E+1	2.42E+0	1.00E+0	3.44E-1	1.18E-1	2.65E-2	5.30E-3	3.11E-4	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer2	177.55	8.40E+0	2.33E+0	9.90E-1	3.32E-1	1.12E-1	2.72E-2	4.15E-3	2.97E-4	0.00E+0	0.00E+0	0.00E+0	0.00E+0
						Fully loaded, C-dolly							
Tractor	406.21	1.07E+1	2.04E+0	8.32E-1	2.66E-1	1.02E-1	2.61E-2	4.40E-3	2.60E-4	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer1	313.10	9.53E+0	2.04E+0	8.70E-1	3.02E-1	1.10E-1	2.43E-2	3.88E-3	1.69E-4	8.87E-6	0.00E+0	0.00E+0	0.00E+0
Trailer2	308.60	1.16E+1	2.00E+0	7.82E-1	2.51E-1	8.70E-2	1.88E-2	3.57E-3	1.17E-4	0.00E+0	0.00E+0	0.00E+0	0.00E+0
						Mixed load, A-dolly							
Tractor	26.37	5.81E+0	1.22E+0	6.07E-1	2.02E-1	6.97E-2	1.14E-2	1.69E-3	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer1	34.04	2.02E+1	2.94E+0	1.33E+0	3.77E-1	1.04E-1	2.24E-2	4.73E-3	2.45E-4	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer2	28.77	3.35E+1	2.99E+0	1.22E+0	3.09E-1	8.05E-2	2.22E-2	5.02E-3	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
						Mixed load, C-dolly							
Tractor	95.21	5.81E+0	1.24E+0	5.84E-1	1.97E-1	5.44E-2	9.66E-3	2.68E-3	2.04E-4	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer1	103.92	1.45E+1	2.40E+0	9.99E-1	3.11E-1	1.27E-1	2.76E-2	3.37E-3	8.02E-5	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Trailer2	96.40	1.06E+1	2.22E+0	8.98E-1	2.90E-1	1.06E-1	2.02E-2	3.11E-3	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0

* Total travel time of all vehicle units in a given category that contributed to these results

Table L-19. Cumulative lateral acceleration histogram data for Rocky Mountain doubles for different load conditions and dolly types

Unit Position	*Total Time**	*Percentage of travel time spent above the indicated level of lateral acceleration for speeds greater than 45 mph*											
	Hours	*> 0.00 g's*	*> 0.03 g's*	*> 0.06 g's*	*> 0.09 g's*	*> 0.12 g's*	*> 0.16 g's*	*> 0.19 g's*	*> 0.22 g's*	*> 0.25 g's*	*> 0.34 g's*	*> 0.40 g's*	*> 0.47 g's*
						Empty, A-dolly							
Tractor	106.19	1.00E+2	2.09E+1	4.91E+0	1.63E+0	4.32E-1	1.92E-1	7.38E-2	1.45E-2	4.45E-4	0.00E+0	0.00E+0	0.00E+0
Trailer1	101.54	1.00E+2	1.84E+1	7.93E+0	3.79E+0	1.34E+0	4.92E-1	2.48E-1	9.87E-2	5.79E-2	5.20E-2	4.60E-2	3.22E-2
Trailer2	86.57	1.00E+2	1.20E+1	3.57E+0	1.38E+0	4.13E-1	1.79E-1	7.42E-2	2.97E-2	2.18E-2	1.61E-2	1.38E-2	1.12E-2
						Empty, C-dolly							
Tractor	1053.40	1.00E+2	2.03E+1	7.91E+0	3.83E+0	1.40E+0	5.57E-1	1.99E-1	5.34E-2	9.23E-3	1.57E-3	1.12E-3	0.00E+0
Trailer1	991.34	1.00E+2	2.20E+1	7.20E+0	3.38E+0	1.16E+0	4.77E-1	1.63E-1	5.38E-2	2.83E-2	2.51E-2	2.43E-2	2.28E-2
Trailer2	965.48	1.00E+2	1.80E+1	7.56E+0	3.69E+0	1.31E+0	4.92E-1	1.57E-1	3.57E-2	3.24E-3	4.60E-5	3.45E-5	2.88E-5
						Fully loaded, C-dolly							
Tractor	157.24	1.00E+2	1.80E+1	3.88E+0	1.29E+0	2.97E-1	1.00E-1	2.95E-2	5.39E-3	1.94E-4	0.00E+0	0.00E+0	0.00E+0
Trailer1	132.33	1.00E+2	1.00E+1	3.12E+0	1.27E+0	4.37E-1	1.79E-1	5.35E-2	9.09E-3	1.47E-4	2.10E-5	0.00E+0	0.00E+0
Trailer2	138.49	1.00E+2	9.48E+0	2.63E+0	9.19E-1	2.65E-1	9.45E-2	2.55E-2	5.28E-3	3.81E-4	4.01E-5	0.00E+0	0.00E+0
						Fully loaded, C-dolly							
Tractor	1142.95	1.00E+2	1.90E+1	6.45E+0	2.95E+0	1.01E+0	4.24E-1	1.37E-1	2.55E-2	3.36E-3	1.96E-3	1.95E-3	1.50E-3
Trailer1	1016.77	1.00E+2	1.85E+1	6.42E+0	3.07E+0	1.14E+0	4.94E-1	1.68E-1	4.05E-2	1.50E-2	1.15E-2	1.12E-2	1.10E-2
Trailer2	1098.23	1.00E+2	1.52E+1	5.83E+0	2.73E+0	9.64E-1	4.17E-1	1.41E-1	2.86E-2	2.63E-3	0.00E+0	0.00E+0	0.00E+0

* Total travel time of all vehicle units in a given category that contributed to these results

Table L-20. Cumulative lateral acceleration histogram data for reverse Rocky Mountain doubles for different load conditions and dolly types

Unit Position	*Total Time**	*Percentage of travel time spent above the indicated level of lateral acceleration for speeds greater than 45 mph*											
	Hours	> 0.00 g's	> 0.03 g's	> 0.06 g's	> 0.09 g's	> 0.12 g's	> 0.16 g's	> 0.19 g's	> 0.22 g's	> 0.25 g's	> 0.34 g's	> 0.40 g's	> 0.47 g's
						Empty, A-dolly							
Tractor	119.95	1.00E+2	2.17E+1	5.14E+0	1.76E+0	4.96E-1	2.26E-1	1.01E-1	2.22E-2	1.02E-3	0.00E+0	0.00E+0	0.00E+0
Trailer1	117.26	1.00E+2	1.01E+1	3.22E+0	1.26E+0	4.17E-1	1.79E-1	5.67E-2	1.08E-2	7.11E-4	2.37E-5	0.00E+0	0.00E+0
Trailer2	106.61	1.00E+2	1.32E+1	5.43E+0	2.26E+0	6.50E-1	2.57E-1	9.36E-2	3.81E-2	2.50E-2	1.81E-2	1.57E-2	1.09E-2
						Empty, C-dolly							
Tractor	158.47	1.00E+2	1.80E+1	4.60E+0	1.65E+0	5.29E-1	2.39E-1	9.62E-2	2.35E-2	9.64E-4	0.00E+0	0.00E+0	0.00E+0
Trailer1	158.29	1.00E+2	1.35E+1	4.81E+0	1.99E+0	6.53E-1	2.79E-1	8.89E-2	2.04E-2	2.84E-3	1.75E-5	0.00E+0	0.00E+0
Trailer2	150.03	1.00E+2	1.11E+1	4.06E+0	1.91E+0	5.42E-1	2.46E-1	9.48E-2	2.14E-2	1.18E-3	0.00E+0	0.00E+0	0.00E+0
						Fully loaded, A-dolly							
Tractor	130.43	1.00E+2	1.89E+1	4.67E+0	1.68E+0	4.83E-1	1.81E-1	5.85E-2	1.31E-2	1.00E-3	0.00E+0	0.00E+0	0.00E+0
Trailer1	105.93	1.00E+2	9.32E+0	2.75E+0	1.07E+0	3.31E-1	1.21E-1	3.17E-2	8.29E-3	7.60E-4	0.00E+0	0.00E+0	0.00E+0
Trailer2	116.12	1.00E+2	1.70E+1	7.82E+0	3.36E+0	1.16E+0	4.11E-1	1.16E-1	2.27E-2	2.01E-3	0.00E+0	0.00E+0	0.00E+0
						Fully loaded, C-dolly							
Tractor	203.87	1.00E+2	1.79E+1	4.67E+0	1.76E+0	4.75E-1	1.65E-1	5.15E-2	1.05E-2	2.73E-4	0.00E+0	0.00E+0	0.00E+0
Trailer1	204.88	1.00E+2	1.13E+1	3.98E+0	1.80E+0	5.64E-1	1.95E-1	5.40E-2	1.23E-2	3.09E-3	0.00E+0	0.00E+0	0.00E+0
Trailer2	182.67	1.00E+2	9.49E+0	3.26E+0	1.37E+0	4.18E-1	1.64E-1	5.00E-2	8.11E-3	3.19E-4	0.00E+0	0.00E+0	0.00E+0

* Total travel time of all vehicle units in a given category that contributed to these results

Table L-21. Cumulative lateral acceleration histogram data for fully loaded western doubles

Unit Position	Total Time*	Percentage of travel time spent above the indicated level of lateral acceleration											
	Hours	*> 0.00 g's*	*> 0.03 g's*	*> 0.06 g's*	*> 0.09 g's*	*> 0.12 g's*	*> 0.16 g's*	*> 0.19 g's*	*> 0.22 g's*	*> 0.25 g's*	*> 0.34 g's*	*> 0.40 g's*	*> 0.47 g's*
45–55 mph													
A-dolly													
Tractor	332.92	1.00E+2	1.58E+1	3.57E+0	1.79E+0	6.98E-1	2.60E-1	6.03E-2	1.08E-2	9.18E-4	2.50E-15	2.50E-15	2.50E-15
Trailer1	332.29	1.00E+2	1.54E+1	4.02E+0	2.07E+0	8.40E-1	3.33E-1	8.83E-2	1.46E-2	5.85E-4	-5.82E-15	-5.82E-15	-5.82E-15
Trailer2	322.65	1.00E+2	1.12E+1	4.26E+0	2.23E+0	8.99E-1	3.79E-1	1.05E-1	1.91E-2	1.64E-3	2.85E-14	2.85E-14	2.85E-14
C-dolly													
Tractor	771.36	1.00E+2	1.37E+1	2.95E+0	1.37E+0	5.31E-1	2.55E-1	7.72E-2	1.51E-2	9.72E-4	-4.51E-15	-4.51E-15	-4.51E-15
Trailer1	639.86	1.00E+2	1.22E+1	3.25E+0	1.69E+0	6.87E-1	2.94E-1	8.91E-2	1.77E-2	7.38E-4	4.34E-5	-6.91E-15	-6.91E-15
Trailer2	621.83	1.00E+2	1.31E+1	2.96E+0	1.37E+0	5.41E-1	2.39E-1	7.18E-2	1.61E-2	3.57E-4	2.18E-14	2.18E-14	2.18E-14
55–65 mph													
A-dolly													
Tractor	1556.76	1.00E+2	8.37E+0	1.46E+0	5.33E-1	1.40E-1	3.15E-2	4.39E-3	3.39E-4	2.03E-15	2.03E-15	2.03E-15	2.03E-15
Trailer1	1445.19	1.00E+2	1.38E+1	2.05E+0	7.56E-1	2.32E-1	6.90E-2	1.25E-2	3.19E-3	2.50E-4	2.52E-14	2.52E-14	2.52E-14
Trailer2	1443.84	1.00E+2	7.74E+0	1.90E+0	7.16E-1	2.08E-1	5.34E-2	1.00E-2	8.27E-4	1.82E-15	1.82E-15	1.82E-15	1.82E-15
C-dolly													
Tractor	3134.27	1.00E+2	1.02E+1	1.82E+0	7.16E-1	2.09E-1	6.72E-2	1.42E-2	1.92E-3	9.75E-5	2.55E-14	2.55E-14	2.55E-14
Trailer1	2381.48	1.00E+2	8.96E+0	1.73E+0	6.71E-1	2.09E-1	6.47E-2	8.06E-3	3.50E-4	2.33E-5	-1.02E-14	-1.02E-14	-1.02E-14
Trailer2	2383.25	1.00E+2	1.13E+1	1.77E+0	6.44E-1	1.83E-1	5.01E-2	5.63E-3	4.31E-4	5.83E-5	6.10E-16	6.10E-16	6.10E-16
>65 mph													
A-dolly													
Tractor	8.50	1.00E+2	6.60E+0	1.43E+0	7.19E-2	5.19E-15	5.19E-15	5.19E-15	5.19E-15	5.19E-15	5.19E-15	5.19E-15	5.19E-15
Trailer1	8.16	1.00E+2	1.87E+1	2.66E+0	5.82E-1	2.04E-2	3.60E-15	3.60E-15	3.60E-15	3.60E-15	3.60E-15	3.60E-15	3.60E-15
Trailer2	8.96	1.00E+2	1.23E+1	2.16E+0	5.76E-1	6.20E-3	-5.51E-15	-5.51E-15	-5.51E-15	-5.51E-15	-5.51E-15	-5.51E-15	-5.51E-15
C-dolly													
Tractor	156.44	1.00E+2	6.63E+0	1.85E+0	5.36E-1	9.41E-2	3.62E-2	1.35E-2	1.60E-3	-1.17E-14	-1.17E-14	-1.17E-14	-1.17E-14
Trailer1	109.63	1.00E+2	6.03E+0	1.58E+0	4.27E-1	7.96E-2	8.61E-3	1.72E-15	1.72E-15	1.72E-15	1.72E-15	1.72E-15	1.72E-15
Trailer2	80.94	1.00E+2	7.37E+0	1.41E+0	3.54E-1	3.09E-2	3.77E-3	-1.12E-14	-1.12E-14	-1.12E-14	-1.12E-14	-1.12E-14	-1.12E-14

Table L-22. Cumulative lateral acceleration histogram data for empty western doubles

Unit Position	Total Time*	Percentage of travel time spent above the indicated level of lateral acceleration											
	Hours	> 0.00 g's	> 0.03 g's	> 0.06 g's	> 0.09 g's	> 0.12 g's	> 0.16 g's	> 0.19 g's	> 0.22 g's	> 0.25 g's	> 0.34 g's	> 0.40 g's	> 0.47 g's
45–55 mph													
A-dolly													
Tractor	108.73	1.00E+2	1.60E+1	4.77E+0	2.45E+0	9.01E-1	3.16E-1	9.76E-2	2.73E-2	2.81E-3	1.94E-16	1.94E-16	1.94E-16
Trailer1	120.29	1.00E+2	1.52E+1	4.62E+0	2.51E+0	1.03E+0	4.94E-1	2.01E-1	3.58E-2	2.31E-3	-1.12E-14	-1.12E-14	-1.12E-14
Trailer2	125.60	1.00E+2	1.79E+1	5.53E+0	2.96E+0	1.25E+0	5.70E-1	2.03E-1	3.78E-2	4.42E-3	-1.38E-14	-1.38E-14	-1.38E-14
C-dolly													
Tractor	471.27	1.00E+2	1.87E+1	5.23E+0	2.61E+0	9.00E-1	3.71E-1	1.30E-1	2.41E-2	2.06E-3	-1.34E-15	-1.34E-15	-1.34E-15
Trailer1	488.43	1.00E+2	1.48E+1	4.88E+0	2.43E+0	8.96E-1	3.85E-1	1.36E-1	2.62E-2	1.59E-3	5.69E-5	-5.65E-15	-5.65E-15
Trailer2	534.93	1.00E+2	1.23E+1	4.05E+0	1.99E+0	7.33E-1	3.00E-1	1.02E-1	2.33E-2	9.35E-4	-9.54E-15	-9.54E-15	-9.54E-15
55–65 mph													
A-dolly													
Tractor	752.86	1.00E+2	1.10E+1	1.93E+0	7.22E-1	2.20E-1	6.32E-2	5.02E-3	1.92E-3	1.07E-3	2.42E-14	2.42E-14	2.42E-14
Trailer1	642.20	1.00E+2	1.09E+1	1.98E+0	7.88E-1	2.88E-1	9.94E-2	1.60E-2	2.03E-3	1.25E-3	2.94E-14	2.94E-14	2.94E-14
Trailer2	656.04	1.00E+2	1.69E+1	2.14E+0	8.17E-1	2.75E-1	9.02E-2	1.30E-2	3.13E-3	1.31E-3	-1.24E-14	-1.24E-14	-1.24E-14
C-dolly													
Tractor	2648.31	1.00E+2	9.21E+0	1.64E+0	6.20E-1	2.05E-1	8.15E-2	2.53E-2	4.22E-3	1.15E-4	-2.53E-15	-2.53E-15	-2.53E-15
Trailer1	2408.23	1.00E+2	8.18E+0	1.66E+0	6.34E-1	1.98E-1	7.61E-2	1.86E-2	2.90E-3	3.58E-4	6.92E-5	1.15E-5	-7.71E-15
Trailer2	2391.07	1.00E+2	8.12E+0	1.68E+0	6.16E-1	1.81E-1	6.20E-2	1.44E-2	2.39E-3	2.21E-4	-1.52E-14	-1.52E-14	-1.52E-14
>65 mph													
A-dolly													
Tractor	0.86	1.00E+2	1.57E+1	1.04E+1	7.41E+0	4.81E+0	6.17E-1	-6.55E-15	-6.55E-15	-6.55E-15	-6.55E-15	-6.55E-15	-6.55E-15
Trailer1	0.66	1.00E+2	1.74E+1	8.68E+0	5.94E+0	2.95E-1	-6.77E-15	-6.77E-15	-6.77E-15	-6.77E-15	-6.77E-15	-6.77E-15	-6.77E-15
Trailer2	0.68	1.00E+2	1.69E+1	9.01E+0	5.11E+0	4.46E-1	6.00E-15	6.00E-15	6.00E-15	6.00E-15	6.00E-15	6.00E-15	6.00E-15
C-dolly													
Tractor	86.93	1.00E+2	7.63E+0	2.46E+0	7.32E-1	1.46E-1	4.12E-2	1.25E-2	1.60E-3	2.50E-14	2.50E-14	2.50E-14	2.50E-14
Trailer1	67.18	1.00E+2	8.40E+0	2.58E+0	7.79E-1	1.17E-1	3.93E-2	9.92E-3	2.70E-14	2.70E-14	2.70E-14	2.70E-14	2.70E-14
Trailer2	124.54	1.00E+2	6.11E+0	1.81E+0	4.35E-1	5.67E-2	1.18E-2	1.79E-15	1.79E-15	1.79E-15	1.79E-15	1.79E-15	1.79E-15

Table L-24. Cumulative lateral acceleration histogram data for fully loaded Rocky Mountain doubles

Unit Position	*Total Time**	*Percentage of travel time spent above the indicated level of lateral acceleration*											
	Hours	*> 0.00 g's*	*> 0.03 g's*	*> 0.06 g's*	*> 0.09 g's*	*> 0.12 g's*	*> 0.16 g's*	*> 0.19 g's*	*> 0.22 g's*	*> 0.25 g's*	*> 0.34 g's*	*> 0.40 g's*	*> 0.47 g's*
45–55 mph													
A-dolly													
Tractor	193.52	1.00E+2	2.04E+1	4.69E+0	1.93E+0	7.56E-1	3.58E-1	1.51E-1	3.63E-2	1.15E-3	3.68E-15	3.68E-15	3.68E-15
Trailer1	188.92	1.00E+2	1.13E+1	3.76E+0	1.86E+0	7.64E-1	3.24E-1	9.65E-2	1.88E-2	5.88E-4	-5.80E-15	-5.80E-15	-5.80E-15
Trailer2	176.86	1.00E+2	1.09E+1	3.68E+0	1.88E+0	7.98E-1	3.60E-1	1.27E-1	3.11E-2	1.57E-3	-1.44E-14	-1.44E-14	-1.44E-14
C-dolly													
Tractor	2652.78	1.00E+2	2.22E+1	8.75E+0	4.54E+0	1.84E+0	8.25E-1	2.89E-1	6.82E-2	1.12E-2	7.46E-3	7.43E-3	6.47E-3
Trailer1	2578.11	1.00E+2	2.23E+1	8.18E+0	4.26E+0	1.75E+0	7.74E-1	2.67E-1	7.67E-2	3.12E-2	2.66E-2	2.59E-2	2.53E-2
Trailer2	2773.28	1.00E+2	1.84E+1	7.96E+0	4.15E+0	1.68E+0	7.49E-1	2.60E-1	5.83E-2	5.70E-3	-7.66E-15	-7.66E-15	-7.66E-15
55–65 mph													
A-dolly													
Tractor	1367.00	1.00E+2	1.76E+1	3.75E+0	1.19E+0	2.32E-1	6.41E-2	1.25E-2	1.06E-3	6.10E-5	-1.61E-14	-1.61E-14	-1.61E-14
Trailer1	1127.21	1.00E+2	9.78E+0	2.98E+0	1.16E+0	3.73E-1	1.56E-1	4.66E-2	7.44E-3	7.39E-5	2.46E-5	-1.24E-14	-1.24E-14
Trailer2	1197.11	1.00E+2	9.20E+0	2.44E+0	7.69E-1	1.85E-1	5.56E-2	1.06E-2	1.51E-3	2.09E-4	4.64E-5	3.12E-15	3.12E-15
C-dolly													
Tractor	8472.18	1.00E+2	1.80E+1	5.68E+0	2.44E+0	7.44E-1	3.01E-1	8.96E-2	1.29E-2	1.03E-3	3.11E-4	3.05E-4	-2.28E-15
Trailer1	7072.16	1.00E+2	1.71E+1	5.72E+0	2.64E+0	9.39E-1	3.98E-1	1.34E-1	2.93E-2	1.01E-2	6.81E-3	6.59E-3	6.54E-3
Trailer2	7913.29	1.00E+2	1.39E+1	5.04E+0	2.22E+0	7.18E-1	3.06E-1	1.01E-1	1.85E-2	1.59E-3	-4.34E-15	-4.34E-15	-4.34E-15
>65 mph													
A-dolly													
Tractor	11.84	1.00E+2	2.01E+1	5.61E+0	2.82E+0	3.47E-1	3.29E-2	-8.49E-15	-8.49E-15	-8.49E-15	-8.49E-15	-8.49E-15	-8.49E-15
Trailer1	7.22	1.00E+2	1.97E+1	8.04E+0	3.88E+0	1.79E+0	1.92E-2	1.54E-2	1.15E-2	-1.36E-15	-1.36E-15	-1.36E-15	-1.36E-15
Trailer2	10.93	1.00E+2	1.65E+1	5.70E+0	1.75E+0	3.71E-1	5.85E-2	1.53E-2	-1.19E-14	-1.19E-14	-1.19E-14	-1.19E-14	-1.19E-14
C-dolly													
Tractor	304.50	1.00E+2	2.04E+1	7.89E+0	3.44E+0	1.00E+0	3.45E-1	1.13E-1	4.38E-3	3.37E-16	3.37E-16	3.37E-16	3.37E-16
Trailer1	517.38	1.00E+2	1.96E+1	7.20E+0	3.08E+0	9.05E-1	4.09E-1	1.40E-1	1.35E-2	3.29E-14	3.29E-14	3.29E-14	3.29E-14
Trailer2	295.77	1.00E+2	1.84E+1	6.93E+0	3.03E+0	8.45E-1	2.81E-1	9.69E-2	1.93E-2	1.50E-3	-1.04E-14	-1.04E-14	-1.04E-14

Table L-23. Cumulative lateral acceleration histogram data for mixed-load western doubles

Unit Position	*Total Time* Hours*	*Percentage of travel time spent above the indicated level of lateral acceleration* > 0.00 g's	> 0.03 g's	> 0.06 g's	> 0.09 g's	> 0.12 g's	> 0.16 g's	> 0.19 g's	> 0.22 g's	> 0.25 g's	> 0.34 g's	> 0.40 g's	> 0.47 g's
45–55 mph													
A-dolly													
Tractor	49.00	1.00E+2	2.09E+1	4.83E+0	2.67E+0	9.79E-1	3.54E-1	6.12E-2	9.07E-3	7.93E-15	7.93E-15	7.93E-15	7.93E-15
Trailer1	65.38	1.00E+2	2.28E+1	5.86E+0	3.16E+0	1.09E+0	4.15E-1	1.05E-1	2.25E-2	1.27E-3	7.96E-15	7.96E-15	7.96E-15
Trailer2	76.26	1.00E+2	3.02E+1	5.26E+0	2.52E+0	7.53E-1	2.56E-1	8.38E-2	1.89E-2	-1.17E-14	-1.17E-14	-1.17E-14	-1.17E-14
C-dolly													
Tractor	159.24	1.00E+2	1.59E+1	2.64E+0	1.44E+0	6.29E-1	2.01E-1	3.40E-2	6.45E-3	5.94E-15	5.94E-15	5.94E-15	5.94E-15
Trailer1	173.09	1.00E+2	1.66E+1	4.14E+0	2.06E+0	7.18E-1	3.18E-1	9.97E-2	1.43E-2	-5.89E-15	-5.89E-15	-5.89E-15	-5.89E-15
Trailer2	166.10	1.00E+2	1.46E+1	4.22E+0	2.13E+0	7.95E-1	3.11E-1	8.06E-2	1.39E-2	3.19E-15	3.19E-15	3.19E-15	3.19E-15
55–65 mph													
A-dolly													
Tractor	213.16	1.00E+2	2.30E+0	3.93E-1	1.35E-1	2.49E-2	4.82E-3	-1.20E-14	-1.20E-14	-1.20E-14	-1.20E-14	-1.20E-14	-1.20E-14
Trailer1	273.50	1.00E+2	1.95E+1	2.22E+0	8.92E-1	2.07E-1	3.04E-2	2.64E-3	5.08E-4	-8.84E-15	-8.84E-15	-8.84E-15	-8.84E-15
Trailer2	210.45	1.00E+2	3.46E+1	2.16E+0	7.45E-1	1.49E-1	1.72E-2	-9.83E-15	-9.83E-15	-9.83E-15	-9.83E-15	-9.83E-15	-9.83E-15
C-dolly													
Tractor	790.79	1.00E+2	3.77E+0	9.66E-1	4.12E-1	1.10E-1	2.51E-2	4.78E-3	1.93E-3	2.46E-4	2.36E-15	2.36E-15	2.36E-15
Trailer1	863.45	1.00E+2	1.40E+1	2.05E+0	7.88E-1	2.30E-1	8.93E-2	1.33E-2	1.19E-3	9.65E-5	-2.39E-14	-2.39E-14	-2.39E-14
Trailer2	795.82	1.00E+2	9.70E+0	1.80E+0	6.42E-1	1.85E-1	6.37E-2	7.61E-3	8.73E-4	8.19E-15	8.19E-15	8.19E-15	8.19E-15
>65 mph													
A-dolly													
Tractor	1.56	1.00E+2	1.00E+1	1.43E-1	1.25E-1	2.91E-14	2.91E-14	2.91E-14	2.91E-14	2.91E-14	2.91E-14	2.91E-14	2.91E-14
Trailer1	1.48	1.00E+2	2.83E+1	7.19E+0	2.08E+0	5.62E-2	-1.22E-14	-1.22E-14	-1.22E-14	-1.22E-14	-1.22E-14	-1.22E-14	-1.22E-14
Trailer2	1.01	1.00E+2	4.16E+1	4.97E+0	1.65E+0	1.10E-1	4.72E-16	4.72E-16	4.72E-16	4.72E-16	4.72E-16	4.72E-16	4.72E-16
C-dolly													
Tractor	2.02	1.00E+2	1.09E+1	2.75E-1	2.34E-1	9.62E-2	-9.87E-15	-9.87E-15	-9.87E-15	-9.87E-15	-9.87E-15	-9.87E-15	-9.87E-15
Trailer1	2.66	1.00E+2	2.25E+1	2.05E+0	9.40E-1	1.67E-1	3.89E-16	3.89E-16	3.89E-16	3.89E-16	3.89E-16	3.89E-16	3.89E-16
Trailer2	2.13	1.00E+2	1.89E+1	1.38E+0	5.22E-1	1.12E-14	1.12E-14	1.12E-14	1.12E-14	1.12E-14	1.12E-14	1.12E-14	1.12E-14

Table L-25. Cumulative lateral acceleration histogram data for empty Rocky Mountain doubles

Unit Position	Total Time*	Percentage of travel time spent above the indicated level of lateral acceleration											
	Hours	*> 0.00 g's*	*> 0.03 g's*	*> 0.06 g's*	*> 0.09 g's*	*> 0.12 g's*	*> 0.16 g's*	*> 0.19 g's*	*> 0.22 g's*	*> 0.25 g's*	*> 0.34 g's*	*> 0.40 g's*	*> 0.47 g's*
45–55 mph													
A-dolly													
Tractor	145.61	1.00E+2	2.39E+1	6.48E+0	3.08E+0	1.37E+0	8.04E-1	3.53E-1	7.04E-2	3.24E-3	-6.58E-15	-6.58E-15	-6.58E-15
Trailer1	174.39	1.00E+2	1.72E+1	6.84E+0	3.29E+0	1.48E+0	6.77E-1	2.32E-1	3.98E-2	7.96E-3	4.30E-3	2.00E-15	2.00E-15
Trailer2	121.79	1.00E+2	1.35E+1	5.36E+0	2.89E+0	1.39E+0	6.96E-1	2.50E-1	3.26E-2	2.74E-3	6.84E-4	4.56E-4	4.56E-4
C-dolly													
Tractor	2198.39	1.00E+2	2.63E+1	1.28E+1	7.27E+0	3.04E+0	1.39E+0	5.38E-1	1.45E-1	1.42E-2	3.29E-4	-1.82E-14	-1.82E-14
Trailer1	2069.79	1.00E+2	2.94E+1	1.20E+1	6.56E+0	2.74E+0	1.23E+0	4.40E-1	1.37E-1	6.01E-2	5.55E-2	5.55E-2	5.54E-2
Trailer2	2142.13	1.00E+2	2.42E+1	1.23E+1	6.94E+0	2.87E+0	1.23E+0	4.32E-1	1.09E-1	1.02E-2	5.19E-5	5.19E-5	5.19E-5
55–65 mph													
A-dolly													
Tractor	911.20	1.00E+2	2.03E+1	4.61E+0	1.38E+0	2.77E-1	9.48E-2	2.96E-2	5.64E-3	-2.47E-15	-2.47E-15	-2.47E-15	-2.47E-15
Trailer1	836.77	1.00E+2	1.86E+1	8.15E+0	3.89E+0	1.31E+0	4.56E-1	2.52E-1	1.11E-1	6.86E-2	6.22E-2	5.58E-2	3.90E-2
Trailer2	739.34	1.00E+2	1.17E+1	3.24E+0	1.11E+0	2.52E-1	9.50E-2	4.56E-2	2.95E-2	2.50E-2	1.87E-2	1.61E-2	1.30E-2
C-dolly													
Tractor	7984.57	1.00E+2	1.87E+1	6.55E+0	2.87E+0	9.68E-1	3.42E-1	1.12E-1	3.01E-2	8.15E-3	1.98E-3	1.47E-3	2.52E-14
Trailer1	7239.68	1.00E+2	2.02E+1	5.90E+0	2.53E+0	7.48E-1	2.82E-1	9.24E-2	3.38E-2	2.15E-2	1.84E-2	1.74E-2	1.54E-2
Trailer2	7217.73	1.00E+2	1.62E+1	6.24E+0	2.78E+0	8.80E-1	2.85E-1	8.00E-2	1.49E-2	1.19E-3	1.15E-5	3.85E-6	-2.04E-14
>65 mph													
A-dolly													
Tractor	5.10	1.00E+2	3.13E+1	1.29E+1	5.32E+0	1.27E+0	5.99E-2	-4.77E-15	-4.77E-15	-4.77E-15	-4.77E-15	-4.77E-15	-4.77E-15
Trailer1	4.21	1.00E+2	2.47E+1	9.08E+0	4.05E+0	4.82E-1	-4.83E-15	-4.83E-15	-4.83E-15	-4.83E-15	-4.83E-15	-4.83E-15	-4.83E-15
Trailer2	4.58	1.00E+2	2.34E+1	8.51E+0	4.12E+0	5.34E-1	3.03E-2	2.17E-15	2.17E-15	2.17E-15	2.17E-15	2.17E-15	2.17E-15
C-dolly													
Tractor	351.04	1.00E+2	1.82E+1	8.34E+0	3.99E+0	8.83E-1	2.52E-1	6.46E-2	9.89E-3	2.61E-3	8.02E-15	8.02E-15	8.02E-15
Trailer1	603.89	1.00E+2	1.87E+1	6.32E+0	2.67E+0	7.41E-1	2.24E-1	5.56E-2	8.14E-3	7.36E-4	6.90E-4	6.90E-4	-8.29E-15
Trailer2	294.93	1.00E+2	1.64E+1	5.31E+0	2.28E+0	6.47E-1	2.01E-1	5.02E-2	1.11E-2	2.64E-3	8.48E-4	6.59E-4	5.65E-4

Table L-26. Cumulative lateral acceleration histogram data for fully loaded reverse Rockies

Unit Position	Total Time* Hours	Percentage of travel time spent above the indicated level of lateral acceleration											
		> 0.00 g's	*> 0.03 g's*	*> 0.06 g's*	*> 0.09 g's*	*> 0.12 g's*	*> 0.16 g's*	*> 0.19 g's*	*> 0.22 g's*	*> 0.25 g's*	*> 0.34 g's*	*> 0.40 g's*	*> 0.47 g's*
45–55 mph													
A-dolly													
Tractor	178.15	1.00E+2	2.21E+1	5.71E+0	2.36E+0	9.43E-1	4.06E-1	1.67E-1	5.33E-2	5.15E-3	4.45E-15	4.45E-15	4.45E-15
Trailer1	154.06	1.00E+2	1.07E+1	3.37E+0	1.85E+0	8.81E-1	3.77E-1	1.38E-1	4.44E-2	3.43E-3	-7.78E-15	-7.78E-15	-7.78E-15
Trailer2	177.93	1.00E+2	1.64E+1	8.28E+0	4.68E+0	2.24E+0	8.44E-1	2.44E-1	5.50E-2	5.00E-3	2.48E-14	2.48E-14	2.48E-14
C-dolly													
Tractor	300.68	1.00E+2	2.23E+1	5.95E+0	2.66E+0	1.01E+0	4.35E-1	1.57E-1	4.43E-2	8.31E-4	5.69E-15	5.69E-15	5.69E-15
Trailer1	329.44	1.00E+2	1.26E+1	4.70E+0	2.44E+0	9.41E-1	4.10E-1	1.36E-1	1.75E-2	1.77E-3	-1.55E-14	-1.55E-14	-1.55E-14
Trailer2	291.41	1.00E+2	1.09E+1	4.34E+0	2.24E+0	8.94E-1	4.13E-1	1.56E-1	3.38E-2	9.53E-4	-7.28E-16	-7.28E-16	-7.28E-16
55–65 mph													
A-dolly													
Tractor	1109.71	1.00E+2	1.83E+1	4.42E+0	1.53E+0	3.95E-1	1.36E-1	3.91E-2	6.73E-3	3.50E-4	-2.58E-14	-2.58E-14	-2.58E-14
Trailer1	891.49	1.00E+2	8.90E+0	2.57E+0	8.98E-1	2.25E-1	7.26E-2	1.30E-2	1.99E-3	2.49E-4	-1.10E-14	-1.10E-14	-1.10E-14
Trailer2	969.81	1.00E+2	1.70E+1	7.70E+0	3.11E+0	9.54E-1	3.33E-1	9.36E-2	1.72E-2	1.49E-3	4.26E-15	4.26E-15	4.26E-15
C-dolly													
Tractor	1717.05	1.00E+2	1.70E+1	4.37E+0	1.58E+0	3.76E-1	1.16E-1	3.34E-2	4.69E-3	1.78E-4	5.03E-15	5.03E-15	5.03E-15
Trailer1	1699.66	1.00E+2	1.10E+1	3.78E+0	1.65E+0	4.88E-1	1.53E-1	3.87E-2	1.14E-2	3.38E-3	-9.05E-15	-9.05E-15	-9.05E-15
Trailer2	1520.75	1.00E+2	9.11E+0	2.99E+0	1.18E+0	3.23E-1	1.16E-1	3.01E-2	3.25E-3	2.01E-4	6.43E-15	6.43E-15	6.43E-15
>65 mph													
A-dolly													
Tractor	16.47	1.00E+2	2.77E+1	1.03E+1	3.97E+0	1.43E+0	7.76E-1	1.96E-1	8.43E-3	-1.49E-14	-1.49E-14	-1.49E-14	-1.49E-14
Trailer1	13.76	1.00E+2	2.06E+1	7.48E+0	3.25E+0	1.05E+0	3.63E-1	5.25E-2	1.21E-2	4.04E-3	-1.04E-14	-1.04E-14	-1.04E-14
Trailer2	13.47	1.00E+2	2.24E+1	1.04E+1	4.24E+0	1.97E+0	3.30E-1	6.18E-3	-1.06E-14	-1.06E-14	-1.06E-14	-1.06E-14	-1.06E-14
C-dolly													
Tractor	20.97	1.00E+2	2.66E+1	1.12E+1	3.82E+0	8.80E-1	2.44E-1	1.32E-2	-5.55E-16	-5.55E-16	-5.55E-16	-5.55E-16	-5.55E-16
Trailer1	19.69	1.00E+2	2.28E+1	9.24E+0	3.52E+0	7.45E-1	1.54E-1	2.82E-3	-1.72E-14	-1.72E-14	-1.72E-14	-1.72E-14	-1.72E-14
Trailer2	14.52	1.00E+2	2.21E+1	9.22E+0	3.71E+0	7.46E-1	1.47E-1	-7.94E-15	-7.94E-15	-7.94E-15	-7.94E-15	-7.94E-15	-7.94E-15

Table L-27. Cumulative lateral acceleration histogram data for empty reverse Rockies

Unit Position	Total Time*	Percentage of travel time spent above the indicated level of lateral acceleration											
	Hours	> 0.00 g's	> 0.03 g's	> 0.06 g's	> 0.09 g's	> 0.12 g's	> 0.16 g's	> 0.19 g's	> 0.22 g's	> 0.25 g's	> 0.34 g's	> 0.40 g's	> 0.47 g's
45–55 mph													
A-dolly													
Tractor	131.62	1.00E+2	2.69E+1	7.65E+0	3.71E+0	1.73E+0	9.97E-1	4.88E-1	1.19E-1	4.64E-3	-7.35E-15	-7.35E-15	-7.35E-15
Trailer1	144.85	1.00E+2	1.28E+1	5.36E+0	3.06E+0	1.52E+0	7.62E-1	2.76E-1	4.53E-2	2.30E-3	-2.47E-15	-2.47E-15	-2.47E-15
Trailer2	143.59	1.00E+2	1.47E+1	6.22E+0	3.18E+0	1.41E+0	6.81E-1	2.78E-1	7.60E-2	2.63E-2	1.88E-2	1.84E-2	1.55E-2
C-dolly													
Tractor	191.80	1.00E+2	2.42E+1	7.80E+0	3.97E+0	1.75E+0	8.87E-1	3.63E-1	9.30E-2	5.50E-3	6.02E-15	6.02E-15	6.02E-15
Trailer1	218.38	1.00E+2	1.76E+1	7.84E+0	4.22E+0	1.70E+0	8.21E-1	3.07E-1	7.43E-2	1.02E-2	-4.77E-15	-4.77E-15	-4.77E-15
Trailer2	221.71	1.00E+2	1.42E+1	6.27E+0	3.65E+0	1.60E+0	7.84E-1	2.84E-1	6.36E-2	2.13E-3	-1.87E-14	-1.87E-14	-1.87E-14
55–65 mph													
A-dolly													
Tractor	1061.97	1.00E+2	2.10E+1	4.78E+0	1.48E+0	3.38E-1	1.30E-1	5.33E-2	1.03E-2	5.75E-4	-1.81E-14	-1.81E-14	-1.81E-14
Trailer1	1022.51	1.00E+2	9.65E+0	2.88E+0	9.92E-1	2.58E-1	9.65E-2	2.59E-2	5.95E-3	4.89E-4	2.72E-5	-1.95E-14	-1.95E-14
Trailer2	917.78	1.00E+2	1.29E+1	5.27E+0	2.10E+0	5.30E-1	1.90E-1	6.51E-2	3.24E-2	2.49E-2	1.81E-2	1.54E-2	1.03E-2
C-dolly													
Tractor	1383.56	1.00E+2	1.70E+1	4.08E+0	1.28E+0	3.37E-1	1.44E-1	5.74E-2	1.33E-2	3.41E-4	7.56E-16	7.56E-16	7.56E-16
Trailer1	1356.72	1.00E+2	1.27E+1	4.27E+0	1.60E+0	4.75E-1	1.92E-1	5.43E-2	1.18E-2	1.68E-3	2.05E-5	4.68E-15	4.68E-15
Trailer2	1270.68	1.00E+2	1.04E+1	3.60E+0	1.57E+0	3.39E-1	1.45E-1	5.79E-2	1.26E-2	9.40E-4	-3.40E-15	-3.40E-15	-3.40E-15
>65 mph													
A-dolly													
Tractor	5.88	1.00E+2	3.67E+1	1.45E+1	7.30E+0	1.30E+0	2.08E-1	6.61E-2	-7.66E-15	-7.66E-15	-7.66E-15	-7.66E-15	-7.66E-15
Trailer1	5.25	1.00E+2	2.55E+1	1.11E+1	4.72E+0	8.63E-1	1.80E-1	-2.41E-15	-2.41E-15	-2.41E-15	-2.41E-15	-2.41E-15	-2.41E-15
Trailer2	4.75	1.00E+2	2.76E+1	1.25E+1	4.92E+0	9.77E-1	2.46E-1	5.85E-3	-1.17E-14	-1.17E-14	-1.17E-14	-1.17E-14	-1.17E-14
C-dolly													
Tractor	9.31	1.00E+2	2.96E+1	1.62E+1	9.12E+0	3.90E+0	9.42E-1	3.64E-1	1.16E-1	-5.20E-15	-5.20E-15	-5.20E-15	-5.20E-15
Trailer1	7.79	1.00E+2	2.47E+1	1.35E+1	7.37E+0	2.22E+0	3.03E-1	1.07E-2	-4.86E-15	-4.86E-15	-4.86E-15	-4.86E-15	-4.86E-15
Trailer2	7.88	1.00E+2	2.80E+1	1.64E+1	9.27E+0	3.34E+0	1.34E+0	7.36E-1	2.57E-1	1.41E-2	-5.85E-16	-5.85E-16	-5.85E-16

Table L-28. Cumulative lateral acceleration histogram data for fully loaded triples

Unit Position	Total Time* Hours	Percentage of travel time spent above the indicated level of lateral acceleration										
		> 0.00 g's	> 0.03 g's	> 0.06 g's	> 0.09 g's	> 0.12 g's	> 0.16 g's	> 0.19 g's	> 0.22 g's	> 0.25 g's	> 0.34 g's	> 0.40 g's	> 0.47 g's
45–55 mph													
A-dolly													
Tractor	169.46	1.00E+2	1.05E+1	2.10E+0	9.07E-1	2.90E-1	1.04E-1	1.62E-2	3.28E-4	1.64E-4	-1.19E-14	-1.19E-14	-1.19E-14
Trailer1	80.62	1.00E+2	6.56E+0	1.80E+0	9.79E-1	4.03E-1	2.03E-1	4.34E-2	4.13E-3	1.03E-3	2.45E-16	2.45E-16	2.45E-16
Trailer2	92.73	1.00E+2	7.93E+0	1.92E+0	1.02E+0	4.45E-1	1.91E-1	3.74E-2	6.29E-3	8.99E-4	1.84E-15	1.84E-15	1.84E-15
Trailer3	82.40	1.00E+2	9.98E+0	2.10E+0	1.09E+0	4.88E-1	2.21E-1	8.19E-2	1.35E-2	1.01E-3	-3.31E-15	-3.31E-15	-3.31E-15
C-dolly													
Tractor	987.34	1.00E+2	1.02E+1	3.15E+0	1.66E+0	7.22E-1	4.16E-1	1.90E-1	5.31E-2	2.15E-2	2.05E-2	1.86E-2	8.02E-3
Trailer1	1062.46	1.00E+2	8.81E+0	2.87E+0	1.38E+0	5.56E-1	2.58E-1	1.15E-1	5.56E-2	3.19E-2	2.30E-14	2.30E-14	2.30E-14
Trailer2	1013.56	1.00E+2	7.81E+0	1.76E+0	7.81E-1	2.86E-1	1.23E-1	3.16E-2	7.89E-3	8.50E-4	2.74E-5	-7.39E-16	-7.39E-16
Trailer3	1028.47	1.00E+2	9.04E+0	2.13E+0	9.22E-1	3.20E-1	1.26E-1	4.26E-2	7.81E-3	8.64E-4	-5.20E-15	-5.20E-15	-5.20E-15
55–65 mph													
A-dolly													
Tractor	699.12	1.00E+2	9.19E+0	2.14E+0	7.15E-1	1.61E-1	4.02E-2	4.69E-3	5.56E-4	1.99E-4	-4.25E-15	-4.25E-15	-4.25E-15
Trailer1	269.90	1.00E+2	7.27E+0	2.17E+0	7.82E-1	2.24E-1	5.46E-2	7.82E-3	1.34E-3	3.09E-4	2.35E-15	2.35E-15	2.35E-15
Trailer2	322.38	1.00E+2	9.50E+0	2.38E+0	9.44E-1	2.67E-1	6.70E-2	9.05E-3	2.67E-3	2.58E-4	-3.40E-15	-3.40E-15	-3.40E-15
Trailer3	289.74	1.00E+2	9.77E+0	2.47E+0	9.70E-1	2.81E-1	7.40E-2	1.03E-2	1.15E-3	2.88E-4	3.70E-15	3.70E-15	3.70E-15
C-dolly													
Tractor	4954.93	1.00E+2	8.34E+0	2.15E+0	9.65E-1	3.37E-1	1.46E-1	5.50E-2	1.53E-2	8.19E-3	6.46E-3	6.44E-3	4.68E-3
Trailer1	5323.67	1.00E+2	7.01E+0	2.35E+0	1.11E+0	4.11E-1	1.80E-1	7.68E-2	3.96E-2	2.32E-2	2.09E-3	1.57E-5	3.51E-14
Trailer2	4783.52	1.00E+2	5.86E+0	1.21E+0	4.65E-1	1.43E-1	5.41E-2	1.34E-2	1.49E-3	1.39E-4	8.63E-15	8.63E-15	8.63E-15
Trailer3	4882.89	1.00E+2	6.57E+0	1.36E+0	5.01E-1	1.47E-1	4.70E-2	1.06E-2	1.38E-3	1.37E-4	-2.56E-15	-2.56E-15	-2.56E-15
>65 mph													
A-dolly													
Tractor	2.17	1.00E+2	1.39E+1	5.83E+0	3.20E+0	-5.33E-15	-5.33E-15	-5.33E-15	-5.33E-15	-5.33E-15	-5.33E-15	-5.33E-15	-5.33E-15
Trailer1	1.77	1.00E+2	1.45E+1	5.74E+0	2.82E+0	5.80E-1	-2.32E-14	-2.32E-14	-2.32E-14	-2.32E-14	-2.32E-14	-2.32E-14	-2.32E-14
Trailer2	1.70	1.00E+2	2.48E+1	6.57E+0	3.19E+0	1.63E-2	-1.22E-14	-1.22E-14	-1.22E-14	-1.22E-14	-1.22E-14	-1.22E-14	-1.22E-14
Trailer3	1.62	1.00E+2	1.37E+1	4.02E+0	1.79E+0	3.60E-1	-5.55E-17	-5.55E-17	-5.55E-17	-5.55E-17	-5.55E-17	-5.55E-17	-5.55E-17
C-dolly													
Tractor	515.88	1.00E+2	7.61E+0	1.61E+0	5.34E-1	8.08E-2	2.56E-2	1.39E-2	4.36E-3	5.38E-5	2.93E-14	2.93E-14	2.93E-14
Trailer1	475.48	1.00E+2	9.57E+0	3.63E+0	1.77E+0	8.48E-1	5.10E-1	2.90E-1	8.35E-2	2.63E-2	1.09E-2	5.90E-3	2.73E-14
Trailer2	447.49	1.00E+2	6.18E+0	1.49E+0	4.38E-1	6.25E-2	2.21E-2	7.08E-3	1.55E-3	-8.27E-15	-8.27E-15	-8.27E-15	-8.27E-15
Trailer3	422.47	1.00E+2	7.07E+0	1.60E+0	5.21E-1	7.18E-2	2.27E-2	4.27E-3	7.89E-4	1.65E-16	1.65E-16	1.65E-16	1.65E-16

Table L-29. Cumulative lateral acceleration histogram data for empty triples

Unit Position	Total Time*	Percentage of travel time spent above the indicated level of lateral acceleration											
	Hours	*> 0.00 g's*	*> 0.03 g's*	*> 0.06 g's*	*> 0.09 g's*	*> 0.12 g's*	*> 0.16 g's*	*> 0.19 g's*	*> 0.22 g's*	*> 0.25 g's*	*> 0.34 g's*	*> 0.40 g's*	*> 0.47 g's*
45–55 mph													
A-dolly													
Tractor	25.79	1.00E+2	1.62E+1	4.09E+0	2.08E+0	9.65E-1	3.24E-1	7.65E-2	6.46E-3	-6.94E-15	-6.94E-15	-6.94E-15	-6.94E-15
Trailer1	26.42	1.00E+2	1.30E+1	3.78E+0	1.78E+0	7.80E-1	2.99E-1	1.02E-1	-1.13E-14	-1.13E-14	-1.13E-14	-1.13E-14	-1.13E-14
Trailer2	28.20	1.00E+2	1.17E+1	4.05E+0	2.00E+0	8.82E-1	3.24E-1	1.31E-1	8.87E-3	-8.03E-15	-8.03E-15	-8.03E-15	-8.03E-15
Trailer3	25.38	1.00E+2	2.57E+1	8.85E+0	4.82E+0	2.50E+0	1.15E+0	2.51E-1	3.61E-2	2.19E-3	-3.88E-15	-3.88E-15	-3.88E-15
C-dolly													
Tractor	512.75	1.00E+2	1.61E+1	6.10E+0	3.47E+0	1.57E+0	7.49E-1	3.14E-1	1.46E-1	9.36E-2	8.00E-2	1.97E-2	8.19E-16
Trailer1	604.22	1.00E+2	1.03E+1	3.23E+0	1.73E+0	8.88E-1	3.95E-1	1.12E-1	2.83E-2	6.48E-3	9.19E-4	-6.13E-16	-6.13E-16
Trailer2	544.78	1.00E+2	1.09E+1	3.73E+0	2.03E+0	1.04E+0	4.20E-1	1.42E-1	5.62E-2	4.26E-2	9.13E-3	8.67E-4	-3.47E-15
Trailer3	538.23	1.00E+2	9.02E+0	2.31E+0	1.10E+0	5.24E-1	2.09E-1	5.95E-2	7.53E-3	6.19E-4	-2.27E-15	-2.27E-15	-2.27E-15
55–65 mph													
A-dolly													
Tractor	130.93	1.00E+2	1.33E+1	1.67E+0	4.94E-1	1.04E-1	4.20E-2	1.44E-2	2.42E-15	2.42E-15	2.42E-15	2.42E-15	2.42E-15
Trailer1	96.67	1.00E+2	8.95E+0	1.61E+0	4.36E-1	8.99E-2	4.11E-2	1.47E-2	1.95E-14	1.95E-14	1.95E-14	1.95E-14	1.95E-14
Trailer2	127.66	1.00E+2	6.49E+0	1.42E+0	4.33E-1	9.53E-2	4.53E-2	1.46E-2	1.31E-3	1.99E-15	1.99E-15	1.99E-15	1.99E-15
Trailer3	111.63	1.00E+2	2.60E+1	1.28E+1	7.02E+0	2.20E+0	8.32E-1	2.06E-1	1.82E-2	1.99E-3	5.14E-15	5.14E-15	5.14E-15
C-dolly													
Tractor	4183.94	1.00E+2	9.76E+0	4.21E+0	2.53E+0	5.45E-1	2.71E-1	1.44E-1	1.00E-1	8.92E-2	8.71E-2	3.72E-2	5.50E-3
Trailer1	4875.45	1.00E+2	5.74E+0	1.72E+0	7.25E-1	2.14E-1	8.63E-2	3.03E-2	7.67E-3	7.29E-4	-4.62E-15	-4.62E-15	-4.62E-15
Trailer2	4406.37	1.00E+2	6.03E+0	1.94E+0	8.57E-1	3.55E-1	1.61E-1	7.91E-2	4.61E-2	2.31E-2	5.86E-4	1.89E-5	-6.47E-15
Trailer3	4315.76	1.00E+2	5.43E+0	1.33E+0	5.19E-1	1.80E-1	8.06E-2	3.16E-2	7.50E-3	7.21E-4	9.65E-5	9.01E-5	5.15E-5
>65 mph													
A-dolly													
Tractor	0.06	1.00E+2	3.99E+1	1.87E+1	1.67E+1	1.21E+1	3.55E-15	3.55E-15	3.55E-15	3.55E-15	3.55E-15	3.55E-15	3.55E-15
Trailer1	0.06	1.00E+2	3.00E+1	1.74E+1	1.55E+1	1.01E+1	2.42E+0	-8.88E-16	-8.88E-16	-8.88E-16	-8.88E-16	-8.88E-16	-8.88E-16
Trailer2	0.07	1.00E+2	2.31E+1	1.43E+1	1.30E+1	5.46E+0	2.94E+0	-3.11E-15	-3.11E-15	-3.11E-15	-3.11E-15	-3.11E-15	-3.11E-15
Trailer3	0.06	1.00E+2	7.21E+1	6.07E+1	3.36E+1	1.14E+1	9.61E+0	8.30E+0	2.18E+0	1.31E+0	-3.11E-15	-3.11E-15	-3.11E-15
C-dolly													
Tractor	545.94	1.00E+2	6.97E+0	2.33E+0	7.96E-1	1.40E-1	6.81E-2	2.98E-2	1.05E-2	8.19E-3	8.14E-3	1.83E-3	3.45E-14
Trailer1	445.04	1.00E+2	6.39E+0	2.10E+0	5.81E-1	8.39E-2	3.19E-2	9.36E-3	2.06E-3	-3.94E-16	-3.94E-16	-3.94E-16	-3.94E-16
Trailer2	511.66	1.00E+2	1.45E+1	7.40E+0	3.60E+0	1.49E+0	7.23E-1	4.75E-1	3.38E-1	2.58E-1	2.55E-3	5.37E-15	5.37E-15
Trailer3	452.02	1.00E+2	8.47E+0	2.10E+0	5.81E-1	6.76E-2	2.53E-2	5.16E-3	4.92E-4	1.78E-15	1.78E-15	1.78E-15	1.78E-15

Table L-30. Cumulative lateral acceleration histogram data for mixed-load triples

Unit Position	Total Time*	Percentage of travel time spent above the indicated level of lateral acceleration											
	Hours	*> 0.00 g's*	*> 0.03 g's*	*> 0.06 g's*	*> 0.09 g's*	*> 0.12 g's*	*> 0.16 g's*	*> 0.19 g's*	*> 0.22 g's*	*> 0.25 g's*	*> 0.34 g's*	*> 0.40 g's*	*> 0.47 g's*
45–55 mph													
A-dolly													
Tractor	46.17	1.00E+2	7.62E+0	2.54E+0	1.40E+0	5.88E-1	2.23E-1	1.08E-1	1.74E-2	3.06E-14	3.06E-14	3.06E-14	3.06E-14
Trailer1	48.00	1.00E+2	2.26E+1	3.68E+0	1.85E+0	6.58E-1	3.15E-1	1.33E-1	3.65E-2	1.74E-3	-9.28E-16	-9.28E-16	-9.28E-16
Trailer2	48.36	1.00E+2	9.72E+0	3.20E+0	1.71E+0	6.13E-1	2.68E-1	1.03E-1	4.37E-2	5.74E-4	6.43E-15	6.43E-15	6.43E-15
Trailer3	25.72	1.00E+2	7.80E+0	2.74E+0	1.24E+0	2.59E-1	1.14E-1	7.78E-2	4.00E-2	2.16E-3	-1.81E-14	-1.81E-14	-1.81E-14
C-dolly													
Tractor	269.89	1.00E+2	6.37E+0	2.56E+0	1.39E+0	5.05E-1	1.75E-1	2.89E-2	2.68E-3	-1.67E-14	-1.67E-14	-1.67E-14	-1.67E-14
Trailer1	247.76	1.00E+2	1.07E+1	2.63E+0	1.40E+0	4.58E-1	1.57E-1	4.90E-2	8.63E-3	-2.22E-15	-2.22E-15	-2.22E-15	-2.22E-15
Trailer2	266.39	1.00E+2	1.19E+1	2.36E+0	1.20E+0	3.75E-1	1.13E-1	2.13E-2	-1.32E-14	-1.32E-14	-1.32E-14	-1.32E-14	-1.32E-14
Trailer3	300.62	1.00E+2	1.14E+1	2.95E+0	1.42E+0	4.08E-1	1.21E-1	2.69E-2	4.99E-3	8.32E-4	-1.08E-14	-1.08E-14	-1.08E-14
55–65 mph													
A-dolly													
Tractor	188.79	1.00E+2	7.93E+0	2.24E+0	9.68E-1	3.04E-1	1.28E-1	3.08E-2	4.56E-3	2.94E-4	-2.02E-14	-2.02E-14	-2.02E-14
Trailer1	186.35	1.00E+2	1.87E+1	2.60E+0	1.13E+0	3.70E-1	1.77E-1	5.57E-2	1.28E-2	4.47E-4	-4.21E-15	-4.21E-15	-4.21E-15
Trailer2	179.07	1.00E+2	8.09E+0	2.42E+0	1.05E+0	3.65E-1	1.74E-1	5.71E-2	9.77E-3	4.65E-4	6.58E-15	6.58E-15	6.58E-15
Trailer3	105.72	1.00E+2	5.44E+0	1.79E+0	6.42E-1	2.15E-1	9.72E-2	2.76E-2	4.20E-3	3.34E-14	3.34E-14	3.34E-14	3.34E-14
C-dolly													
Tractor	1469.96	1.00E+2	5.47E+0	2.12E+0	9.25E-1	2.90E-1	1.07E-1	1.79E-2	7.56E-4	1.89E-5	2.07E-14	2.07E-14	2.07E-14
Trailer1	1322.33	1.00E+2	1.00E+1	2.29E+0	9.59E-1	3.18E-1	1.10E-1	2.12E-2	1.83E-3	-6.24E-15	-6.24E-15	-6.24E-15	-6.24E-15
Trailer2	1385.97	1.00E+2	1.27E+1	2.03E+0	8.26E-1	2.36E-1	5.73E-2	5.57E-3	1.00E-4	2.69E-15	2.69E-15	2.69E-15	2.69E-15
Trailer3	1463.55	1.00E+2	1.14E+1	2.43E+0	9.40E-1	2.79E-1	7.66E-2	8.86E-3	1.06E-3	4.18E-4	1.90E-5	-1.83E-14	-1.83E-14
>65 mph													
A-dolly													
Tractor	1.91	1.00E+2	2.79E+1	9.55E+0	4.95E+0	2.39E+0	4.35E-1	6.77E-15	6.77E-15	6.77E-15	6.77E-15	6.77E-15	6.77E-15
Trailer1	2.05	1.00E+2	2.45E+1	8.04E+0	4.99E+0	2.46E+0	4.19E-1	4.06E-2	6.56E-15	6.56E-15	6.56E-15	6.56E-15	6.56E-15
Trailer2	2.01	1.00E+2	2.18E+1	8.11E+0	4.83E+0	1.74E+0	1.80E-1	4.72E-16	4.72E-16	4.72E-16	4.72E-16	4.72E-16	4.72E-16
Trailer3	0.52	1.00E+2	2.27E+1	3.55E+0	1.08E+0	-1.18E-14	-1.18E-14	-1.18E-14	-1.18E-14	-1.18E-14	-1.18E-14	-1.18E-14	-1.18E-14
C-dolly													
Tractor	10.53	1.00E+2	1.08E+1	4.90E+0	2.51E+0	1.31E+0	7.28E-1	3.46E-1	2.64E-2	2.64E-3	-1.80E-14	-1.80E-14	-1.80E-14
Trailer1	9.96	1.00E+2	1.85E+1	5.55E+0	3.14E+0	1.17E+0	5.58E-1	2.20E-1	-1.96E-14	-1.96E-14	-1.96E-14	-1.96E-14	-1.96E-14
Trailer2	9.35	1.00E+2	2.04E+1	4.90E+0	2.31E+0	7.79E-1	2.50E-1	1.78E-2	1.19E-2	-2.46E-14	-2.46E-14	-2.46E-14	-2.46E-14
Trailer3	7.73	1.00E+2	1.93E+1	5.12E+0	2.09E+0	8.33E-1	3.88E-1	1.62E-1	4.67E-2	2.51E-2	-4.51E-15	-4.51E-15	-4.51E-15

APPENDIX M

TIRE WEAR DIFFERENCES BETWEEN A-DOLLIES AND C-DOLLIES

UMTRI's field representative visited each of the fleets participating in the LCV field study monthly from August 1993, through April 1995, to gather data on tire wear rates. This including recording tread depths and hubometer mileages for the twenty-eight C-dollies in the study plus another ten A-dollies in general use by the fleets during the time period of the study.[1] In addition, it was possible to obtain adequate data to determine tire wear rates on an additional seventeen C-dollies and nine A-dollies from the historical records of two of the participating fleets.

These data—from a total of forty-five C-dollies and nineteen A-dollies—were used in linear regression analyses to determine tire wear rates. The data were pooled to obtain representative tire wear rates for A-dollies and for C-dollies, respectively. These representative rates were used in the cost analyses of this report. The data from the various sources were also analyzed individually to provide a sense of the variability within the data.

The figures and associated tables below present the tire wear rates for the following:

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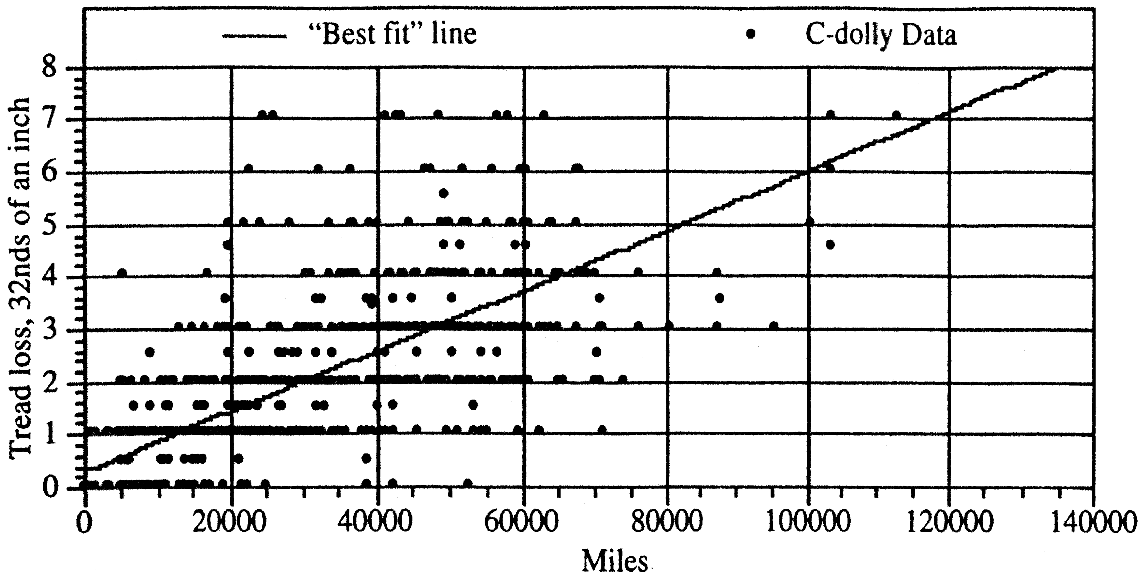
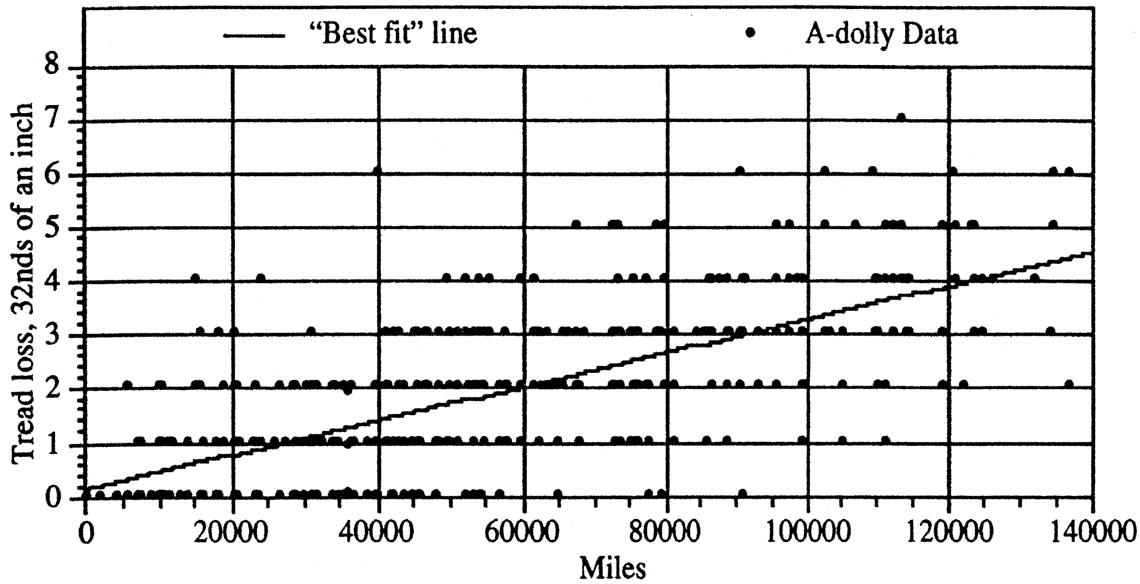
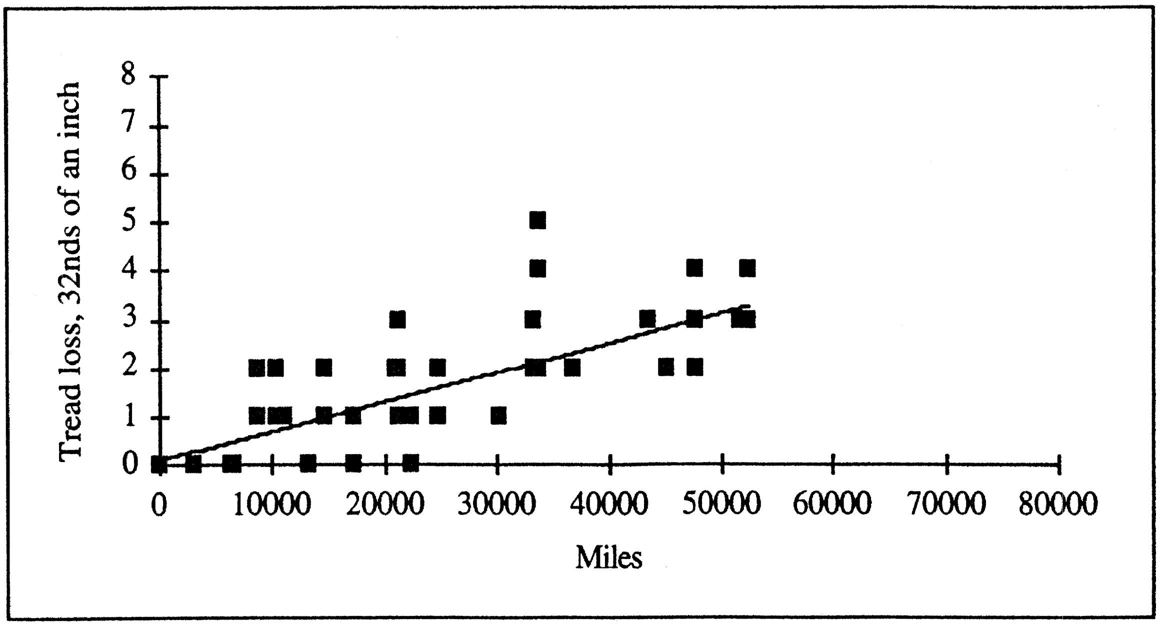
[1] The intent was to track sixteen A-dollies. However, since these units were not under the routing constraints of the C-dollies in the study, in the end, adequate data could only be obtained on ten.





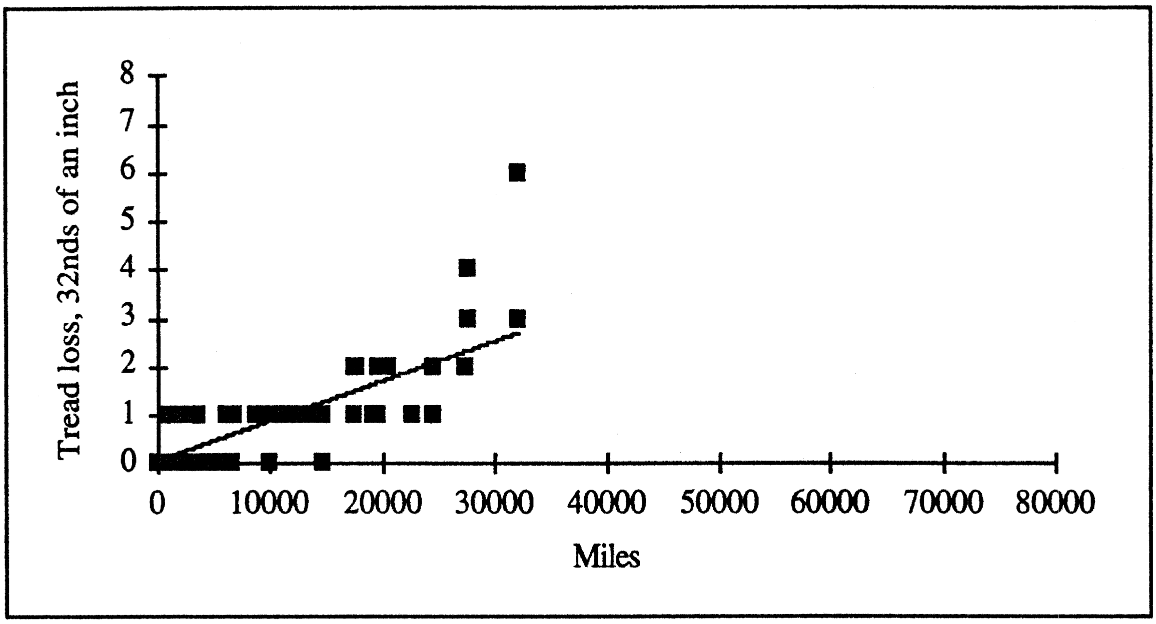
Dolly Type	C-dolly	A-dolly
Number of Units:	45 Dollies	19 Dollies
Data Collection Dates	April 1990 to April 1995	Jan. 1990 to April 1995
Total Miles Traveled:	3.48 Million Miles	2.2 Million Miles
Average Miles per Unit:	77,452 Miles	115,899 Miles
Tread Wear Rate:	17,550 Miles per 32^{nd}	31,908 Miles per 32^{nd}

Figure M-1. Tread depth data and tread loss rate for all C- and A-dollies



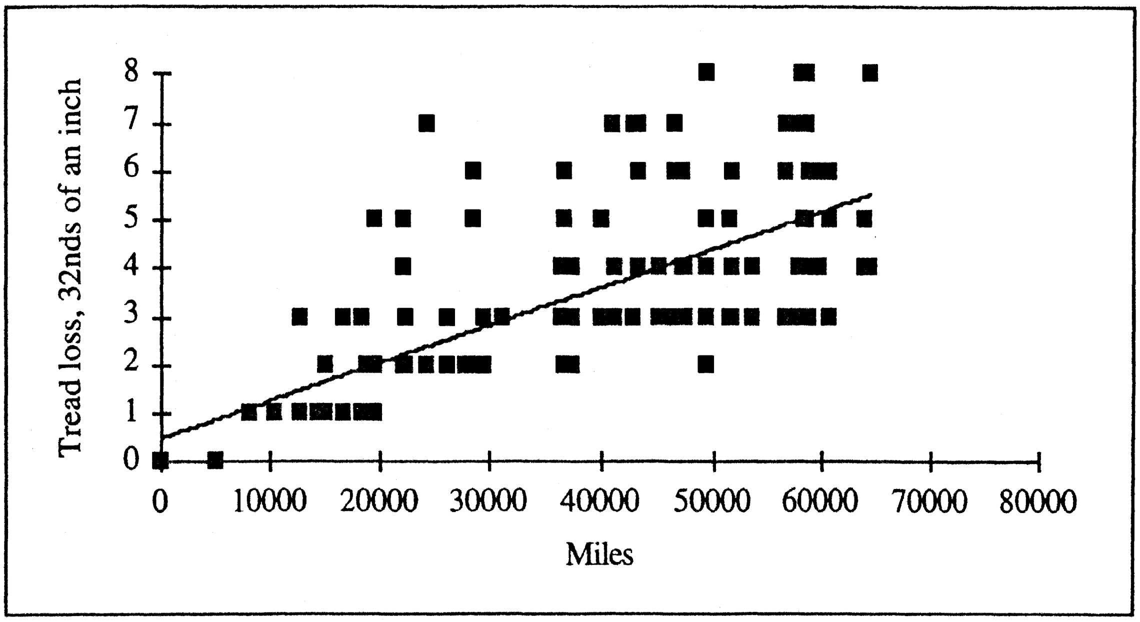
Number of Dollies:	3
Tread Wear Rate:	16,616 Miles per 32nd

Figure M-2. Tread depth data and tread loss rate for all C-dollies in fleet A



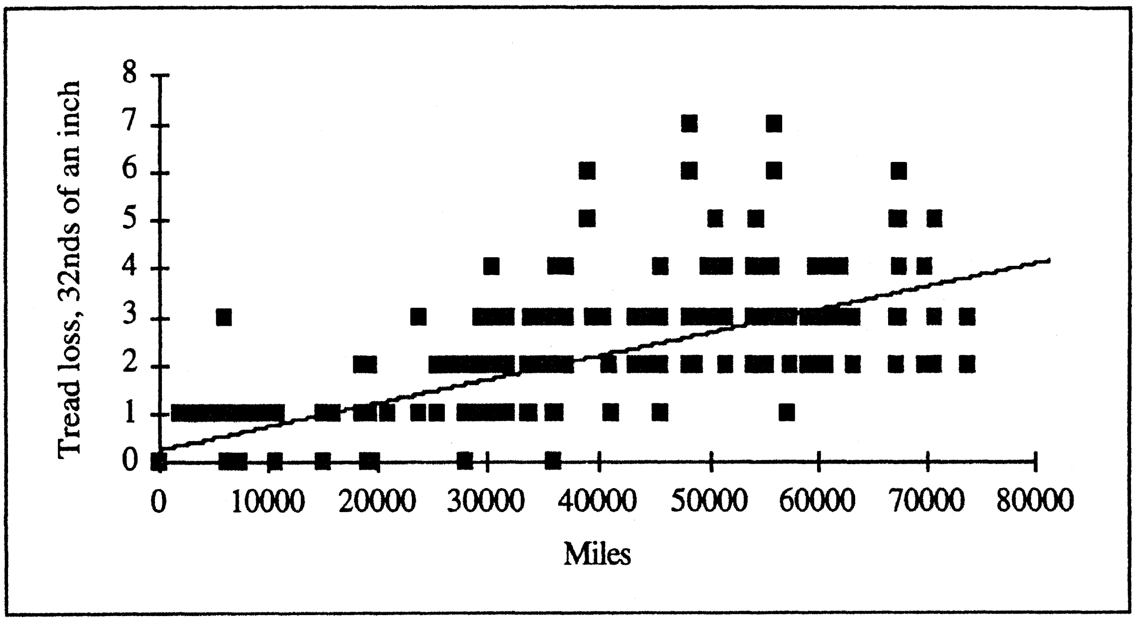
Number of Dollies:	6
Tread Wear Rate:	12,126 Miles per 32nd

Figure M-3. Tread depth data and tread loss rate for all C-dollies in fleet B



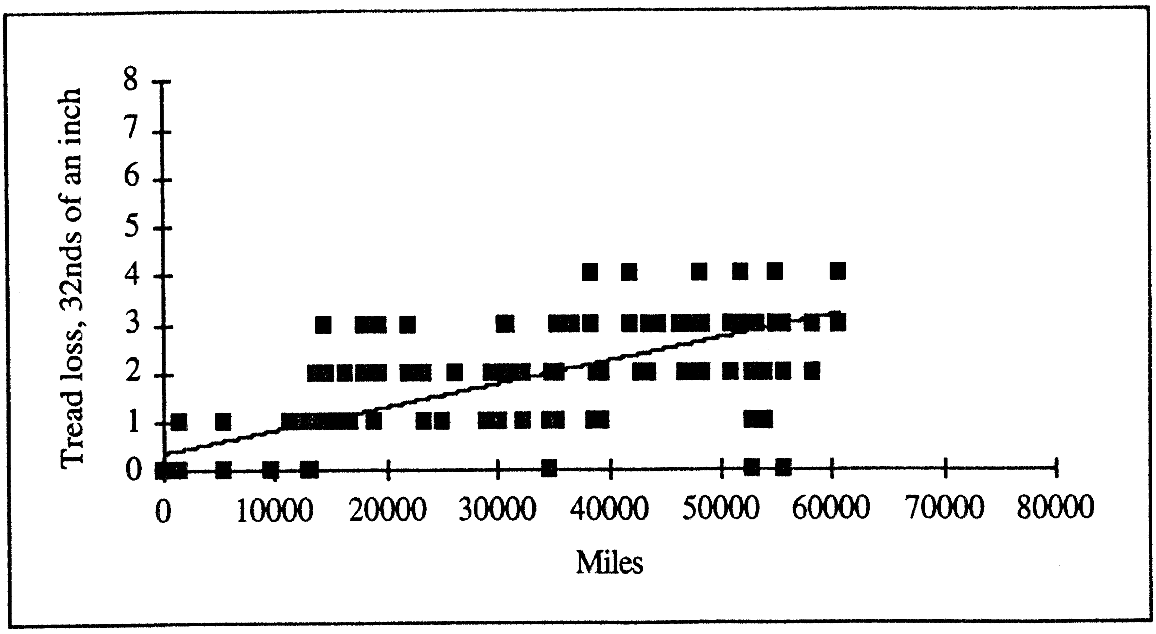
Number of Dollies:	4
Tread Wear Rate:	12,824 Miles per 32nd

Figure M-4. Tread depth data and tread loss rate for all C-dollies in fleet C



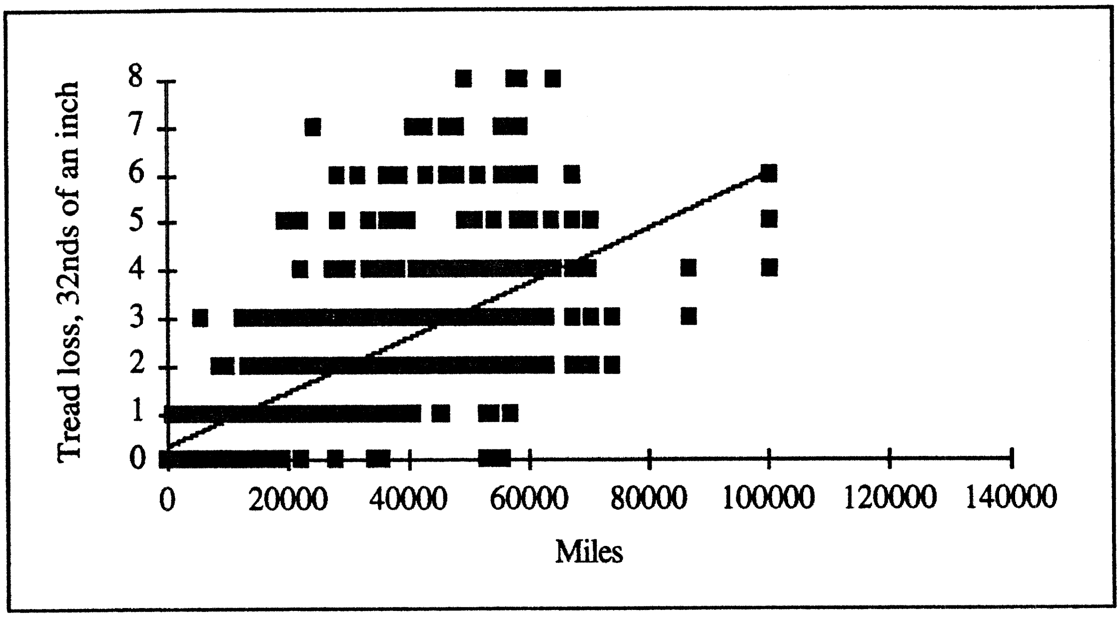
Number of Dollies:	9
Tread Wear Rate:	20,804 Miles per 32nd

Figure M-5. Tread depth data and tread loss rate for all C-dollies in fleet D



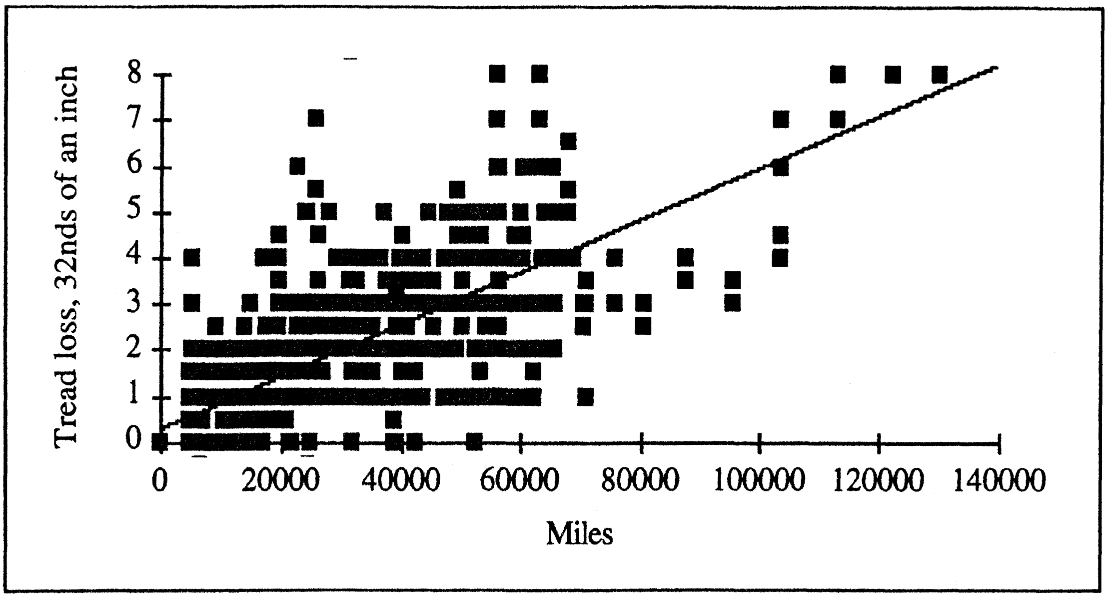
Number of Dollies:	6
Tread Wear Rate:	21,365 Miles per 32nd

Figure M-6. Tread depth data and tread loss rate for all C-dollies in fleet E



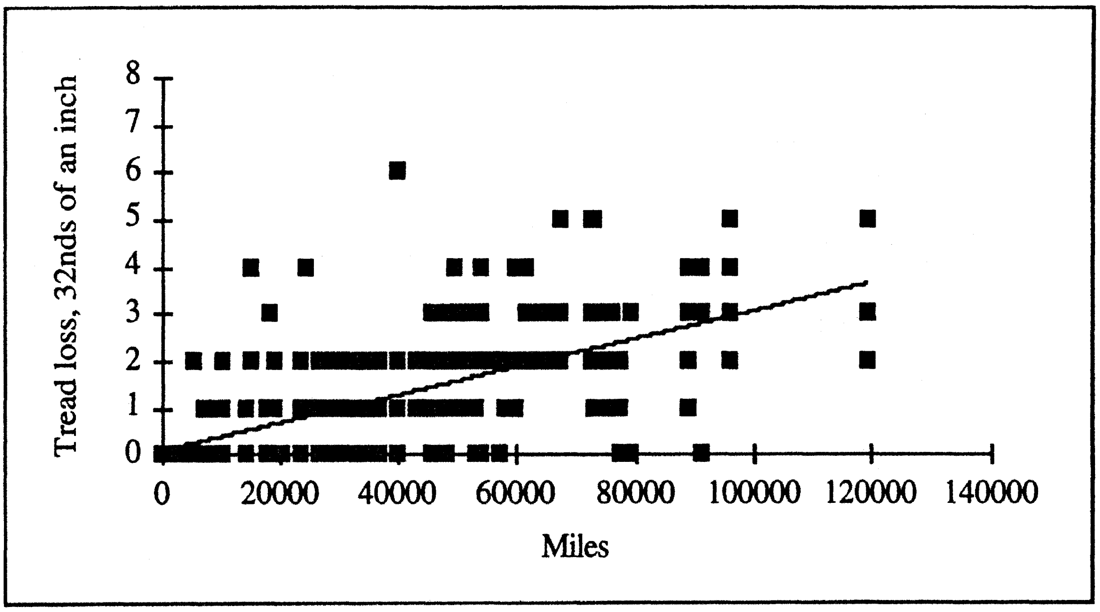
Number of Dollies:	28
Tread Wear Rate:	17,492 Miles per 32nd

Figure M-7. Tread depth data and tread loss rate for all C-dollies in the study



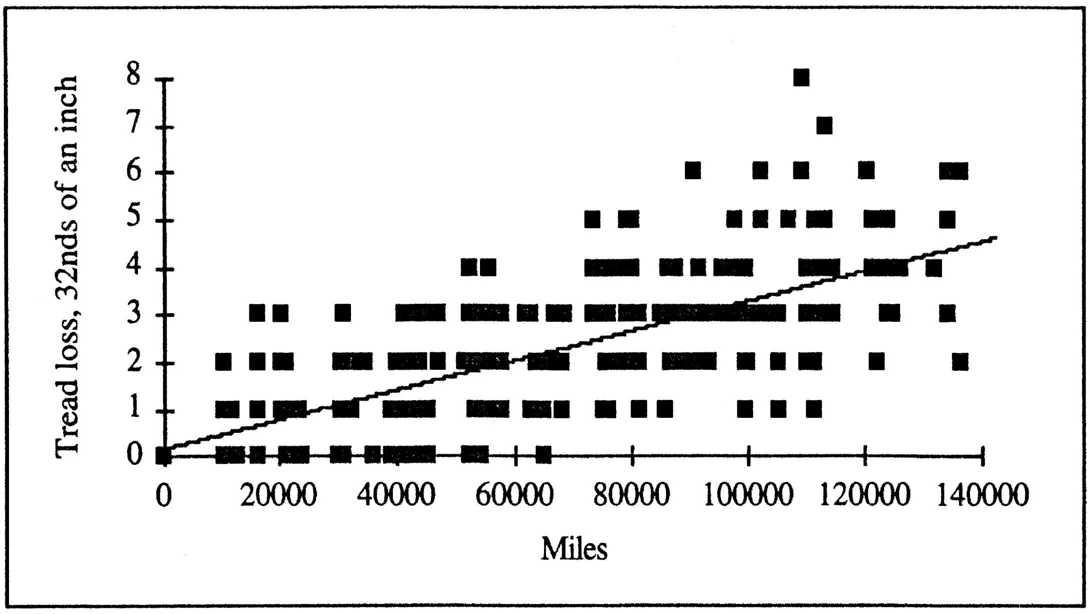
Number of Dollies:	17
Tread Wear Rate:	17,600 Miles per 32nd

Figure M-8. Tread depth data and tread loss rate based on historical records for C-dollies



Number of Dollies:	10
Tread Wear Rate:	33,572 Miles per 32nd

Figure M-9. Tread depth data and tread loss rate for all A-dollies in the study



Number of Dollies:	9
Tread Wear Rate:	31,965 Miles per 32^{nd}

Figure M-10. Tread depth data and tread loss rate based on historical records for A-dollies

APPENDIX N

ANALYSIS OF AN LCV ACCIDENT

One serious accident involving a test vehicle occurred during the LCV field study. The vehicle involved was a Rocky Mountain double. The accident took place while the installation of the electronic data systems was still in progress and before regular downloading of data had commenced. Nonetheless, data records of the event were retrieved from the tandem-axle lead trailer and the C-dolly. The analysis which follows is based on those data recordings, engineering drawings of the highway in the area of the accident site, the police accident report, and additional information provided by UMTRI's on-site investigation.

The accident occurred when the driver of a passenger car failed to stop at the stop sign at an intersection between a primary highway (on which the LCV was traveling) and a secondary road (on which the passenger car was traveling). The car apparently slowed, but did not stop for the sign and then pulled directly in front of the truck. According to his statement, the LCV driver "swerved to the left and applied...full braking..." The front of the tractor struck the left side of the passenger car while both were near the center of the intersection. The car continued across the road and came to rest off of the road surface. The LCV came to rest straddling a raised lane divider. Reports from the driver and witnesses indicate that the LCV came to rest under directional control and with both trailers in line behind the tractor. The car was severely damaged over the entire left side of the passenger compartment. The tractor sustained moderate damage to the front bumper and panels.

The available instrument data show a great deal of ABS activity on the lead trailer and C-dolly. Lack of data from either the tractor or rear trailer prevents any analyses of rearward amplification response.

Figure N-1 is a sketch of the accident site. The highway geometry is to scale from state highway department drawings. The final positions of the vehicles are per the sketch in the police report. The path of the lead trailer of the LCV, and its indicated velocities, was calculated from the data recordings taken from the logger on that unit. (The terminal point of that path was established by the final position of the vehicle. The calculated path was superimposed on the scene to mate with that point.) The path of the car was estimated based on witness statements, the geometry of the road, and the accident report. The figure suggests that the truck was traveling between 15 and 20 mph when it struck the car.

Figure N-2 is intended to simply show the overall quality of the *braking* event. The six wheel speeds and two service brake pressures of the two units are displayed. Wheel speed

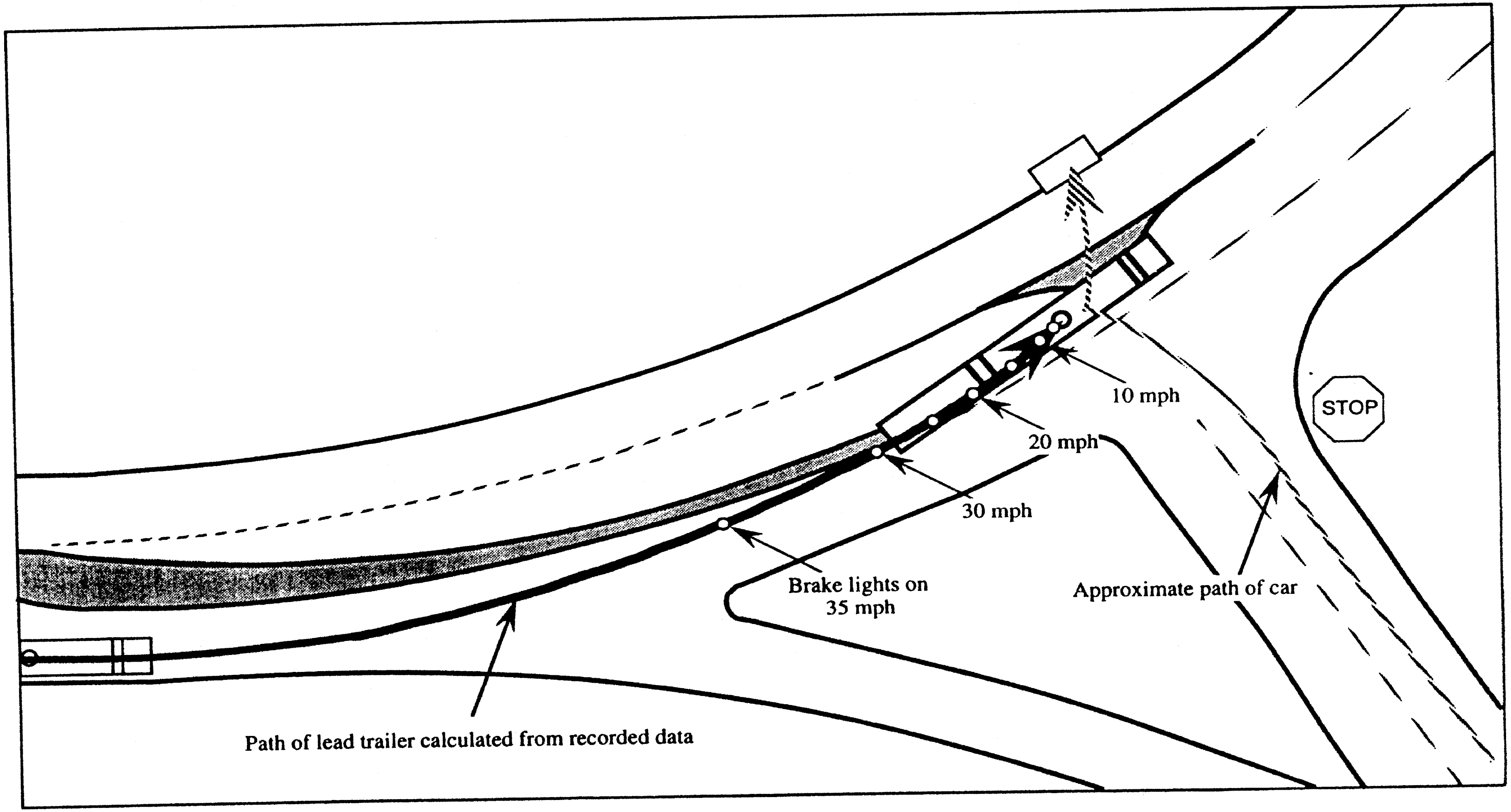


Figure N-1. Scale drawing of the accident scene

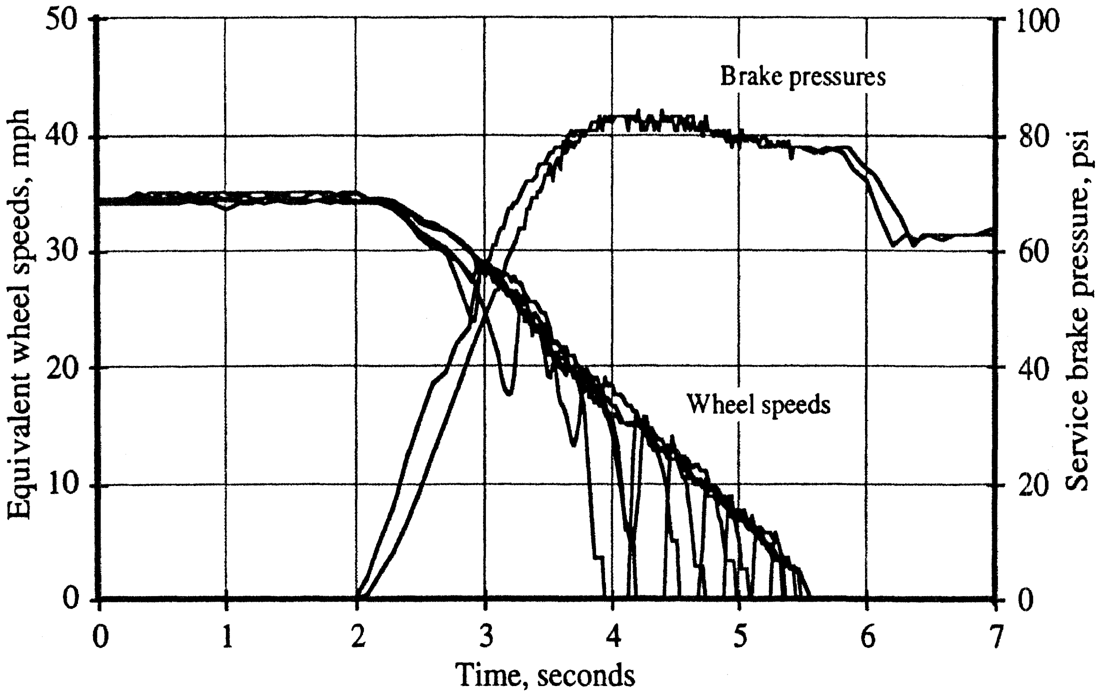


Figure N-2. Wheel speeds and service brake pressures of the lead trailer and dolly

traces indicate that the vehicle was traveling at 34 to 35 mph at the beginning of the event. The maximum difference between the several wheel speeds at the start of the event is 1 mph and is probably accounted for by turn radius and minor differences in tire diameters relative to the assumed value. Brake pressure onset takes place at 2 seconds on the time axis. Pressures rise rapidly to about 83 psi with the dolly lagging the trailer slightly. The first lock up cycle commenced at about 2.7 seconds. (Figure N-3 will show more clearly that cycling begins first on the trailer. The first cycle on the dolly starts just a little later.) ABS activity appears to consume a few psi of supply pressure. The vehicle decelerates to zero speed at a nominal deceleration of 0.46 g. When the vehicle comes to rest, the driver appears to relax slightly on the brake pedal and the service pressures decline accordingly. Again, pressure change on the dolly lags the change on the trailer slightly.

Note that the first lockup cycles on the trailer and dolly are the triggers that generate the recording of this event. Prior to those moments (about 2.7 and 2.9 seconds on trailer and dolly, respectively), data is logged at 10 hz yielding a 0.1-second time resolution. From that time to about 5.5 seconds, data is logged at 50 hz yielding a 0.02-second time resolution. After 5.5 seconds, the system reverts to the 10 hz logging rate and the courser time resolution.

The accuracy of time justification of the traces from the two different loggers is related to the slower data logging rate. The internal clocks of the loggers are not accurate enough over long periods of time to provide precise justification of data gathered on different units. Rather, the data from the two loggers involved were justified by using the step change in

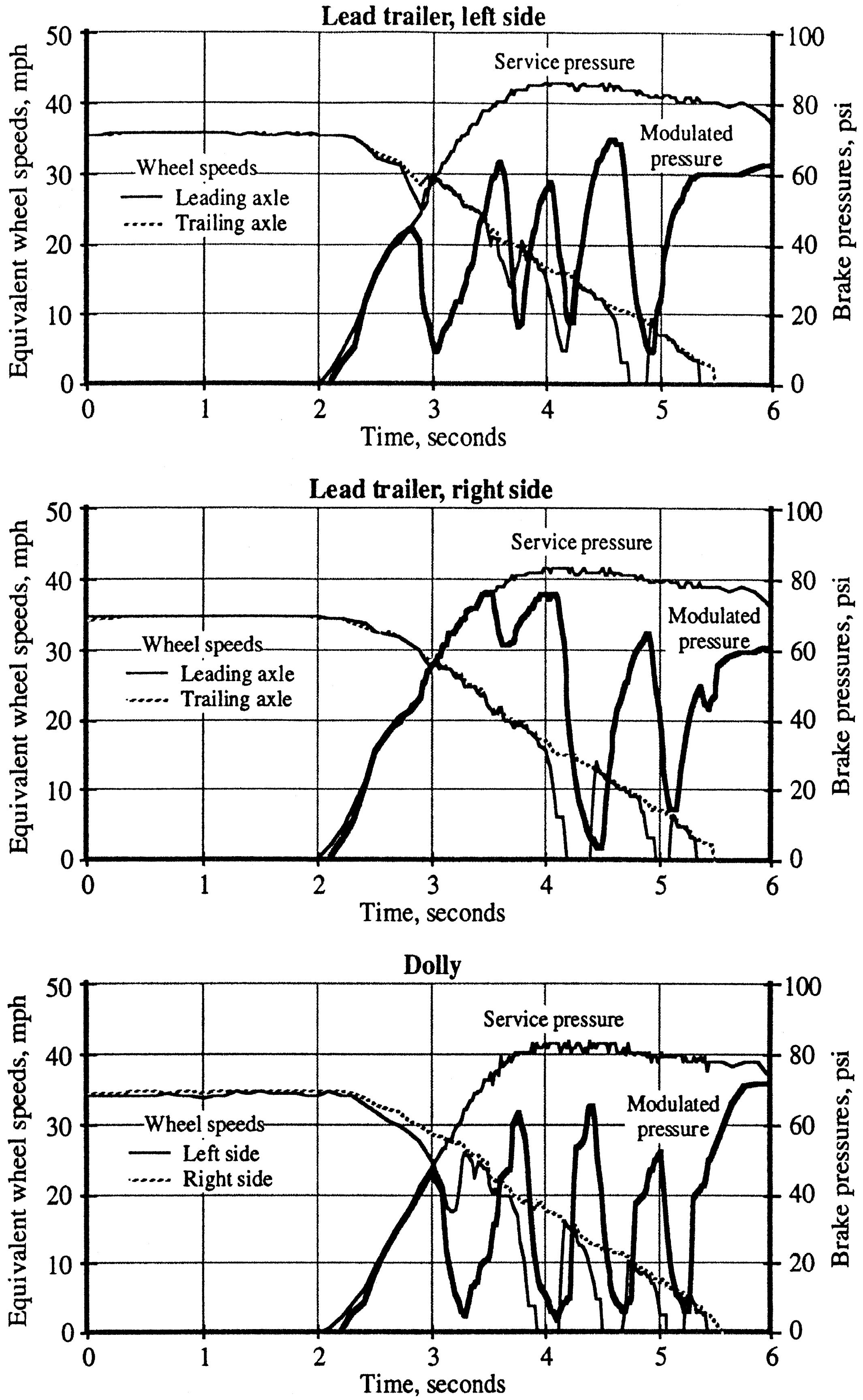


Figure N-3. Detailed wheel speed and brake pressure activity

brake-light voltage registered by each logger as a common *event mark* across files. (See Figure N-6.) Since this takes place in the first phase when data sampling is at 10 hz, the time justification of data from different units can be as poor as 0.1 seconds.

Figure N-3 shows wheel speeds and brake pressure activity in more detail. The three graphs are associated with the three modulator valves: two on the tandem axle lead trailer and one on the dolly. Modulators 1 and 2 on the trailer control the left and right wheels, respectively. The dolly has only one modulator valve. Each graph shows the pressure trace of a modulator valve plus the service pressure and wheel speeds associated with that valve.

As would be expected, since the vehicle was in a left turn, ABS activity was triggered by the left wheels. The top graph shows that the first cycle on the trailer involves both left wheels and commences with chamber pressures of about 40 psi. The left wheel of the lead axle cycles more deeply toward lockup than does the wheel of the trailing axle. The third graph shows that the situation on the dolly is similar, with the left wheel starting to slip significantly at about 40 psi. There is also a hint of increased longitudinal slip in the trace of the right wheel speed. Note that the right wheels of the trailer (second graph) do not trigger modulator activity until chamber pressure exceeds 70 psi. As the event proceeds, the left wheels of the trailer lead and dolly axles cycle deeply three more times, and these modulator valves control chamber pressure to a time-average of more-or-less 30 to 40 psi. The right wheel of the lead axle cycles deeply twice. Once this begins, this modulator valve generates about the same time-averaged pressure.

Figure N-4 displays ABS supply voltages at the top and modulator-valve control signals at the bottom. When the brakes are first applied, ABS voltages on the trailer and dolly are 12.7 to 12.8 volts, respectively. Prior to ABS activity, these voltages are very stable. When ABS activity begins, noise of about ±0.25 volts is apparent at frequencies clearly associated with modulator switching. Also when ABS activity begins, an exponential decline in voltage with a time constant of roughly one second begins. The voltages appear to asymptotically approach a new nominal value that is about 1.5 volts lower than their initial value. Then, when ABS activity suddenly subsides at the end of the event, about half of this voltage loss is recovered.

Significant points in all of this are: (1) The nominal brake-light circuit voltages at the start of this particular event (before ABS activity) are quite high—nearly 12.7 volts at the dolly and declining only about 0.1 volts unit-to-unit. (2) Voltage drop due directly to a high level of ABS activity appears to be about 0.75 volts as indicated by the amount of recovery in voltages at the end of the event. (3) The reason for the remaining portion of the voltage drop—another 0.75 volts—is not clear. A prime possibility would seem to be that the driver depressed the clutch and the alternator supply voltage declined with engine speed.

As a point of interest, the reader may note that the traces for the modulator valve on the second trailer and the modulator valve on the dolly are high as long as 0.7 seconds after the

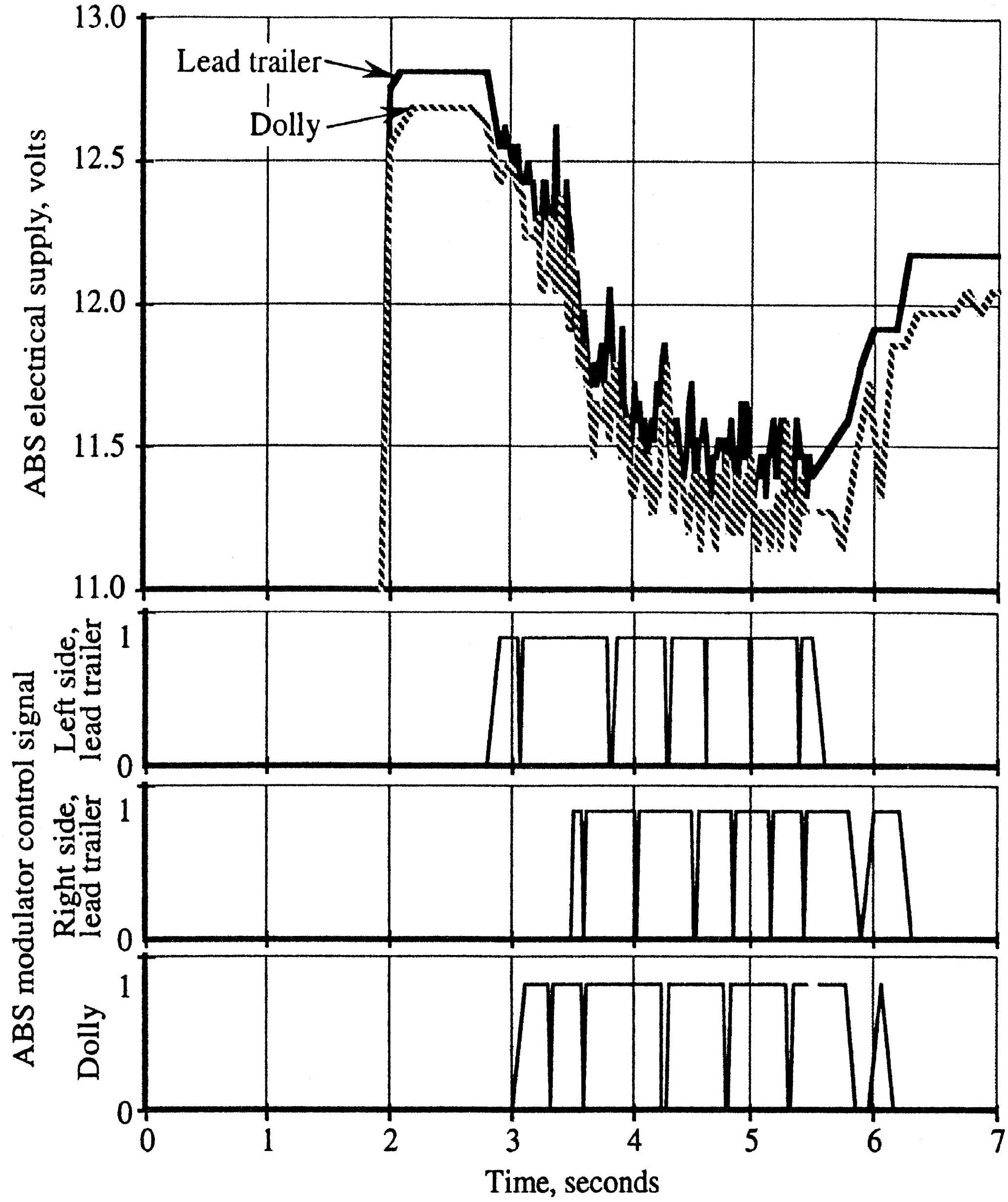


Figure N-4. ABS supply voltages and modulator control signals

vehicle has come to a complete stop (at about 5.5 seconds). The adaptive logic of the ECUs have clearly "learned" to expect incipient lockup at a control pressure well below the service line pressure, and the controllers are being cautious in how they allow chamber pressures to increase above 50 psi or so, even though the vehicle has stopped. This is confirmed by the chamber pressure traces of Figure N-3.

Figures N-5 and N-6 show the general *lateral-motion* qualities of the event. Figure N-5 shows the nominal vehicle speed (the speed of wheel 4, which does not experience high slip) and the lateral acceleration as measured on the lead trailer.[1] Figure N-6 repeats the

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1 The accelerometer signal is corrected for the super elevation of the highway, known from highway department drawings, and for estimated body roll.

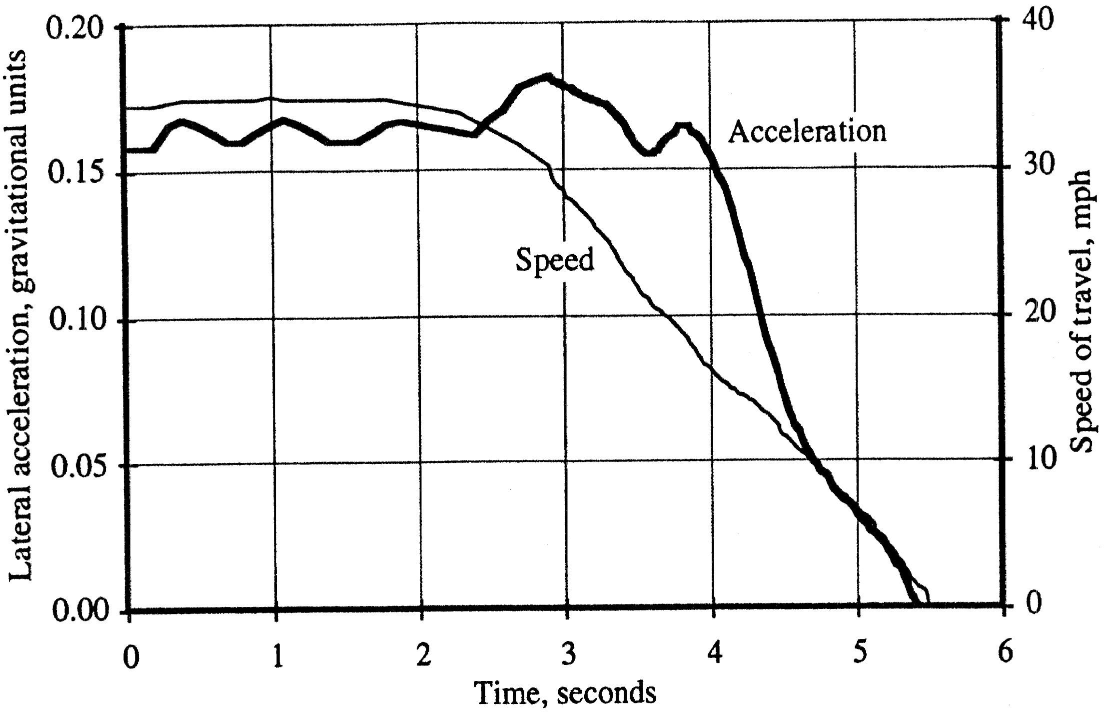

Figure N-5. Lateral acceleration and speed of the lead trailer

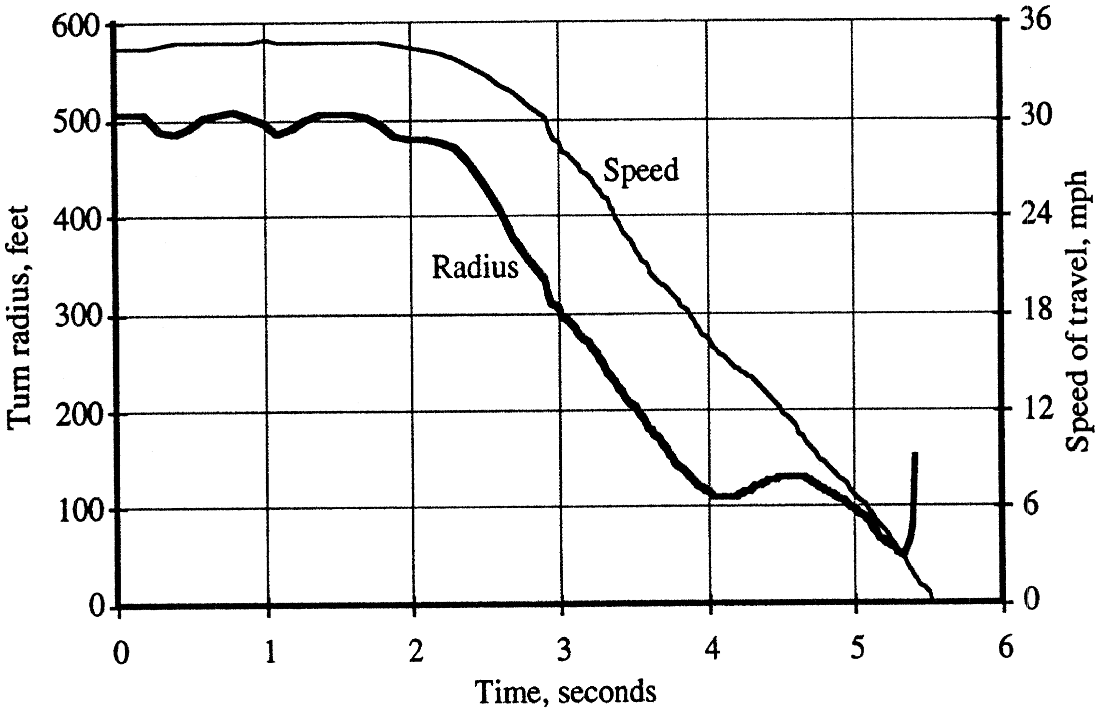

Figure N-6. Turn radius and speed of the lead trailer

speed trace and superimposes the calculated turn radius.[2]

With that preamble, the data indicates that the vehicle is in a left turn of some 0.16 g and about 500-foot radius prior to braking. (At that point, the turn radius of the lane is approximately 520 feet.) Simultaneously with the onset of braking, the turn to the left is tightened (radius decreases) and lateral acceleration increases as a result. As the vehicle slows, the turn continues to tighten, but lateral acceleration declines due to the influence of lessening speed. The turn radius settles to about 100 feet four to five seconds into the event, and then briefly drops to fifty feet before the vehicle comes to a stop. (Note that as velocities and accelerations fall to very small values near the end of the event, calculation of radius becomes less reliable.)

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[2] This latter trace is approximate in that it is based on the simple transformation: $R = v^2/a_y$. This formula is strictly valid only at steady state. In this maneuver, this term almost surely dominates, but dynamic components could be significant. However, the calculated path, which follows from the radius and velocity calculations and which is shown in figure N-1, superimposes very well on the known geometry of the highway.