Draft Final Report

Light-Duty Vehicle Driving Behavior: Private Vehicle Instrumentation

VOLUME 1: TECHNICAL REPORT

Presented to:

Certification Division
Office of Mobile Sources
U.S. Environmental Protection Agency
2565 Plymouth Road
Ann Arbor, Michigan 48105

Prepared by:

Radian Corporation
8501 N. Mopac Blvd.
Austin, TX 78759

24 August 1992

RADIAN
CORPORATION

RADIAN
CORPORATION

DCN 92-254-036-90-04
RCN 254-036-90-06

(Mailing Address)
P.O. Box 201088
Austin, TX 78720-1088
(Shipping Address)
8501 North Mopac Blvd.
Austin, TX 78759
(512) 454-4797

Light-Duty Vehicle Driving Behavior: Private Vehicle Instrumentation

Draft Final Report

Prepared for:

Jim Markey
Certification Division
Office of Mobile Sources
U.S. Environmental Protection Agency
2565 Plymouth Road
Ann Arbor, Michigan 48105

Prepared by:

T.H. DeFries
S. Kishan
Radian Corporation
8501 N. Mopac Blvd
Austin, Texas 78759

24 August 1992

TABLE OF CONTENTS

		Page
VOLUME 1: TECHNICAL REPORT		
	EXECUTIVE SUMMARY	1
	ACKNOWLEDGEMENTS	
1.0	INTRODUCTION	1-1
	1.1 The Current Federal Test Procedure	1-2
	1.2 Project Description	1-3
	1.3 Structure of This Report	1-5
2.0	DATALOGGING EQUIPMENT	2-1
	2.1 3-Parameter Datalogger	2-1
	2.1.1 3-Parameter Logger Measurements	2-2
	2.1.2 Quantitative Quality Assurance Objectives	2-5
	2.1.3 3-Parameter Datalogging Equipment Design	2-8
	2.1.4 Laboratory Function Checks	2-11
	2.1.5 Test Track Speed Accuracy Checks	2-17
	2.1.6 Pilot Testing	2-36
	2.2 6-Parameter Data Collection	2-39
	2.2.1 6-Parameter Logger Measurements	2-39
	2.2.2 Quantitative Quality Assurance Objectives for the 6-Parameter Datalogger	2-42
	2.2.3 6-Parameter Datalogging Equipment Design	2-42
	2.2.4 Pilot Testing	2-53
3.0	FIELD PROCEDURES	3-1
	3.1 Field Administrative Procedures	3-1
	3.1.1 Introductory Leaflet	3-4
	3.1.2 Cover Sheet	3-5
	3.1.3 Vehicle Selection	3-5
	3.1.4 Replacement Vehicle Selection	3-12
	3.1.5 Interactions with Drivers	3-17
	3.1.6 Vehicle Condition Check	3-20
	3.1.7 Final Vehicle Acceptance	3-20
	3.1.8 Handling of Driver/Owner Problems	3-23

TABLE OF CONTENTS (Continued)

		Page
3.2	Datalogger Installation Procedures	3-23
3.2.1	3-Parameter Logger Installation	3-25
3.2.2	6-Parameter Logger Installation and Checkout	3-33
3.3	Datalogger Removal Procedures	3-43
3.3.1	3-Parameter Logger Removal	3-43
3.3.2	6-Parameter Logger Removal	3-46
3.3.3	Data Handling	3-49
4.0	FIELD RESULTS	4-1
4.1	Selection of Cities	4-1
4.2	Activities at Inspection/Maintenance Facilities	4-6
4.2.1	Spokane, Washington	4-7
4.2.2	Baltimore, Maryland	4-11
4.3	Vehicle Sampling	4-14
4.3.1	Summary of Vehicles Solicited	4-14
4.3.2	3-Parameter Instrumentation	4-35
4.3.3	6-Parameter Instrumentation	4-38
4.4	Factors Affecting the Data	4-54
5.0	DATA QUALITY CHECKING AND ARCHIVING	5-1
5.1	Data Quality Checking Methodology	5-1
5.2	Data Correction Guidelines	5-11
5.2.1	Guidelines for Spokane 3-Parameter Data Editing	5-12
5.2.2	Guidelines for Baltimore 3-Parameter Editing	5-14
5.2.3	Guidelines for 6-Parameter Data Editing	5-17
5.3	Data Archiving Format	5-19
5.4	Results of Data Quality Checking	5-23
6.0	DATA ANALYSIS	6-1
6.1	Statistical Analysis	6-3
6.1.1	Definitions of Terms	6-4
6.1.2	Discussion of Results	6-7
6.1.3	Comparison with Current FTP	6-38
6.2	Data Biases	6-44
6.2.1	Speed and Acceleration Biases	6-44
6.2.2	Vehicle Selection Bias	6-52
6.2.3	Datalogger Presence Bias	6-59

TABLE OF CONTENTS (Continued)

		Page
6.3	Options for the Advanced Analysis and Simulation of Driving Patterns	6-73
	6.3.1 Advanced Statistical Analysis	6-76
	6.3.2 Signal Processing Analysis	6-95
6.4	Options for Formulating Driving Cycles	6-111
	6.4.1 Two Possible Bases for a Certification Test Procedure	6-112
	6.4.2 Format Options for a New Test Procedure	6-115
7.0	REFERENCES	7-1
	APPENDIX A: SAMPLE QUALITY CHECKING PLOTS	A-1
	APPENDIX B: DATA ANALYSIS PLOTS AND TABLES	B-1

TABLE OF CONTENTS (Continued)

Page

VOLUME 2: SPEED AND ACCELERATION MEASURES

All Data Without Stratification 1

FTP 21

Site. 32
- Spokane
- Baltimore

Baltimore Station 62
- Baltimore-Rossville
- Baltimore-Exeter

Logger Type 88
- 3-Parameter
- 6-Parameter

Observation Phase 119
- First Day
- Remaining Days

Moving Only 151

Time of Day 169
- 0100-0600
- 0600-0900
- 0900-1600
- 1600-1900
- 1900-0100

Vehicle Type 239
- Sedan, Luxury, Station Wagon
- Van, Pickup, Utility
- Sports Car

TABLE OF CONTENTS (Continued)

Page

VOLUME 3: TRIP MEASURES

All Data Without Stratification 1

Data for Major Trips Only 22

FTP 44

Site. 60
Spokane
Baltimore

Station. 105
Baltimore-Rossville
Baltimore-Exeter

Logger Type. 150
3-Parameter
6-Parameter

Vehicle Type 195
Sedan/Luxury/Station Wagon
Pickup/Van/Utility
Sports Car

Observation Phase 258
First Day
Remaining Days

Vehicle Age. 303
1970s
1980s
1990s

Time of Day. 365
0100-0600
0600-0900
0900-1600
1600-1900
1900-0100

TABLE OF CONTENTS (Continued)

	Page
Time of Week	470
Weekday	
Weekend	
Driver Age	515
<25	
25-65	
>65	

TABLE OF CONTENTS (Continued)

Page

VOLUME 4: VEHICLE DRIVER MEASURES

All Data Without Stratification 1

Data for Major Trips Only 13

Site. 25
Spokane
Baltimore

Station. 48
Baltimore-Rossville
Baltimore-Exeter

Logger Type. 71
3-Parameter
6-Parameter

Vehicle Type 94
Sedan/Luxury/Station Wagon
Pickup/Van/Utility
Sports Car

Vehicle Age. 128
1970s
1980s
1990s

Driver Age 162
<25
25-65
>65

Transmission 196
Manual
Automatic

LIST OF FIGURES

		Page
1	Acceleration Distribution Comparison for Spokane, Baltimore, and the FTP	6
2	Number of Vehicles with 1% of Accelerations Greater Than Indicated Accelerations	7
3	Speed Distribution Comparison for Spokane, Baltimore, and the FTP	9
4	Specific Power Distribution Comparison for Spokane, Baltimore, and the FTP	10
1-1	The LA-4 Driving Cycle of the FTP	1-4
2-1	Pressure Measured by Datalogger (kPa)	2-16
2-2	Actual Absolute Pressure (kPa)	2-18
2-3	Constant Speed Performance for Magnet Speed Sensor	2-22
2-4	Constant Speed Performance for OEM Speed Sensor	2-23
2-5	Constant Speed Performance for Speedometer Cable Sensor	2-24
2-6	Low Speed Accuracy for Magnet Speed Sensor	2-27
2-7	Low Speed Accuracy for OEM Speed Sensor	2-28
2-8	High Speed Accuracy for Magnet Speed Sensor	2-29
2-9	High Speed Accuracy for OEM Speed Sensor	2-30
2-10	High Speed Accuracy for Speedometer Cable Sensor	2-31
2-11	Transient Performance for Magnet Speed Sensor	2-33
2-12	Transient Performance for OEM Speed Sensor	2-34
2-13	Transient Performance for Speedometer Cable Sensor	2-35

LIST OF FIGURES (Continued)

		Page
2-14	Wiring Diagram for the 6-Parameter Non-GM Datalogger	2-45
3-1	Datalogger Installation Procedure Flow Diagram	3-2
3-2	Introductory Leaflet	3-6
3-3	Cover Sheet	3-7
3-4	Passes and Waivers Issued Per Day	3-9
3-5	Inspection Time Profile for Baltimore	3-10
3-6	Vehicle Selection Sheet	3-18
3-7	Vehicle Study Participation Agreement	3-21
3-8	Instrument Removal Appointment Form	3-22
3-9	The Volunteer Vehicle Test Program	3-24
3-10	3-Parameter Logger Installation Notes	3-26
3-11	3-Parameter Logger Calibration Sheet	3-31
3-12	6-Parameter Logger Identification and Sensor Verification	3-35
3-13	6-Parameter Logger Installation Notes	3-39
3-14	6-Parameter Logger Calibration Sheet	3-40
3-15	3-Parameter Logger Removal Report	3-44
3-16	Usage Information	3-45
3-17	3-Parameter Data Downloading Sheet	3-47
3-18	6-Parameter Logger Removal Report	3-48
3-19	3-Parameter Downloaded Data Format	3-50
3-20	6-Parameter Data Downloading Sheet (GM Only)	3-52

LIST OF FIGURES (Continued)

		Page
3-21	6-Parameter Data Downloading Sheet (Non-GM)	3-53
3-22	6-Parameter Downloaded Data Format	3-54
4-1	Howe Street Spokane Site	4-9
4-2	Howe Street Facility-Spokane	4-10
4-3	Baltimore City I/M Station	4-12
4-4	Baltimore County I/M Station	4-13
5-1	Data Quality Checking Methodology	5-2
5-2	Vehicle/Engine Operating Scenarios Relevant to Datalogger Operation	5-15
6-1	Speed/Acceleration Contours for All Observations	6-13
6-2	Speed Distribution for All Observations	6-14
6-3	Acceleration Distribution for All Observations	6-15
6-4	Specific Power Distribution for All Observations	6-17
6-5	Trip Time Distribution for All Trips	6-19
6-6	Trip Time Distribution for Major Trips Only	6-20
6-7	Soak Time Distribution for All Trips	6-21
6-8	Soak Time Distribution for Major Trips Only	6-22
6-9	Time and Idle Distribution for All Trips	6-24
6-10	Running Time Distribution for All Trips	6-25
6-11	Time and Idle Distribution for Major Trips Only	6-26
6-12	Running Time Distribution for Major Trips Only	6-27

LIST OF FIGURES (Continued)

		Page
6-13	Trip Distance Distribution for All Trips	6-28
6-14	Trip Distance Distribution for Major Trips Only	6-29
6-15	Daily Driven Distance Distribution	6-31
6-16	Daily Operating Time Distribution	6-32
6-17	Distribution of Number of Trips per Day for All Trips	6-34
6-18	Distribution of Number of Trips per Day for Major Trips Only	6-35
6-19	Distribution of Number of Stops per Hour for All Trips	6-36
6-20	Distribution of Number of Stops per Hour for Major Trips Only	6-37
6-21	Speed Distribution for the FTP Cycle	6-41
6-22	Acceleration Distribution for the FTP Cycle	6-42
6-23	Specific Power Distribution for the FTP Cycle	6-43
6-24	Acceleration/Speed Contours for the FTP Cycle	6-45
6-25	Speed Profile Example	6-47
6-26	Evaluation of Calculated Accelerations for the Speedometer Cable Speed Sensor	6-49
6-27	Evaluation of Calculated Accelerations for the Magnet Speed Sensor	6-50
6-28	Evaluation of Calculated Accelerations for the OEM Speed Sensor	6-51
6-29	Vehicle Make Distribution of Baltimore Eligible Population	6-55
6-30	Model Year Distribution of Baltimore Eligible Population	6-56
6-31	Vehicle Make Distribution of 3-Parameter Baltimore Instrumented Vehicles	6-57

LIST OF FIGURES (Continued)

		Page
6-32	Model Year Distribution of 3-Parameter Baltimore Instrumented Vehicles	6-58
6-33	Vehicle Make Distribution of Solicited 3-Parameter Vehicles That Were Replaced	6-60
6-34	Model Year Distribution of Solicited 3-Parameter Vehicles That Were Replaced	6-61
6-35	Vehicle Make Distribution of 3-Parameter Replacement Vehicles	6-62
6-36	Model Year Distribution of 3-Parameter Replacement Vehicles	6-63
6-37	Make Distribution of 6-Parameter Eligible Baltimore Population	6-64
6-38	Model Year Distribution of 6-Parameter Eligible Baltimore Population	6-65
6-39	Make Distribution of 6-Parameter Baltimore Instrumented Vehicles	6-66
6-40	Model Year Distribution of 6-Parameter Baltimore Instrumented Vehicles	6-67
6-41	Acceleration/Speed Contour for First Observation Phase	6-69
6-42	Acceleration/Speed Contour for Second Observation Phase	6-70
6-43	Trip Time Distribution for First Observation Phase	6-71
6-44	Trip Time Distribution for Second Observation Phase	6-72
6-45	Soak Time Distribution for First Observation Phase	6-74
6-46	Soak Time Distribution for Second Observation Phase	6-75
6-47	Telecommunications Signal Transmission	6-97
6-48	Example Driving Segment	6-100
6-49	Obstacle Model for Example Driving Segment	6-108

LIST OF TABLES

		Page
2-1	Summary of Physical Measurements for the 3-Parameter Datalogger	2-3
2-2	QA Objectives for Precision, Accuracy, and Completeness	2-6
2-3	Speed and RPM Function Check Results	2-14
2-4	MAP Sensor Specifications	2-15
2-5	Constant Speed Performance of 3-Parameter Datalogger vs. Fifth Wheel	2-32
2-6	Transient Performance of 3-Parameter Datalogger vs. Fifth Wheel	2-37
2-7	Radian Employee Vehicles Used for Austin Pilot Testing	2-38
2-8	Summary of Physical Measurements for the 6-Parameter Datalogger	2-40
2-9	6-Parameter Datalogger Measurements	2-43
2-10	List of Domestic Models Used for the 6-Parameter Installation	2-47
2-11	List of Foreign Models Used for the 6-Parameter Installation	2-52
3-1	3-Parameter Vehicle Selection Times	3-13
3-2	3-Parameter Replacement Vehicle Characteristics	3-16
3-3	3-Parameter Logger Wiring Harness Connection	3-29
3-4	Oxygen Sensor Calibration Check	3-37
4-1	Attributes of Nonattainment Areas with Centralized I/M Programs	4-4
4-2	Solicitation Summary	4-15
4-3	Summary of Field Activity Rates	4-37
4-4	Vehicles Instrumented with 3-Parameter Dataloggers	4-39

LIST OF TABLES (Continued)

		Page
4-5	Vehicles Solicited But Not Instrumented with 3-Parameter Dataloggers	4-43
4-6	Vehicles Instrumented with 6-Parameter Dataloggers	4-49
4-7	Vehicles Solicited But Not Instrumented with 6-Parameter Dataloggers	4-51
4-8	Road Condition Estimates	4-55
5-1	Suspect Observation Flagging Parameters for 3-Parameter Data	5-5
5-2	Suspect Observation Flagging Parameters for 6-Parameter Data	5-6
5-3	Data Archiving Formats	5-20
5-4	Summary of Data Quality Checking	5-24
6-1	Definition of Terms	6-5
6-2	Variable Descriptions	6-8
6-3	Summary of Statistics for All Observations in the Driving Pattern Data Set	6-11
6-4	Speed, Acceleration, and Specific Power Statistics for the FTP Cycle	6-39
6-5	Speed/Acceleration Distribution for the FTP Cycle	6-40
6-6	Results of Bias Analysis for Vehicle Selection	6-54
6-7	Obstacle Description Parameters	6-109

EXECUTIVE SUMMARY

The LA-4 driving cycle, which is an integral part of the Federal Test Procedure (FTP), has been used for many years to certify the emissions performance of new vehicles. This driving cycle was based on data collected in Los Angeles in the 1960s. In the 1990 Clean Air Act Amendments, Congress asked the U.S. Environmental Protection Agency to evaluate the Federal Test Procedure, including the LA-4 driving cycle, to determine if it is representative of today's driving. The Certification Division of the Office of Mobile Sources has taken the lead role in conducting a study to determine whether, in fact, the LA-4 driving cycle is representative of today's driving. To answer the representativeness question, EPA has chosen to conduct two studies: a chase car study and a private vehicle instrumentation study. This report documents the techniques and the preliminary results obtained from the private vehicle instrumentation study.

In February and March of 1992, 293 privately owned light-duty vehicles were instrumented in Spokane, Washington and Baltimore, Maryland. The instrumentation remained on each vehicle for a one-week period. Vehicle speed, engine RPM, and manifold absolute pressure data were collected on these vehicles for every second that the engine was on. Following the implementation of strict data quality checking procedures, a database was created containing the one-week's worth of data from 216 of the vehicles. This database contained information on 12,073 trips and 6,940,411 seconds of vehicle and engine operating data.

To collect the data, special datalogging equipment was required. Two types of dataloggers were used: a 3-parameter datalogger and a 6-parameter datalogger. The 3-parameter datalogger was custom designed, manufactured, and tested specifically for this project. Some of the key design requirements were that the datalogger had to be able to be installed on any type and age of light-duty vehicle; it had to be installed in the engine compartment; it had to be installed rapidly; it had to be used repeatedly on different vehicles; and it had to measure vehicle speed, RPM, and manifold absolute

pressure. The intent of these requirements was for the datalogger to be placed on many vehicles in a relatively short period of time and for the vehicles to be sampled as close to randomly as possible. A total of 214 vehicles were instrumented with the 3-parameter datalogger.

A 6-parameter datalogger was provided by the Motor Vehicle Manufacturers Association (MVMA) and the Association of International Automobile Manufacturers, Inc. (AIAM). This datalogger, which recorded three additional parameters: throttle position, coolant temperature, and equivalence ratio, was to be used in the study in a different manner. The system tied into the engine's computer, which required restricting the candidate vehicles to 1989-1991 vehicles of the seven manufacturers participating in the study: General Motors, Ford, Chrysler, Nissan, Toyota, Mazda, and Mitsubishi. Honda joined the study in Baltimore but no Honda vehicles were instrumented. In addition, the dataloggers could only be placed on certain models in those model years, depending on the configuration of the power train and electronics. A total of 79 vehicles were instrumented with the 6-parameter datalogger.

Spokane, Washington and Baltimore, Maryland were chosen as the cities where vehicles were to be instrumented, for a variety of reasons relating to the requirements of the private vehicle instrumentation study and the parallel chase car study. the studies occurred in the two cities in roughly the same time frame. Additional data that will be used to evaluate the representativeness of the LA-4 driving cycle are being collected in Los Angeles and Atlanta.

The dataloggers were installed on private vehicles selected at state inspection/maintenance (I/M) stations in Spokane and Baltimore. Vehicles to have 3-parameter dataloggers installed were selected randomly, based on the time of the day. The selection of vehicles to have 6-parameter dataloggers installed was based on a list of makes and models that could be instrumented. As part of the project, a solicitor determined when a vehicle passed the I/M inspection and then approached the driver of

the vehicle to solicit his or her participation in this project. After properly answering some eligibility questions, drivers targeted for 3-parameter installation were offered approximately $100, and drivers targeted for a 6-parameter installation were offered approximately $200, to participate in the project. For the 3-parameter targeted vehicles, if the driver agreed to participate, the vehicle was instrumented. If the driver did not agree to participate, or the installation was not performed for any of a number of other reasons, the characteristics of the vehicle and driver were recorded and used to select a replacement vehicle with similar characteristics. The replacement vehicle was then instrumented instead in an attempt to keep the vehicles instrumented with 3-parameter dataloggers representative of the population.

Both types of dataloggers were installed on the I/M premises in an inactive inspection lane. The 3-parameter datalogger took approximately an hour to install, and the 6-parameter datalogger took approximately 2½ hours to install. The 6-parameter datalogger installation involved installing an oxygen sensor on the exhaust system just behind the catalytic converter to measure equivalence ratio.

After the datalogging equipment was installed, installation crews took the vehicles for a short calibration and calibration check drive around the block to ensure that the dataloggers were operating correctly. The vehicles were then returned to their owners.

After a week of data collection, the owners brought their vehicles back for removal of the dataloggers. In most instances, this occurred at the same I/M station where installations had been performed. The dataloggers were removed from the vehicles and the data were downloaded onto floppy disks for data quality checking and data analysis.

An extensive data quality checking and archiving process was used to convert the raw data collected from the dataloggers into good data that could be

subsequently analyzed. Software was written to highlight suspect data points in the data files. Then each of the suspect data points and surrounding observations were examined by engineering personnel to determine whether the observation should be accepted, changed, or rejected. Some portions of the data obtained from dataloggers were found to be questionable. The vehicles for which questionable data were found were labeled suspect and the data were set aside for a more careful examination later.

The goal of the data analysis was to get an idea of the representativeness of the LA-4 driving cycle by comparing its statistics with the same statistics on the large set of data collected in this study. To do this, summary statistics were calculated for the study and for the LA-4 cycle. However, it is clear that, although a lot of effort has gone into calculating these statistics, the analysis presented in this report should be regarded as exploratory. An examination of the results of this data analysis will produce many additional questions that will need to be answered by a further examination.

The driving behavior of the vehicles can be broken down into two general features: the detailed trip behavior of the vehicle when the engine was on, and the soak periods when the vehicles were off. Both of these features must be characterized because the characteristics of the tailpipe emissions of today's vehicles depend on these features. To get an idea of the trends in the data, various statistics were calculated in three general areas: speed and acceleration, trips, and vehicles and drivers.

When the LA-4 cycle was developed, the raw data used for the LA-4 driving cycle were modified for the FTP so that the chassis dynamometers of the day could handle the accelerations. Accelerations with absolute values greater than 3.3 mph/s were pinned at 3.3 mph/s. Thus, the current FTP has an upper limit on the accelerations to which it subjects automobiles, but it also demands more acceleration time at 3.3 mph/s than did the raw data.

Figure 1 shows a distribution of the accelerations present in the FTP and in the data from this study from Spokane and Baltimore. The plot shows the effect of limiting the accelerations in the FTP. The acceleration distributions for Spokane and Baltimore are similar; however, there are accelerations that significantly exceed 3.3 mph/s. The number of observations for these exceedances is approximately 2.7% of the total number of observations in the database.

Another way to examine the number of accelerations that exceed 3.3 mph/s is to consider the number of vehicles in this study for which any portion of the driving had accelerations greater than 3.3 mph/s. To avoid erroneous conclusions based on a few acceleration outliers, the 99th percentile acceleration was determined for each of the 216 vehicles. The results are shown in Figure 2.

Figure 2 shows that 201 of the 216 vehicles (93%) had at least 1% of their accelerations greater than 3.3 mph/s. Any point on the curve can be used to make an analogous statement. For the 1% criteria, the curve shows a transition region between 3 and 5 mph/s where almost all vehicles have more than 1% of their accelerations greater than 3 mph/s, but very few vehicles have more than 1% of their accelerations greater than 5 mph/s. Each vehicle logged about 32,000 seconds worth of data during the instrumentation week; thus, 1% of observations relate to about 320 seconds or about 5½ minutes of driving each week. A case could be made that if 93% of the vehicles have at least 1% of their accelerations above the FTP cycle accelerations, then the FTP cycle is not representative of today's driving patterns.

It is possible that the FTP-exceeding accelerations, which this study shows are present in the real world, could be responsible for a disproportionate fraction of vehicle tailpipe emissions. The present study does not contain the emissions information for vehicles as a function of driving pattern; therefore, the effect of these acceleration exceedances cannot be estimated here.

Figure 1. Acceleration Distribution Comparison for Spokane, Baltimore, and the FTP

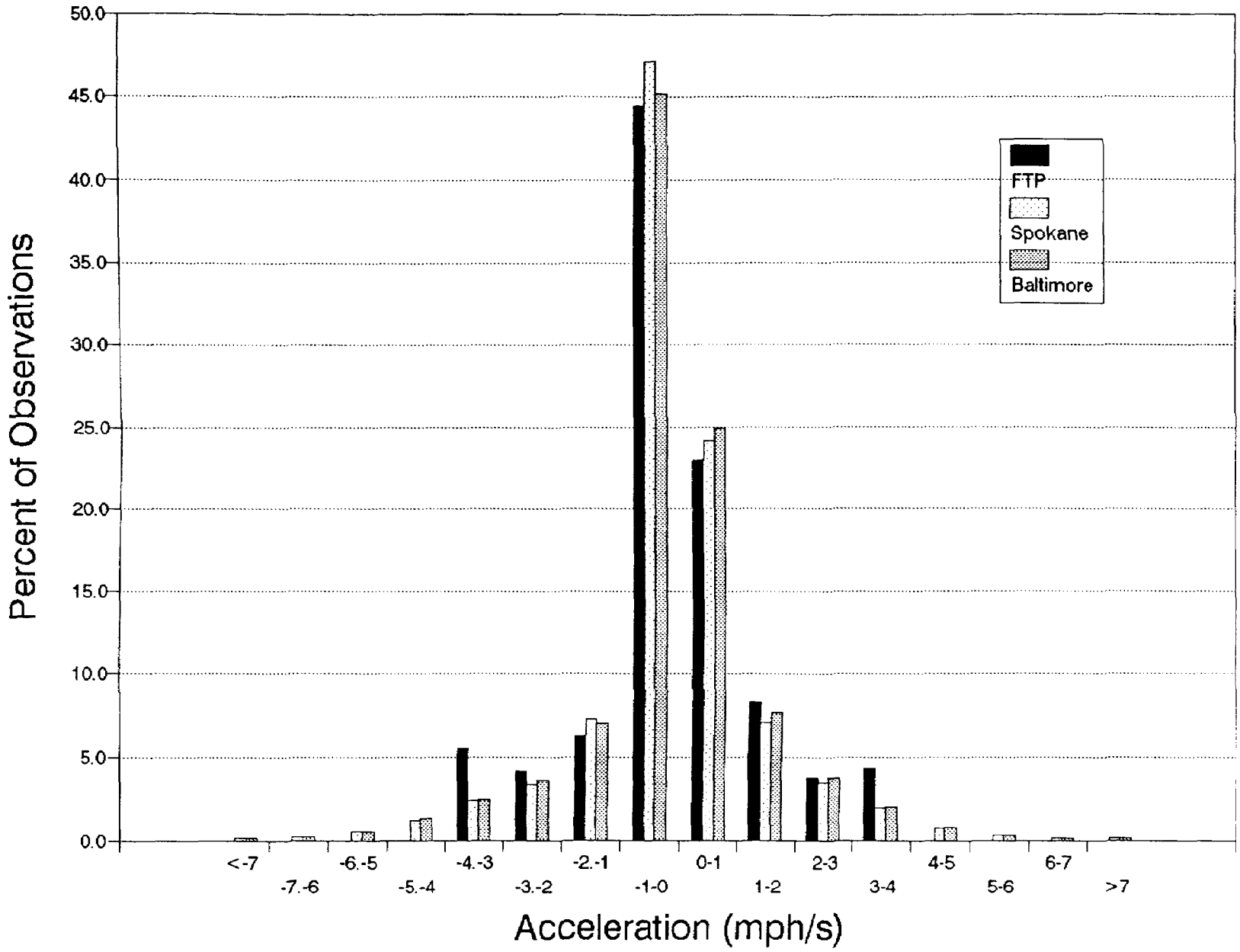
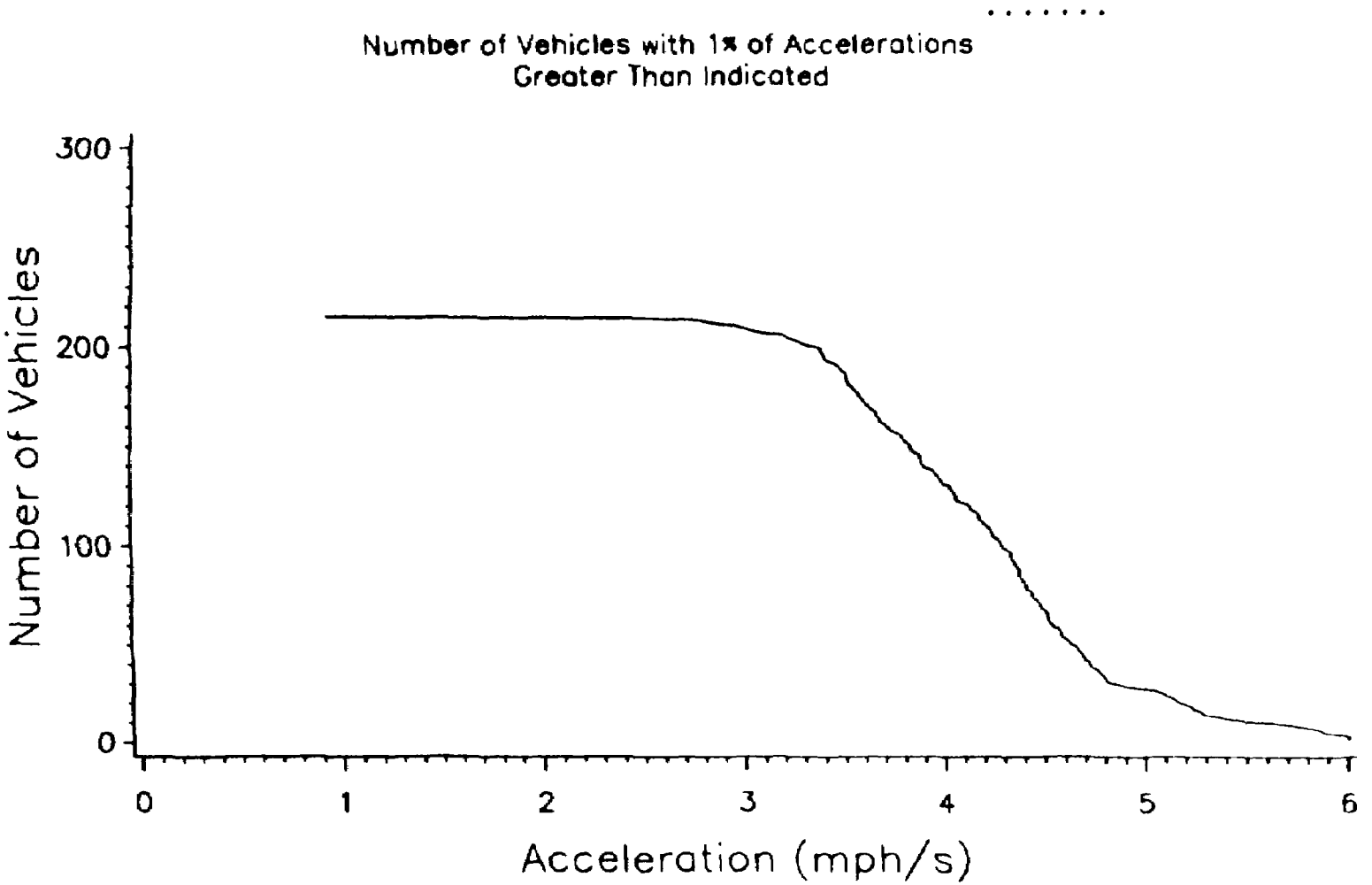


Figure 2. Number of Vehicles with 1% of Accelerations Greater Than Indicated Accelerations



Another parameter which is important to compare is the distribution of vehicle speeds. The FTP speed distribution is compared with those of Spokane and Baltimore in Figure 3. The Spokane and Baltimore speed distributions have peaks at idle, 30-35 mph, and 55-60 mph. On the other hand, the FTP speed distribution has peaks at idle, 20-25 mph, and 50-55 mph. Baltimore shows a larger number of observations at the higher speeds than Spokane.

Specific power is another parameter that can be compared. Specific power is the amount of power required per unit mass of vehicle to accelerate the vehicle from a lower speed to a higher speed. It is another measure of the demands placed on the engine. Figure 4 shows a comparison of the specific power distribution for the FTP and for Spokane and Baltimore as measured in this study. The figure shows that both Spokane and Baltimore drivers demanded more specific power from their vehicles than is represented by the FTP; this is especially noticeable for specific powers greater than 100 mph^2/s. This is the high acceleration region.

A variety of other statistics were calculated for the driving in Spokane and Baltimore. An analysis of trip measures showed that the median trip time was about 6 minutes and was smoothly distributed between 1 minute and 100 minutes. The median trip distance was about 2.5 miles, which agrees well with the median trip distance of 3.0 miles found in the 1979 General Motors diary survey.

Because the Federal Test Procedure is based on only a 12-hour soak and a 10-minute soak, information from the engine-on period (that is, the trips) provides the most detailed data in the procedure. Thus, the simple nature of the soak periods is sometimes overlooked; however, it is known that the emissions produced during cold starts can be as important or more important than emissions produced during heavy acceleration. Soak time had a two-mode distribution. Most of the soaks had lengths between 1 and 300 minutes. The length of a second group of soaks was between 400 and 1500 minutes; these were the overnight soaks.

Figure 3. Speed Distribution Comparison for Spokane, Baltimore, and the FTP

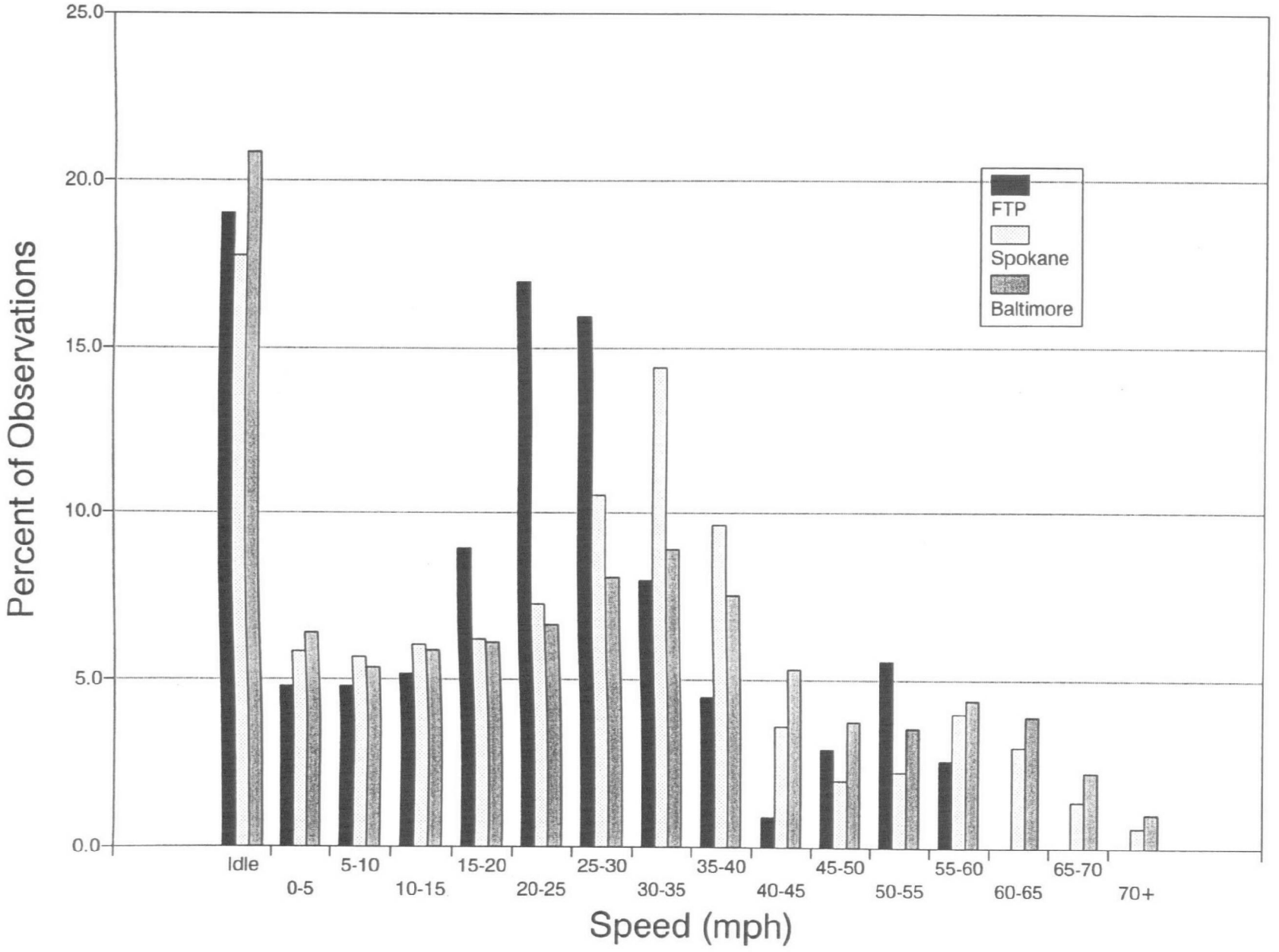
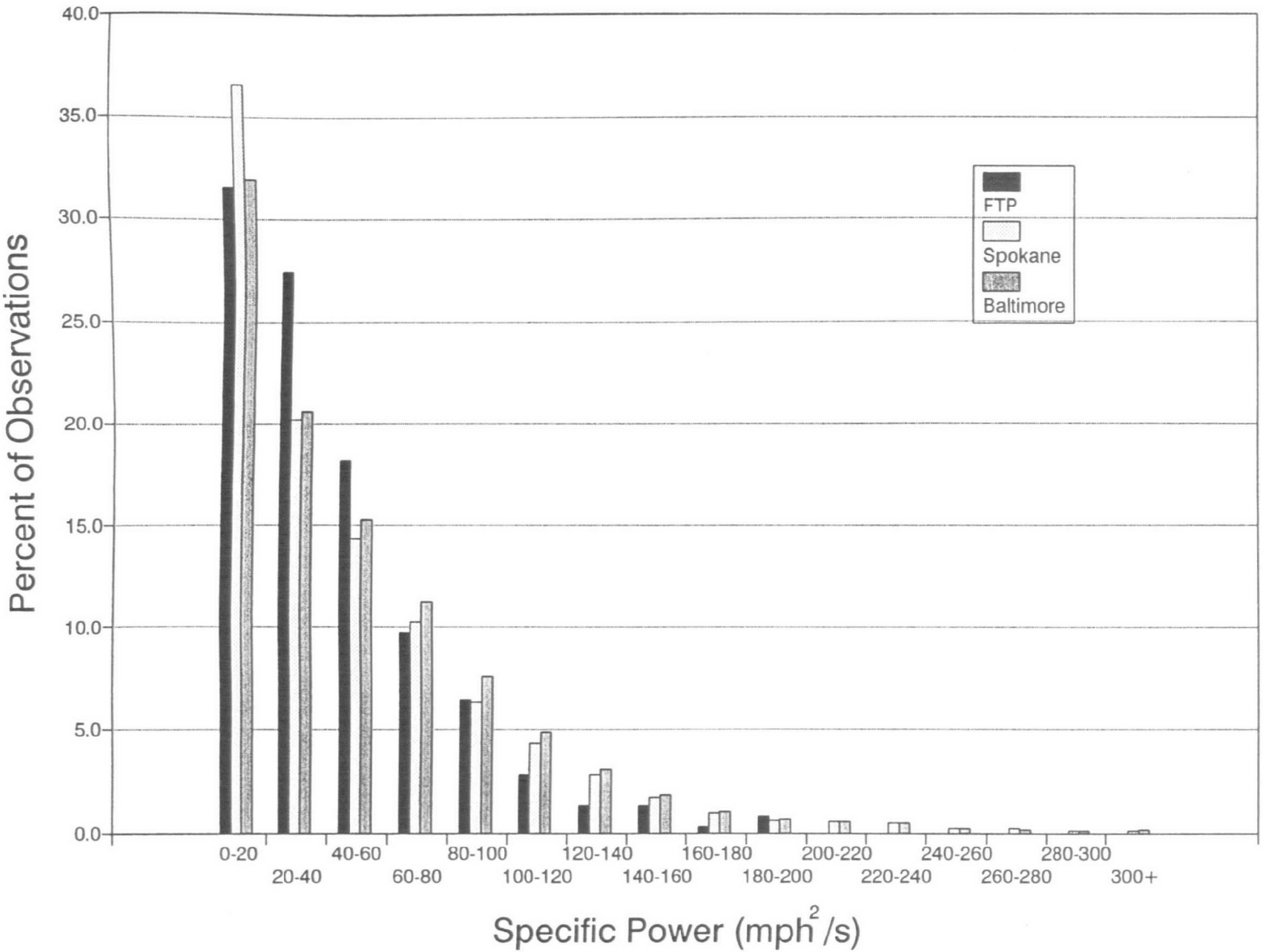


Figure 4. Specific Power Distribution Comparison for Spokane, Baltimore, and the FTP



This report presents some options for advanced analysis of the data in the database for the purpose of understanding the driving behavior of the vehicles instrumented in this study, and also for developing a new Federal Test Procedure if that is desired. Two suggestions discussed are a principal component analysis/cluster analysis option for characterizing trips, and a signal processing/neural network approach for characterizing segments of trips. The latter option has the capability of simulating entire trips and soak periods. While the current Federal Test Procedure is based on a single driving cycle, there are advantages to using a different format for a new Federal Test Procedure, if one is needed. Some of these procedural format options are presented for consideration.

In conclusion, it seems that the current LA-4 driving cycle has the same shape of speed distribution as that observed in Spokane and Baltimore driving; however, the speeds represented by the Federal Test Procedure are somewhat lower than the speeds actually driven in Spokane and Baltimore. Also, the well-known acceleration upper limit imposed on the LA-4 during its creation is exceeded in the Baltimore and Spokane database. While approximately 2.7% of the observations were above the upper limit, the effect on the emissions of today's vehicles may or may not be significant. This depends on the relationship between driving patterns and tailpipe emissions.

ACKNOWLEDGEMENTS

In a study of this magnitude, which dealt with the public and combined work from many disciplines, it is appropriate that the key players and organizations involved be thanked for their contributions.

With the assistance of the Washington and Maryland state agencies and the inspection/maintenance contractors, the recruiting of private vehicles immediately after exhaust inspections became routine. We especially want to thank all of the emissions inspectors who were in the lanes for their assistance in helping us solicit vehicles, the inspection station managers, Mark English, Peggy Vincent, and Jim Bryant, who helped us with day-to-day station logistics, and Leo Carroll of Vehicle Test and Technology, Inc. and Jim Brandenburg of Envirotest Technologies, Inc., who were enthusiastic about the project and helped us get historical information for specific stations to help determine the times of the day when vehicles should be solicited.

We would like to thank the 727 vehicle drivers who patiently listened to our explanation of the program while they were getting their cars inspected at the I/M stations in Spokane and Baltimore. Of these, 293 owners allowed us to attach datalogging systems to their vehicles to acquire the data presented in this report. Many of these vehicle owners greatly appreciated being involved in a study that may help increase understanding of some of the environmental effects of light-duty motor vehicles.

Many people were involved with the data collection process; however, the field installation and retrieval crews deserve special recognition. Automotive Testing Laboratories provided Fred Horne and Bill Kammerer, two experienced automotive mechanics who proved invaluable in the field for instrumentation and removing equipment from vehicles. Kirby Hueske and Rick Baker were the on-site solicitors at Spokane and Baltimore who had the unusual and sometimes challenging job of soliciting vehicle owners for participating in the instrumentation program. Mark Hutson, Jimmy Hand, David Ranum, and Barry Walker provided the bulk of the labor by installing and removing dataloggers from the vehicles and downloading the data onto floppy disks in their hotel rooms at night. Sandeep Kishan was the on-site task leader in both Spokane and Baltimore.

We would like to thank the Motor Vehicle Manufacturer's Association (MVMA) for their contributions of automotive expertise and their piggyback project that accompanied this EPA undertaking. Because of their support, we increased the number of vehicles instrumented from 100 to almost 300 vehicles. Special thanks are due Greg Walker of MVMA and Tom Darlington of General Motors, who was the FTP committee chairman.

Finally, Radian would like to thank the EPA work assignment manager, Jim Markey, for his understanding guidance during this interesting project, which may have far-reaching and long-term effects on the automobiles we drive.

1.0 INTRODUCTION

The Clean Air Act Amendments of 1990 require the U.S. Environmental Protection Agency (EPA) to evaluate the Federal Test Procedure (FTP) and revise it as necessary to ensure that vehicles are tested under circumstances that reflect actual current driving conditions. These conditions include fuel, temperature, acceleration, and altitude. Currently, EPA is making appropriate changes in the procedure to address concerns about the representativeness of the fuel, temperature, and altitude provisions. However, the current driving cycle used in the FTP has not been evaluated to determine if it is representative of vehicles in actual use.

EPA's Certification Division of the Office of Mobile Source Air Pollution Control has been given the lead responsibility to analyze and modify, if necessary, the FTP. The project discussed in this document has been performed to collect information on in-use driving patterns. An evaluation of techniques which could be used to measure driving patterns (1) recommended that driving pattern information should be collected using two complementary techniques: the chase car technique and the instrumentation of private vehicles. Sierra Research has collected data using the chase car technique; Radian Corporation has collected data from instrumented private vehicles. This report discusses the methods, data, and preliminary results of the instrumented private vehicle study.

The purpose of this driving modes project was to collect information on the way a representative cross-section of U.S. light-duty vehicles is actually driven in typical operation. The project involved instrumenting private vehicles with instrumentation packages that measured vehicle and engine parameters on a second-by-second basis whenever the vehicle engines were running.

The most important of the parameters measured from the instrumented vehicles was the vehicle speed. In the data analysis, vehicle speed time profiles for the

sampled vehicles are compared with the current Federal Test Procedure time profile to determine if the FTP is representative of today's driving. Engine operating data were also collected since they can be used to characterize the operating state of the engine in the vehicle. From all of the data together, investigators may be able to estimate the relative exhaust emissions of vehicles in different operating regimes.

The two main objectives of this work were:

- To collect enough quality driving pattern data by instrumenting private vehicles to define the driving patterns of the in-use vehicle population; and
- To analyze the instrumented private vehicle data and compare the measured driving patterns with patterns emerging from other measurement techniques and with the current Federal Test Procedure.

The development of a new prototype certification test procedure is not part of this work.

1.1 The Current Federal Test Procedure

The current Federal Test Procedure is described in the Code of Federal Regulations (2). This procedure involves several specifications for fuel, test temperature, preconditioning of the automobile, as well as the driving cycle used on the chassis dynamometer. The basis for the driving cycle is the so-called LA-4, which was based on a small driving survey made in Los Angeles in the 1960s. In the 1990 Clean Air Act Amendments, Congress has in effect asked EPA to determine whether the LA-4 is representative of today's driving. While vehicles have gone through several changes in the 25 years since the LA-4 was first developed, it is not obvious that the driving patterns of people who use vehicles in their day-to-day lives has changed. One of the reasons it is not obvious is that driving behavior is a complex thing and it can be quantified in many different ways.

To get an idea of the complexity of driving, the current LA-4 is shown in Figure 1-1 as a plot of vehicle speed versus time. This figure shows that the cycle is made up of many accelerations and decelerations in an apparently random sequence. It is not clear at first glance how a large amount of vehicle driving data such as that collected in this study can be distilled down to a single driving cycle.

The Federal Test Procedure was originally designed to be used to test prototype vehicles for their emission control performance. However, in reality, because many laboratories had the ability to perform FTP testing and because of the large amount of data generated from FTP testing, the impact of the FTP has been larger than its originally intended purpose. Thus, it is likely that any new Federal Test Procedure developed may also be used for other purposes.

1.2 Project Description

The Certification Division of EPA's Office of Mobile Sources has been responsible for evaluating the current FTP. In the summer of 1991, the Certification Division decided to proceed with investigating real-world driving patterns using both instrumented private vehicles and the chase car technique. Activities on the private vehicle instrumentation project described in this document began in earnest in August of 1991. EPA planned to instrument 50 vehicles each in Spokane, Washington and Baltimore, Maryland. Because of the automobile industry's interest in the new Federal Test Procedure, the Motor Vehicle Manufacturers Association (MVMA) and the Association of International Automobile Manufacturers, Inc. (AIAM) developed a data-logging system in pilot studies conducted earlier in 1991. When it became clear that EPA was going to instrument vehicles in the field, MVMA/AIAM offered the experience that they had acquired in their pilot study. As a result, in a parallel effort, MVMA/AIAM funded a concurrent project so that the number of instrumented vehicles in the overall study could be increased from 100 to 288. Because of project constraints,

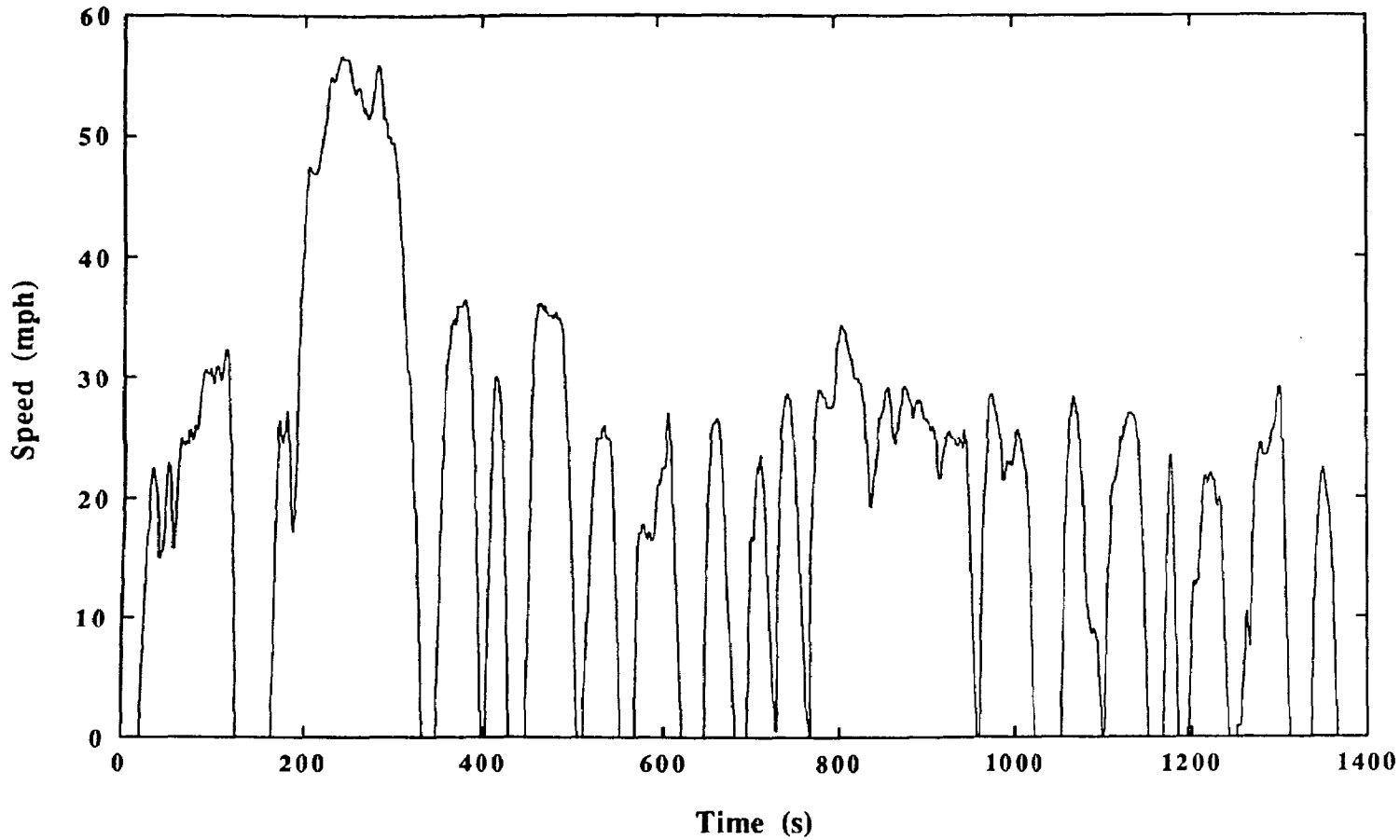


Figure 1-1. The LA-4 Driving Cycle of the FTP

90 of these vehicles were to be instrumented with the MVMA/AIAM datalogging system and 198 vehicles were to be instrumented with an EPA datalogging system.

The EPA datalogging system, known as the 3-parameter datalogger, was built for EPA in the early months of the project by Radian Corporation. It was designed to be used on any vehicle so that data on vehicle speed, engine RPM, and manifold absolute pressure (MAP) would be collected each second the engine was on. The MVMA/AIAM datalogging system was designed to be used only on certain late model vehicles because it had to be tied into the vehicle engine control unit (ECU). However, the MVMA/AIAM system collected 6 parameters: vehicle speed, engine RPM, manifold absolute pressure, coolant temperature, throttle position, and equivalence ratio. Thus, it was felt that a combination of the 3-parameter and 6-parameter dataloggers would provide a good view of how vehicles are driven. Equipment preparations were completed in January of 1992 and actual vehicle installations occurred in February and March of 1992, in Spokane and Baltimore, respectively. A total of 293 vehicles were instrumented, and 74% of the vehicle data files met the strict data quality requirements of the project.

Approximately one gigabyte of data was collected in the study. This report presents the results of a first pass analysis of this large amount of data. In addition, the report discusses advanced methods of analysis that may be useful to understanding the driving patterns of the vehicles. While the report does not develop candidate driving cycles for a new Federal Test Procedure, the statistics that are calculated from the driving patterns observed in Spokane and Baltimore should be useful for evaluating candidate cycles proposed in the future.

1.3 Structure of This Report

This report contains several sections describing the equipment, procedures, results, and data analyses of the vehicle driving patterns. Section 2 describes the

datalogging equipment used for the collection of data with the 3-parameter dataloggers and 6-parameter dataloggers. Section 3 describes the field procedures used to select vehicles for datalogger installations and the detailed activities performed for datalogger installations and removals. This section can be used by the reader to understand the procedures used to select vehicles in a representative fashion. Section 4 describes the selection of the cities used for the study, the facilities where the instruments were installed on the vehicles, and the success rate of solicitation and instrumentation. Section 5 discusses the procedures and standards used to check the quality of the driving pattern data obtained.

Section 6 contains the data analysis. In this report, only the speed measurements are analyzed. The other five vehicle operating parameters have been very useful for determining the quality of the speed data, and they also may be used in the future to determine how vehicles respond to the needs of the driver. The data analysis considers speed, acceleration, trips, vehicle, and driver. In this report, purely statistical measures are being considered. However, the data analysis section presents suggestions for advanced data analysis methods that may be useful for understanding driving patterns, simulating driving patterns, and developing new driving cycles.

2.0 DATALOGGING EQUIPMENT

To determine the driving behavior of vehicles on the road, equipment was needed to record the speed of individual vehicles and the time the vehicles were turned on and off. The method chosen for this was to place a datalogger on selected vehicles for a one-week period. The configuration of the datalogger was considered and the result was that two different types of dataloggers would be used in the study: a 3-parameter datalogger and a 6-parameter datalogger.

Several attributes of the dataloggers were considered when writing the design specifications. Some of the choices included: rent versus buy versus build, under the hood versus in the trunk, PC based versus non-PC based, all model-year vehicles versus late model-year vehicles, OEM sensors versus aftermarket sensors, high temperature electrical components versus normal temperature electrical components, a small package versus a normal-sized package, field installation versus test car lab installation, speed only measurement versus multiple parameter measurement, and several others. The two types of dataloggers which were used in the study were chosen because they had different advantages and disadvantages.

The sections which follow discuss the specifications, the hardware design, the software design, vehicle applications, laboratory function tests, test track testing, and pilot testing of the 3-parameter and 6-parameter dataloggers. The specifications for the datalogger operation and testing are given in the Quality Assurance Project Plan (3).

2.1 3-Parameter Datalogger

The 3-parameter datalogger took more than half of the observations in the study. This datalogger was designed to be small and able to withstand the elevated temperatures found underneath the hoods of vehicles so that it could be installed near to where aftermarket speed sensors would be placed on the vehicle. The objective here

was to enable to installation crew to install the datalogging system as rapidly as possible so that the owners of the vehicles could wait while their vehicle was being instrumented. It was believed that a short installation time and a nonintrusive method of installation would result in a higher percentage of people who were willing to participate in the study.

The initial concepts for the datalogger involved collecting only vehicle speed data; however, it was later realized that the inclusion of engine RPM and manifold absolute pressure helped to determine when the engine was on and provided a better set of data for future analysis of the demands that drivers put on the power plant of their vehicles in normal driving. After the data was collected, it was found that the engine RPM and manifold absolute pressure data also helped in the data quality checking process.

A total of 55 3-parameter dataloggers were fabricated for this project. The first 10 dataloggers were larger than the last 45 "mini" dataloggers.

2.1.1 3-Parameter Logger Measurements

Table 2-1 gives the critical and noncritical measurements in this test program for the 3-parameter logger. To meet the primary objectives of the project, the critical measurements were vehicle speed and date and the time of day the engine was turned on and turned off. Together, these three measurements determined when people took trips, when vehicles were at rest, and how people drove their vehicles during the trips.

Vehicle speed was collected once per second whenever the engine was running. Depending on the vehicle type, the sensor used to measure vehicle speed was either a Hall-effect transducer attached to the speedometer cable, the OEM vehicle speed sensor, which is used on many late-model vehicles, or magnets and an inductive

Table 2-1

Summary of Physical Measurements for the 3-Parameter Datalogger

Measurement	Measurement Classification	Measurement Site	Measurement Frequency
Vehicle Speed	Critical	Speedometer Cable Vehicle Speed Sensor Magnetic Pickup	Once per second when engine is on
Date/Time of Day for Engine Start-Up	Critical	MAP, RPM, and speed signals plus software logic causes datalogger clock to stamp memory	Once at engine start-up
Date/Time of Day for Engine Shut-Down	Critical	MAP, RPM, and speed signals plus software logic causes datalogger clock to stamp memory	Once at engine shut-down
Engine RPM	Noncritical	Ignition coil	Once per second when engine is on
Manifold Absolute Pressure (MAP)	Noncritical	Intake Manifold	Once per second when engine is on

pickup, which was attached to a rotating vehicle drive train component such as the driveshaft.

The date and time of day the engine was started up and shut down were also critical measurements, because they determined when a trip took place and when the vehicle was at rest. These times were determined once at engine startup and once at engine shutdown.

For the 3-parameter datalogging system used in Spokane, the datalogger considered trips to be in progress when the RPM was above 300 rpm. The datalogger stamped the date and time in memory only at engine startup and shutdown. For the 3-parameter datalogger, which needed to sense the RPM of any vehicle from the ignition coil, these criteria worked well in most cases, but on some vehicles a good RPM signal was lost during the one-week instrumentation period. If this occurred, the entire vehicle data file had to be labeled suspect, since the times of trip stop and start were uncertain. To prevent such occurrences for the 3-parameter datalogger in Baltimore, the criteria for the start and end of datalogging were changed by modifying the 3-parameter datalogger software to the following:

- Begin datalogging when:

  Speed > 0.1 m/s

  OR

  RPM > 0 rpm

  OR

  MAP < 80 kPa

- End datalogging when:

  Speed = 0 m/s

  AND

  RPM < 300 rpm

  AND

  MAP > 80 kPa

Using these criteria to define the beginning and end of datalogging greatly improved the robustness of the 3-parameter datalogger and its interface with the vehicle systems. It also provided more information on vehicle and engine operation, which proved useful in the data quality checking process.

Engine RPM was a noncritical measurement, but it was recorded once per second whenever the engine was running. Engine RPM was sensed by monitoring the frequency of the pulses on the tachometer terminal of the ignition coil. By taking into account the number of cylinders on the engine, the number of ignition coils on the engine, and whether the engine was a piston or rotary type, the engine RPM was calculated and recorded in memory.

Manifold absolute pressure (MAP) was a noncritical measurement that was logged once per second when the engine was on by using a pressure transducer on the circuit board of the datalogger connected to any intake manifold vacuum source on the engine by vacuum tubing.

2.1.2 Quantitative Quality Assurance Objectives

Table 2-2 lists the quality assurance objectives for the precision, accuracy, and completeness of the parameters recorded by the datalogger. The measurements for

Table 2-2

QA Objectives for Precision, Accuracy, and Completeness

Measurement	Measurement Classification	Method	Reporting Units	Precision[a]	Accuracy[b]	Completeness
Speed	Critical	3-parameter logger	m/s	<0.16m/s	<0.16m/s	≤2 missing values per trip
RPM	Noncritical	3-parameter logger	rpm	<33 rpm	<33 rpm	≤2 missing values per trip
Manifold Absolute Pressure	Noncritical	3-parameter logger	kPa	<1.6kPa + 6% of pressure reading	<0.8kPa + 3% of pressure reading	≤2 missing values per trip

[a] The largest difference between two loggers being fed the same signals.

[b] The largest difference between the reference signal and the datalogger recorded value.

vehicle speed are based on full-scale, 12-bit resolution at 40.95 m/s. The measurements for engine RPM and manifold absolute pressure are based on full-scale, 8-bit resolution at 8500 rpm and 200 kPa, respectively.

The accuracy of the speed measurement depends on the resolution of the 12-bit value stored in the datalogger and on the number of pulses used to calibrate the speed sensor on each vehicle. It is the driven distance used to calibrate the speed sensor which limits the accuracy of the logged speed values. The calibration distance was chosen to be around 800 feet because this produces at least 256 speed sensor pulses for all vehicle/speed sensor configurations. Thus, the accuracy of the speed measurement is in all cases better than (1/256) * 40.95 m/s or 0.16 m/s (= 0.36 mph).

The precision of the speed measurement is better than 0.16 m/s because of the 12-bit resolution; however, it is probably limited by the number of pulses per second, the times between which are averaged and inverted to get the average speed during each second. At high speeds many time periods are averaged; at low speeds only one or two time periods are averaged; high speeds are possibly more precise than low speeds. Rather than be concerned with these effects on the precision of the speed measurement, it is simplest to claim that the precision is less than 0.16 m/s.

The accuracy of the RPM assumes that errors will be present only because of digitizing error of the least significant bit. This will be about 33 rpm. The precision is not claimed to be better than the accuracy because the accuracy will be 1 bit. Thus, if the accuracy criteria are met, the precision criteria will be met.

Because manifold absolute pressure will be measured in an analog fashion, its accuracy will be no worse than the linearity of the pressure transducer [1% of full-scale (200 kPa)] plus the error of the transducer output amplifier feedback resistors (2% of the reading) plus the digitization error [0.4% of full-scale (200 kPa)]. Precision is

dominated by the tolerances on the pressure transducer and the amplifier feedback resistors. Thus, the precision is twice the accuracy for manifold absolute pressure.

The quality assurance objectives for the completeness of these three parameters is that during any trip the number of missing values recorded will be less than 2 readings. Missing values are determined by comparing the number of observations during a trip with the difference in time stamps at the start and end of the trip.

2.1.3 3-Parameter Datalogging Equipment Design

Radian's Electronic Services Center (RESC) designed and fabricated the 3-parameter logger. The logger contained a single circuit board to store incoming signals on solid-state memory chips. Each logger had 768 Kb of data memory. The logger had hardware to measure the frequency of speed transducer signals and RPM signals, an on-board transducer to convert manifold absolute pressure to an electrical signal, and an internal clock with its own lithium battery. The datalogger circuit board was conformal-coated to protect it from the elements and to reduce the effects of vibration. All components on the circuit board were 85°C-grade components. The circuit board was provided with an RS-232 port for communicating with a laptop PC. The circuit board was placed in a box so that the entire "mini" package measured 5 x 7 x 1.5 inches. The inputs of the datalogger were +12 volts, ground, + speed, - speed, + ignition coil, and a vacuum port for the engine intake manifold vacuum.

The datalogger turned on when signals from the vehicle indicated that the engine was running. At other times, the datalogger was off and no current was drawn from the vehicle's battery. Data were logged every second. At this logging rate for these parameters the logger could acquire data for approximately 54 hours of engine-on time.

The speed sensor used depended on how the stock vehicle was equipped. Older cars were equipped with a speedometer cable that led from the transmission to the back of the speedometer gauge on the dashboard. Speed sensors for most of these vehicles were attached to the vehicle by inserting a pulse generation unit between the transmission and the speedometer cable. These transducers were purchased from Rostra Precision Controls; they are manufactured for after-market cruise controls. For Fords, this type of transducer could not be inserted in the speedometer cable at the transmission because of the method of construction of the cable. Instead, older model year Fords required the installation of magnets on the drive shaft and the mounting of a nearby inductive pickup to provide pulses that were sent to the datalogger. This was a relatively easy installation; however, in a few cases it required drilling two holes in the vehicle's sheet metal floor underneath the front seats.

Many late-model vehicles do not have a speedometer cable but are provided with vehicle speed sensors as a way to determine the speed of the vehicle. The speedometer gauge then converts these signals to a speed which is displayed on the dashboard. The 3-parameter logger tied into the leads from the vehicle speed sensor with a Scotch-Lok connector. This provided a speed signal with a pulse rate proportional to vehicle speed.

Signals proportional to the engine RPM were obtained from the tachometer terminal on the ignition coil. On older vehicles, coils are mounted in the open and the terminal was accessed using a wire with a crimp connector. In many late model cars, the coil is located inside the distributor. For this configuration, special connectors from Thexton were used. These connectors were inserted between the distributor electrical connection and the wiring harness. Several different types of connectors were available for different late model vehicles.

The manifold absolute pressure signal was obtained by teeing into a vacuum line on the vehicle. Vacuum tubing was run to the transducer, which is located on the datalogger circuit board.

Applications

The 3-parameter datalogger was used on any car selected for instrumentation. In this study, light-duty cars and trucks with gross vehicle weights (GVW) less than 8500 pounds were instrumented.

Data Conversion Software

Software was written to reside on the datalogger to provide several functions:

- Enter vehicle information into memory;
- Flag the datalogger operating mode as Calibration or Run;
- Calibrate sensors on each vehicle;
- Convert signals to engineering units;
- Record data in memory;
- Conduct a parity check on each observation as it was taken;
- Display engineering units via a laptop PC as the vehicle is being driven;
- Turn the logger on and off with the engine;
- Dump data from memory to a PC; and
- Erase memory.

During each second of data collection, signals from each of the three transducers were averaged and the average value was stored in memory. For vehicle speed and RPM, this calculation was done by averaging the time between consecutive pulses during each one-second period. The reciprocal of this average time between pulses is proportional to vehicle speed or engine RPM. For manifold absolute pressure, the average of the readings obtained during each one-second period was stored in memory.

Software was written to provide communications between the datalogger and a laptop PC. This allowed calibration and checkout of the datalogger after installation on a vehicle and downloading of the data at the end of the instrumentation period. The downloaded data format was compatible with the SAS files that were created. The date and time were stamped only at the beginning and end of each trip to save memory space. Between these two stamps, vehicle speed, engine RPM, and MAP were recorded every second. SI units were used for speed, RPM, and MAP, that is, m/s, rpm, and kPa.

A parameter was created by the datalogger software to record for each logged observation whether the datalogger status was in the calibration mode or the run mode. This flag was set by the installation and removal crews to differentiate between driving by the crew and driving by the regular vehicle driver. A parameter for parity check was also created to increase the reliability of each observation in the logged data. The set of parameters for each observation were parity-checked and the result logged in memory.

2.1.4 Laboratory Function Checks

The circuit design and software of the datalogger was tested to ensure that the datalogger met the quantitative quality assurance objectives. This was done by

checking a prototype datalogger in the laboratory and on vehicles. Accuracy and precision checks were performed in the laboratory.

Following the fabrication of the 55 dataloggers, the functionality of each unit was checked in the laboratory. These checks were in addition to the mechanical and visual checks to which each datalogger was subjected during manufacture.

For the functional checks, software and hardware were built to provide a rapid checkout of all datalogger functions. This ensured the proper operation of each datalogger in the field. The functional checks included go/no go tests on each input. A memory check program verified memory operation by recording and retrieving data.

2.1.4.1 Speed and RPM Function Tests

The accuracy of the datalogger design for speed and RPM was measured on the test bench by feeding the prototype datalogger a signal from a square wave generator. Simultaneously, the signal was also fed to a frequency counter wired in parallel with the datalogger. Accuracy measurements were made using signals of similar frequency to those found on a vehicle with an 8 cylinder, piston engine with one ignition coil for which 800 distance pulses were obtained in 800 feet. The readings from the frequency counter were converted to speed or RPM, as appropriate, using the following relationships:

$$\text{Speed (m/s)} = [\text{Frequency (pulses/sec)}] * [0.3048 \text{ m/ft}] * \frac{[\text{Measured Road Distance (ft)}]}{[\text{No. of Pulses in Measured Road Distance (pulses)}]}$$

$$\text{RPM (rpm)} = \frac{120 * [\text{Frequency (pulses/sec)}] * [\text{No. of Coils}]}{[\text{No. of Cylinders}]}$$

The values obtained from these expressions and the values stored in the datalogger's memory are shown in Table 2-3 and are within the quality assurance accuracy objectives for speed and RPM, which were 0.16 m/s and 33 rpm, respectively.

2.1.4.2 Manifold Absolute Pressure Function Tests

The 3-parameter datalogger measured manifold absolute pressure using a strain gauge type transducer, which was attached to the surface of the datalogger circuit board. A vacuum hose from the engine was connected to the port on this transducer. The datalogger had appropriate electronics and software to convert the signals from the transducer to manifold absolute pressure readings. Table 2-4 shows the type of transducer (and its specifications) used in the 3-parameter datalogger. The operating range of the transducer was chosen so that manifold pressures of turbo-charged engines could also be measured. The response time of the transducer was chosen so that it was shorter than the 1-second averaging time used in the datalogger software. The following procedures were used to check the precision and accuracy of the MAP transducer before field activities began.

The datalogger software was written to convert the signals from the MAP transducer to logged values as if the transducer produced accurate and precise values. Nine dataloggers with this software and the associated hardware were manufactured. These nine dataloggers were then checked against a two-leg mercury manometer and a vacuum generating system to calibrate the dataloggers. Since the MAP transducers had a useable range of 0 to 200 kPa, they were tested over as wide a range as the vacuum and pumping system was able to produce--from 7 to 183 kPa.

The true pressure at the MAP transducer measurement port with the test system connected was determined by adding the vertical difference between the two legs of the mercury manometer to the local atmospheric pressure and converting to kilopascals. Figure 2-1 shows the comparison of the actual pressure and the pressure

Table 2-3

Speed and RPM Function Check Results

Generator Input Frequency (Hz)	Logged Value in Memory (m/s)	Logged Value in Memory (rpm)	Expected Value in Memory (m/s)	Expected Value in Memory (rpm)
1.48	0.45		0.45	
2.92	0.89		0.89	
7.35	2.24		2.24	
14.66	4.46		4.47	
29.37	8.94		8.95	
73.5	22.39		22.40	
117.48	35.79		35.81	
20.00		300		300
40.02		600		600
80.01		1167		1200
160.02		2367		2400
320.4		4800		4806
400.8		6000		6012

Table 2-4

MAP Sensor Specifications

Type:	SenSym SCX30AN Precision Compensated Pressure Sensor
Operating Pressure Range:	0-30 psi (absolute)
Combined Linearity & Hysteresis:	±0.1% of full scale
Long-Term Stability of Offset & Span:	±1% of full scale
Response Time:	100 ms
Repeatability:	±0.2% of full scale

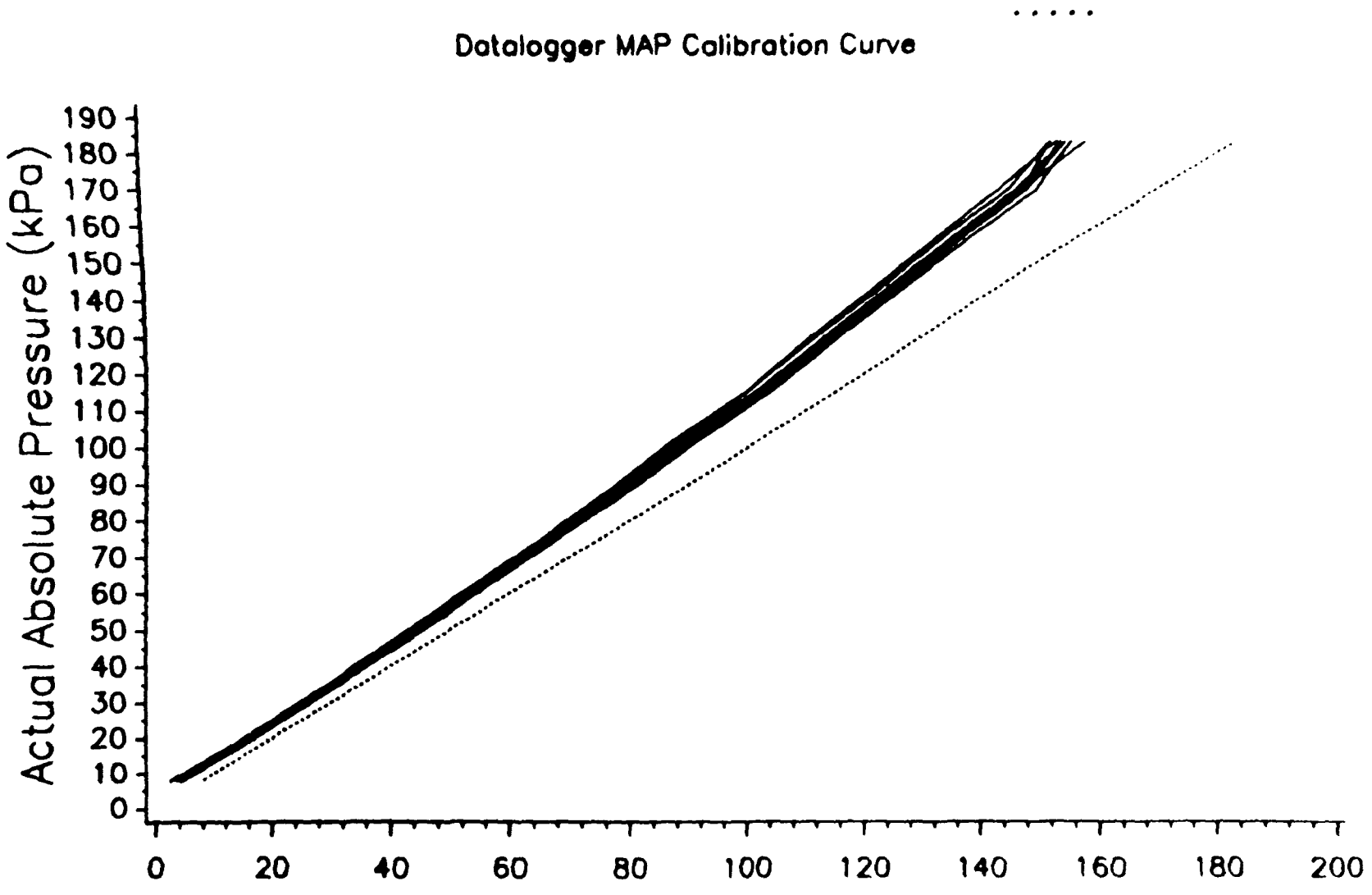


Figure 2-1. Pressure Measured by Datalogger (kPa)

logged by the datalogger. Also shown on the plot is the one-to-one line along which all data points would be expected to fall. The results for all nine datalogger transducers are shown in the figure, which shows that the datalogger underestimated the actual pressure at its measurement port and that the response of the transducer had a definite curvature.

To correct for these observed effects in the transducer response, a regression was made of the actual pressure against the datalogger pressure. A quadratic form of the correction equation was used so that a correction could be made for the curvature observed.

The results of this regression are shown in Figure 2-2. This plot shows the residual of the regression (that is, the datalogger MAP minus the fitted MAP) versus the actual absolute pressure. Each series of lines on the plot represents the response of one transducer. It can be seen that the fit of the data forms a fan-shaped set of residual points that increase in disparity as the actual absolute pressure increases. The lines drawn on the plot show the ± (0.8 kPa + 3% of reading) accuracy requirements stated in the Quality Assurance Project Plan (3). The figure indicates that these requirements were met. The precision between any two dataloggers would be at worst the difference between the upper data and the lower data in the figure. Thus, the precision requirements for MAP were met.

The regression equation derived from these calibration tests was then inserted into the datalogger software. Thus, the data values logged during data collection were automatically corrected for the transducer calibration, and the MAP data in the database therefore needs no correction.

2.1.5 Test Track Speed Accuracy Checks

The speed accuracy of the logged values in the 3-parameter datalogger was tested in a vehicle on the road using a fifth wheel. Separate tests were performed using

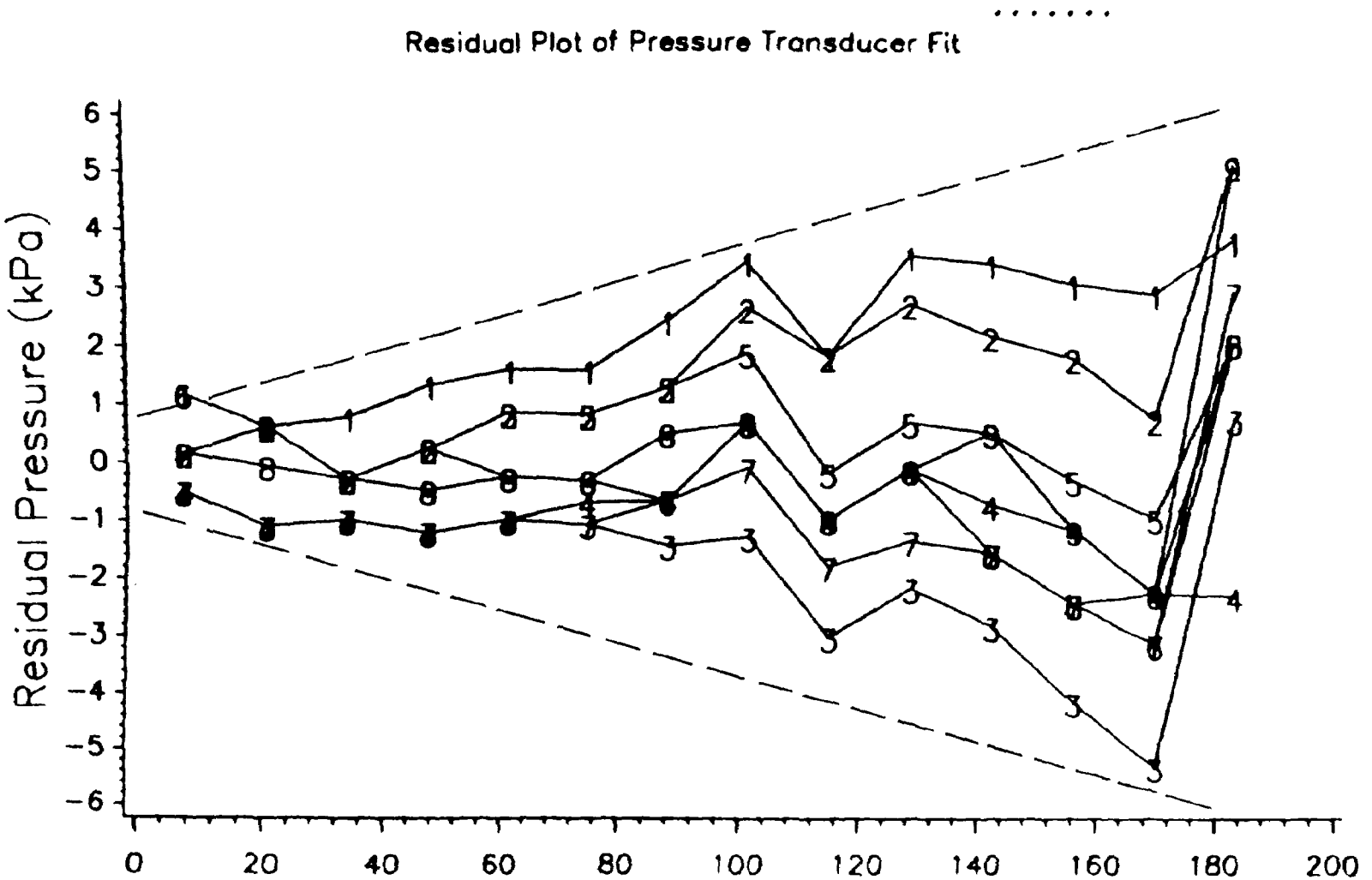


Figure 2-2. Actual Absolute Pressure (kPa)

the three speed sensor configurations available as inputs to the 3-parameter datalogger system configuration. Data were collected from the fifth wheel and from the datalogger simultaneously. Comparison of the simultaneous values indicated the accuracy of the 3-parameter datalogger as it was obtained on a vehicle.

A 1979 Buick LeSabre was equipped with a datalogger and a driveshaft magnet speed sensor. This vehicle was also equipped with another 3-parameter datalogger and a speedometer cable speed sensor. A 1991 Ford Taurus was equipped with a third 3-parameter datalogger. The speed signal on this vehicle was provided by the vehicle's OEM speed sensor wire. Each of the three dataloggers were calibrated using standard techniques in Austin before driving to the test track.

The three vehicles were driven to the Texas Transportation Institute at College Station, Texas, where a fifth wheel was rented for use on the Institute's test track. The fifth wheel was manufactured by Laboratory Equipment Corporation (156 East Harrison Street, Mooresville, Indiana, 46158). The fifth wheel used the conventional configuration with a bicycle-type wheel attached to the rear bumper of the vehicle. The fifth wheel had a pulse generation unit attached to the axle of the wheel. Pulses were transmitted to the electronics unit placed inside the vehicle. The electronics unit provided a readout of speed in miles per hour to the nearest 0.1 mph. The speed was updated about every 1/7 second.

The test track had a measured mile for the purposes of calibrating the fifth wheel. The fifth wheel was calibrated twice before all tests and once after all tests. The fifth wheel indicated that the measured mile had a length of 5325, 5327, and 5324 feet. In the preparation of the speed data before analysis, the indicated speed data from the digital readout of the fifth wheel were corrected for this slight error (0.85%) in the measured mile.

A video camera was used to record the digital display of the fifth wheel during the test drives. The video camera had an on-screen clock which was used to record the camera time during all test runs. This video clock was synchronized with the datalogger clock to within approximately two seconds. This provided a means of synchronizing the fifth wheel speeds with the datalogger speeds in an approximate manner. Adjustment for more precise synchronizing of the data was performed in the data analysis phase by sliding the relative time scales back and forth to achieve a best fit of the fifth wheel and datalogger data.

Three specific drive sequences were used to test the datalogger performance for each of the three speed sensor configurations. In general, the tests were to determine the accuracy of the datalogger at constant speeds, both slow and fast, and to determine the speed accuracy of the datalogger during rapid changes in speeds encountered during accelerations and decelerations. Three types of drives were used. Each drive was made up of a series of operating conditions. For Drives 1 and 2, each operating condition lasted 30 seconds. For Drive 3, each operating condition lasted 15 seconds. The following describes the operating conditions sequentially for each of the three types of drives:

Drive 1:

Turn engine on and idle.
Accelerate wide-open throttle to 50 mph and drive at a constant 50 mph.
Decelerate rapidly to 20 mph and drive at a constant 20 mph.
Decelerate rapidly to 10 mph and drive at a constant 10 mph.
Decelerate rapidly to 5 mph and drive at a constant 5 mph.
Decelerate rapidly to 2 mph and drive at a constant 2 mph.
Decelerate rapidly to 1 mph and drive at a constant 1 mph.
Stop and idle.
Turn engine off.

Drive 2:

Turn engine on and idle.
Accelerate rapidly to 1 mph and drive at a constant 1 mph.
Accelerate rapidly to 2 mph and drive at a constant 2 mph.
Accelerate rapidly to 5 mph and drive at a constant 5 mph.
Accelerate rapidly to 10 mph and drive at a constant 10 mph.
Accelerate rapidly to 20 mph and drive at a constant 20 mph.
Accelerate rapidly to 50 mph and drive at a constant 50 mph.
Decelerate rapidly to 0 mph and idle.
Turn engine off.

Drive 3:

Turn the engine on and idle.
Accelerate wide-open throttle to 50 mph and drive at a constant 50 mph.
Decelerate rapidly to 0 mph and idle.
Turn engine off.

The data from the 3-parameter dataloggers were downloaded to floppy disks in the conventional manner. The speed data from the fifth wheel for each of the three speed sensor configurations were recovered from the videotape by examining each frame of the video for Drives 2 and 3. The values from the videotape were transcribed to a database for data analysis using SAS.

A comparison of the speed logging performance of the 3-parameter datalogger and the fifth wheel can be made by examining plots and statistics. Figures 2-3, 2-4, and 2-5 show the results of Drive 2, where constant speeds of 1, 2, 5, 10, 20, and 50 mph were driven for approximately 30 seconds. The figures show, with a solid line, the values logged by the 3-parameter datalogger and with dots, the individual data points obtained from the fifth wheel. Only those data points for the fifth wheel for 15 seconds during relatively constant speed are shown. The figures show very good agreement for the magnet sensor and for the OEM speed sensor. In fact, the dots are not clearly visible because they are on top of the solid line. They are evident as a slight broadening

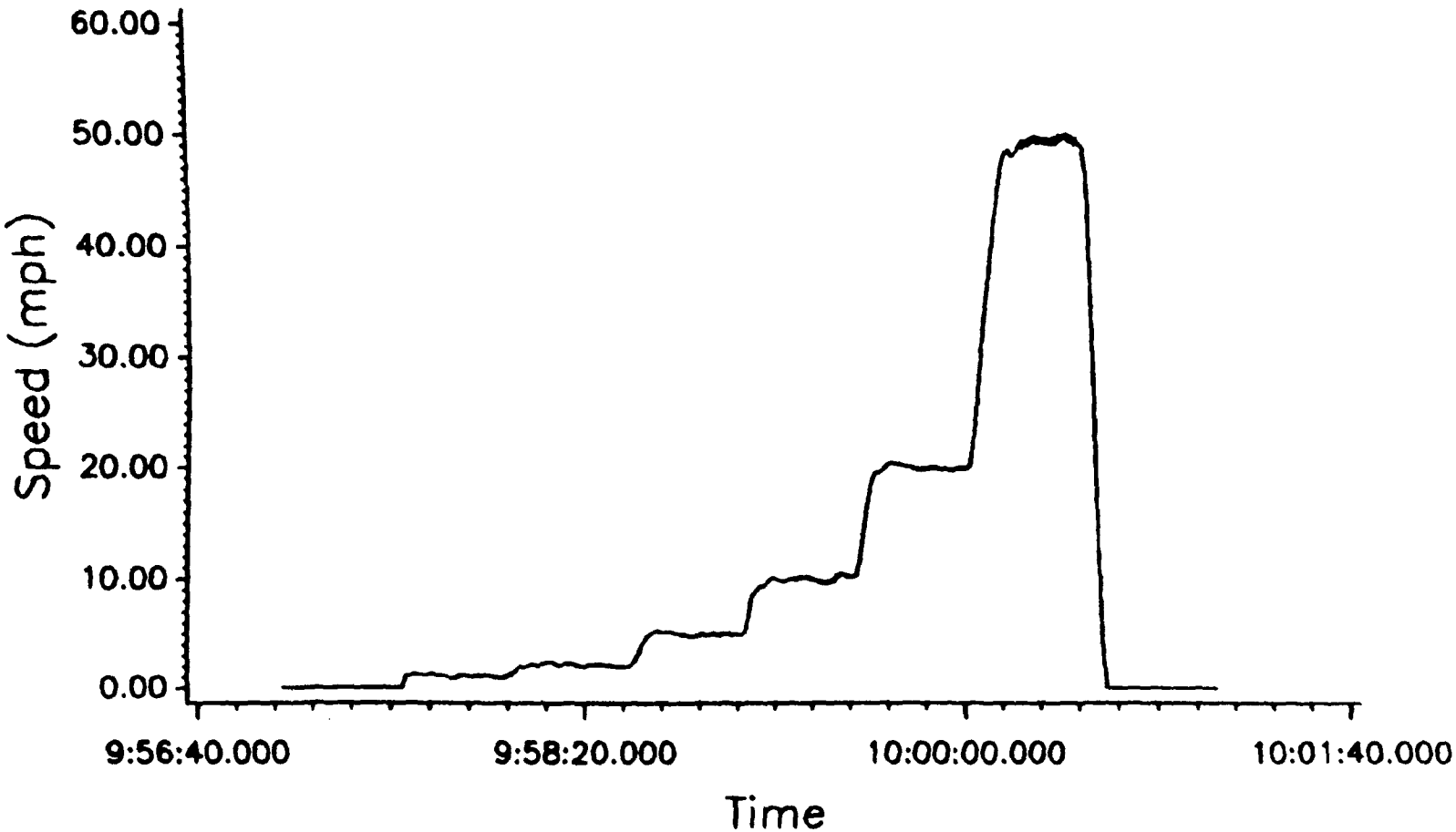


Figure 2-3. Constant Speed Performance for Magnet Speed Sensor

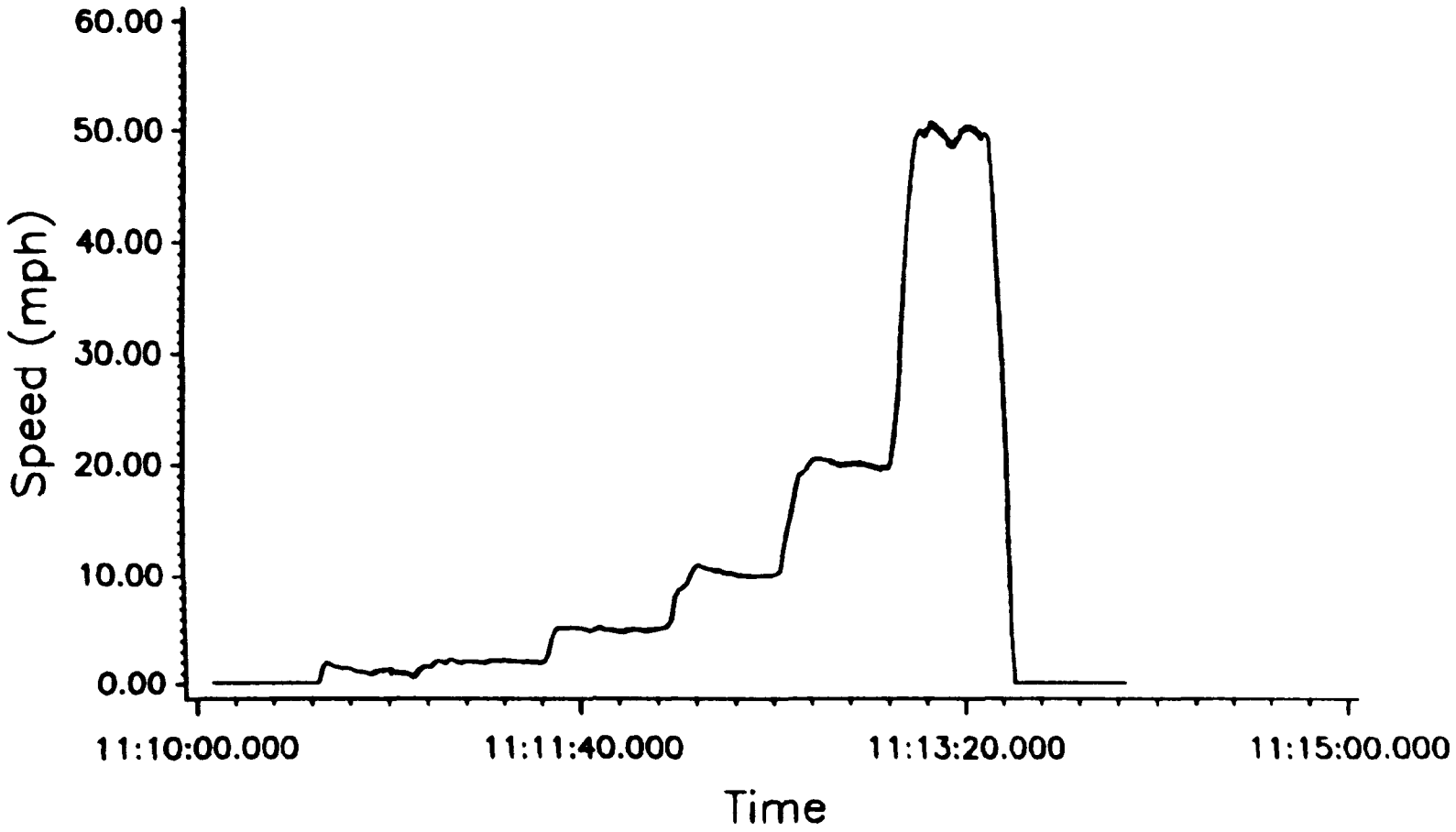


Figure 2-4. Constant Speed Performance for OEM Speed Sensor

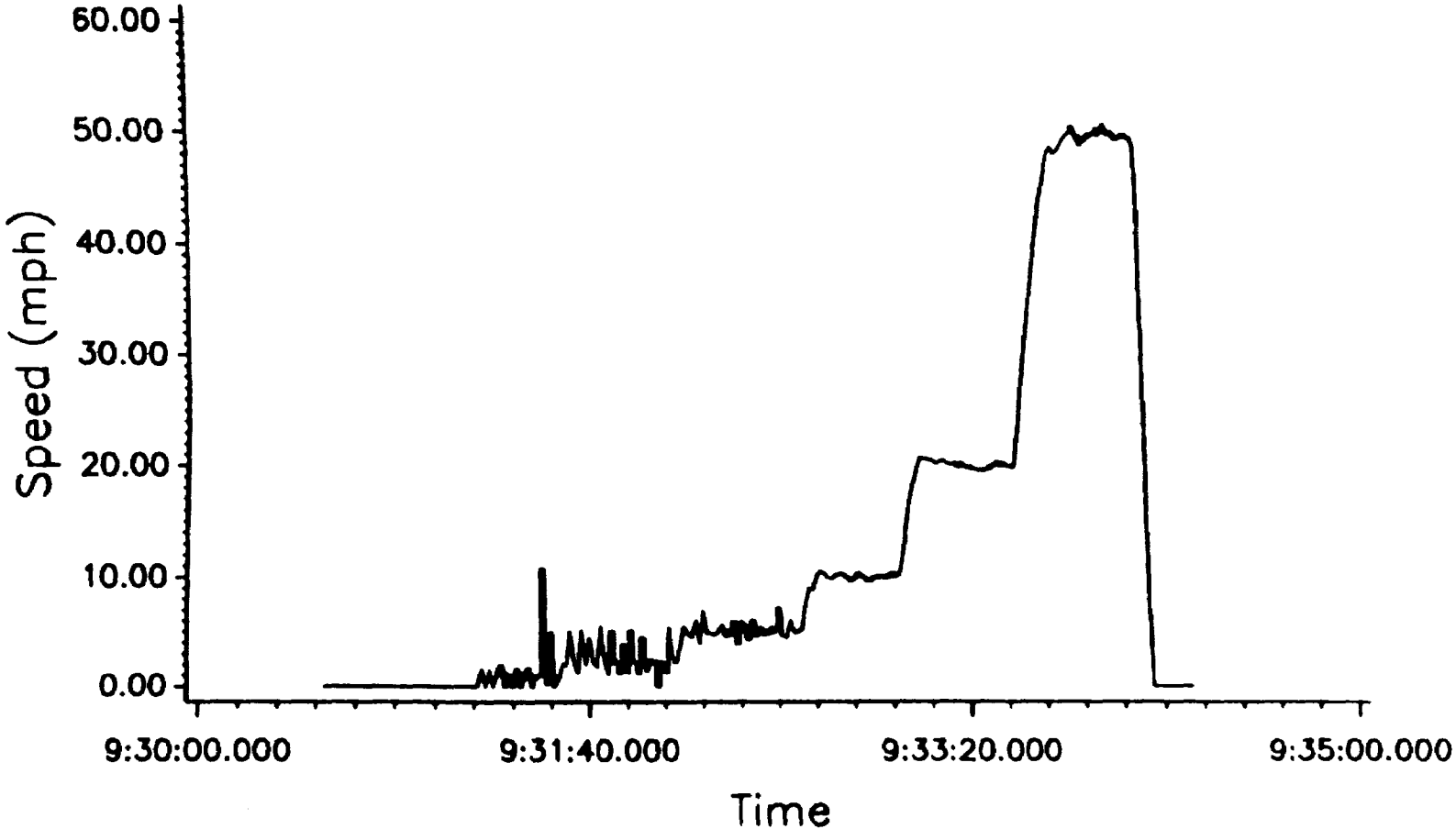


Figure 2-5. Constant Speed Performance for Speedometer Cable Sensor

of the lines at the constant speed plateaus. However, for the speedometer cable sensor, Figure 2-5 shows that the values logged in the 3-parameter datalogger were very erratic for speeds below 10 mph.

The speedometer cable speed sensor was attached to the speedometer cable under the hood as it entered the cruise control transducer. Thus, there was a length of approximately 5 feet of speedometer cable between the transmission and the speed sensor. The erratic behavior of the data was the result of a sharp bend in the speedometer cable which produced a jerky rotation of the inner speedometer cable as the vehicle was driven at low speeds. Unfortunately, the results of these tests were not known until the data analysis portion of these speed accuracy checks, and the check could not be repeated. Since the speedometer cable speed sensor operates by the same Hall effect principle as OEM speed sensors, the accuracy of the speedometer cable sensor at low speeds without jerk will be as good as that of OEM speed sensors.

In the field, every effort was made to install speedometer cable transducers in a manner which did not produce jerky motion of the inner cable. Wherever the speed transducer was placed directly on the transmission, there should be no low speed jerkiness in the logged values, since there is no cable between the transmission and the speed sensor. However, in those cases where the speed sensor was placed on a cruise control unit several feet from the transmission, there is a possibility that the logged values will have spikes in them.

One way to look for these spikes is to examine the jerk (the second derivative of the speed) for vehicles which used speedometer cable adapters. This was done in the data analysis of the Baltimore data. No evidence of this type of jerk in the speed was seen in that portion of the data quality checking; however, there may be such spikes in the Spokane data.

Figures 2-6 and 2-7 show the accuracy of the magnet and OEM speed sensors at the low speed of 1 mph. At this speed, the speed sensor is generating about 1.5 pulses per second. These are enlarged sections of the data taken during Drive 2. It can be seen from these plots that the 3-parameter datalogger takes accurate measurements at these very low speeds. While such low speeds are probably used very little in actual driving, since to maintain them required that the driver keep his foot on the brake, these tests indicate that the datalogging system provides accurate measurements of them.

Accuracy at high speeds is shown in Figures 2-8, 2-9, and 2-10 at 50 mph. These plots are also an enlargement of a portion of the data taken in Drive 2. For all three types of speed sensors, the speeds from the datalogger tracked the true speed of the fifth wheel very well.

Several statistics were calculated for the data taken during Drive 2 for the three types of speed sensors. These statistics are presented in Table 2-5. For each nominal speed for each of the three speed sensors, the table shows the average and maximum absolute speed difference between the fifth wheel and the datalogger for 1-second average values for the 15-second period of each constant speed segment. The table shows that, except for the low speeds on the jerking speedometer cable, the agreement is very good. The speed accuracy specification to be met is 0.16 m/s (=0.36 mph). The table shows this was met.

The transient performance of the 3-parameter datalogger and its sensors is examined by considering the plots in Figures 2-11, 2-12, and 2-13. These are the results for Drive 3, which was the wide-open throttle acceleration followed by a panic stop. It can be seen that the datalogger values and the fifth wheel values fall closely on top of each other.

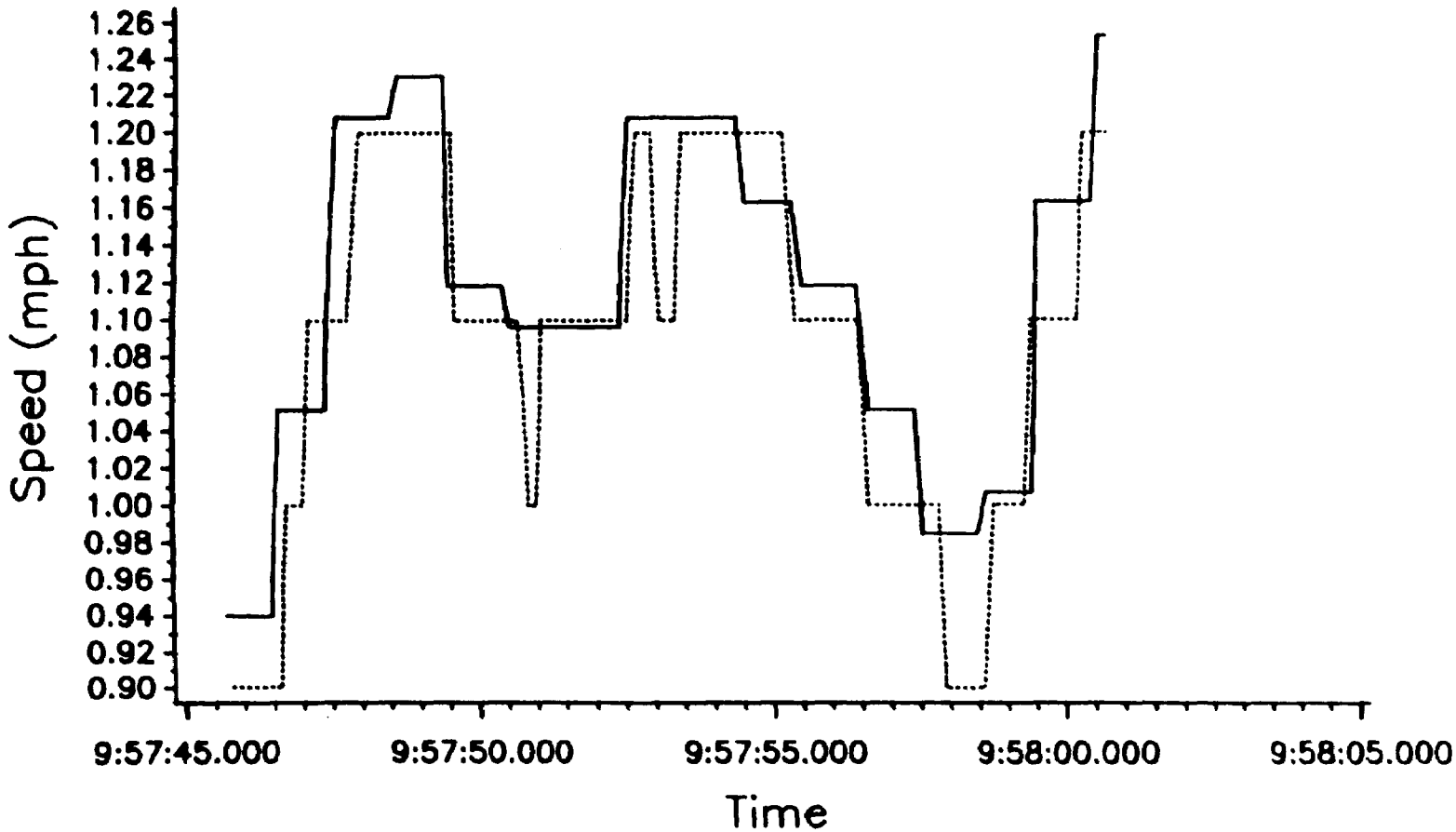


Figure 2-6. Low Speed Accuracy for Magnet Speed Sensor

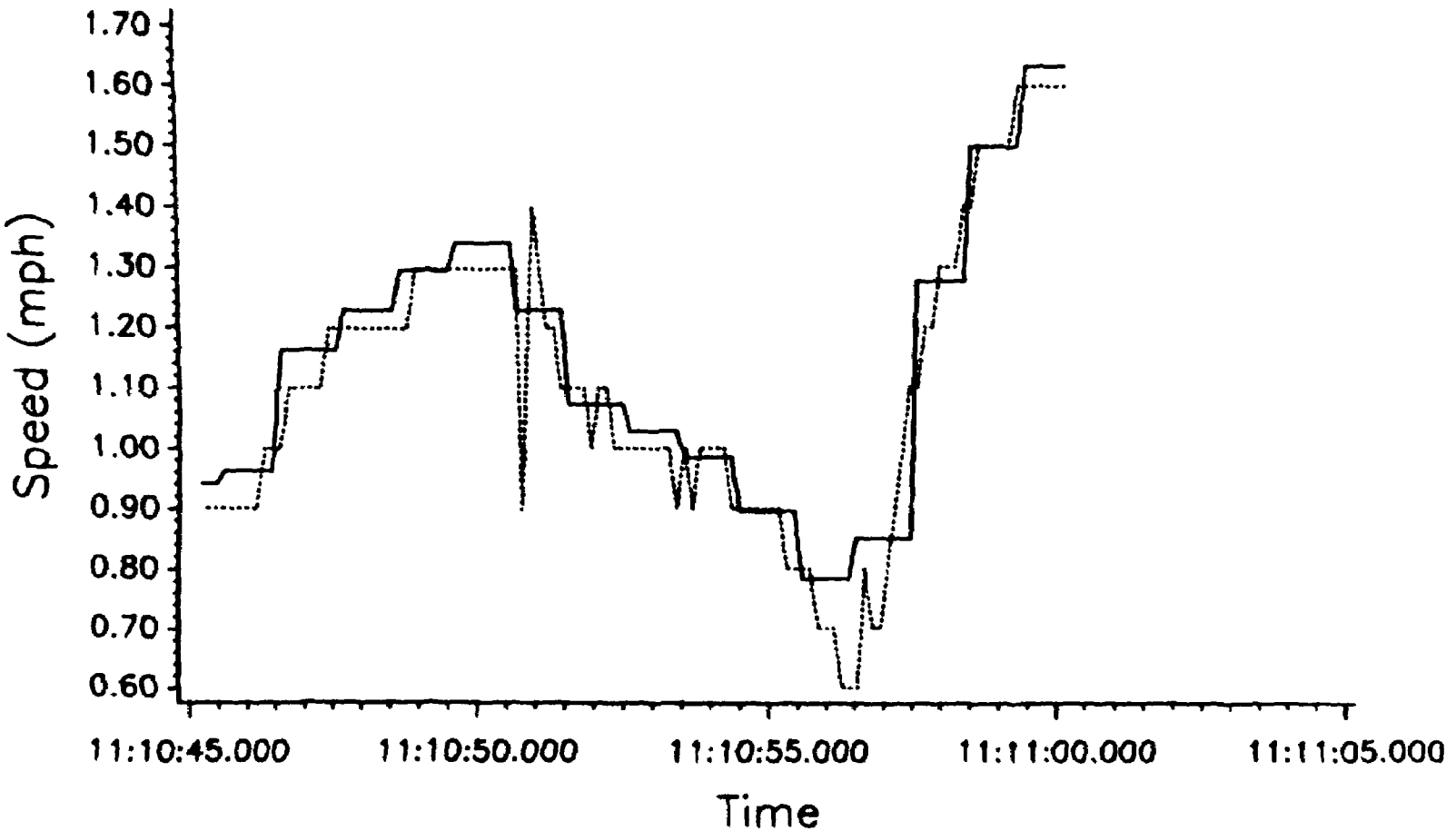


Figure 2-7. Low Speed Accuracy for OEM Speed Sensor

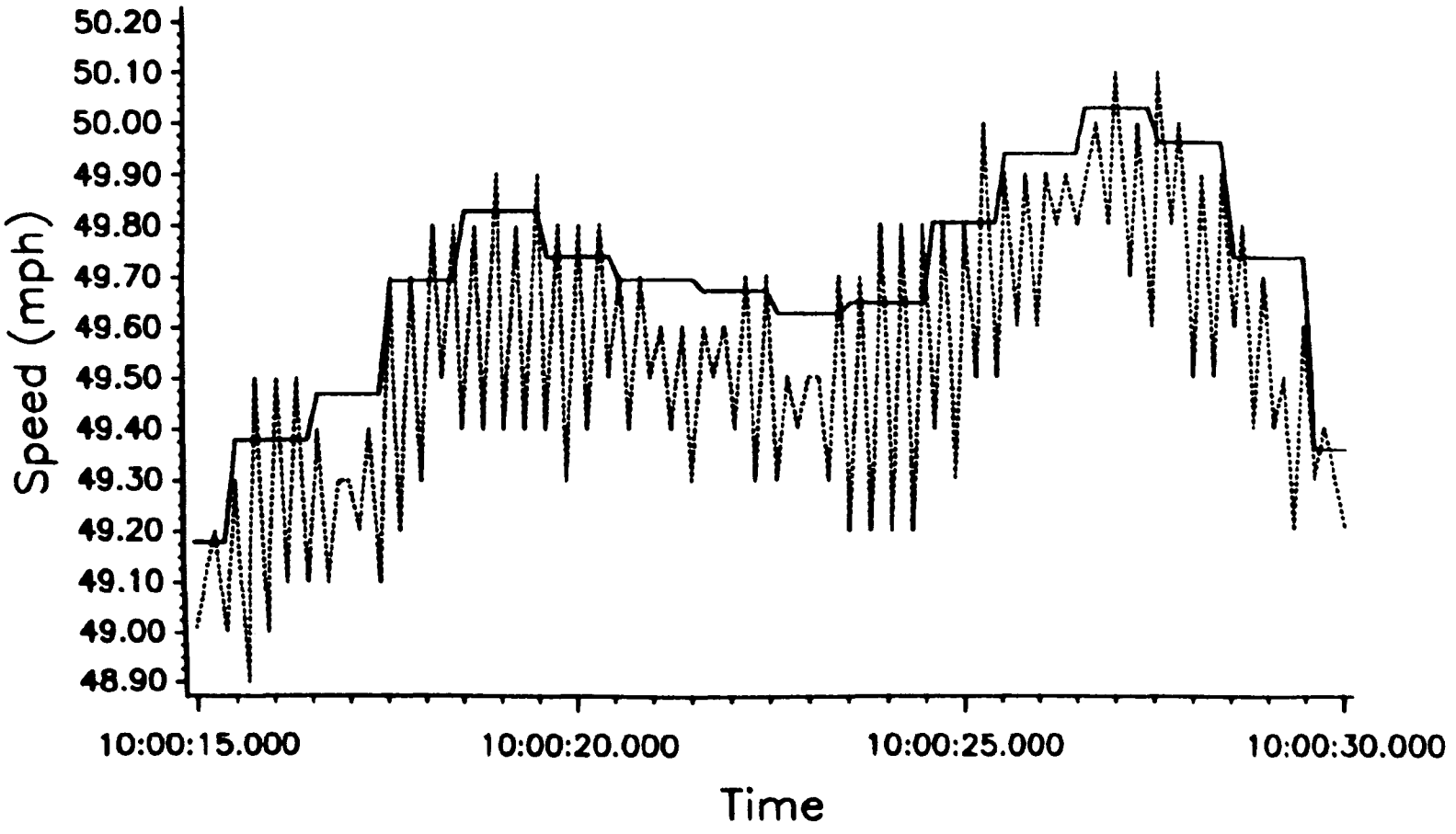


Figure 2-8. High Speed Accuracy for Magnet Speed Sensor

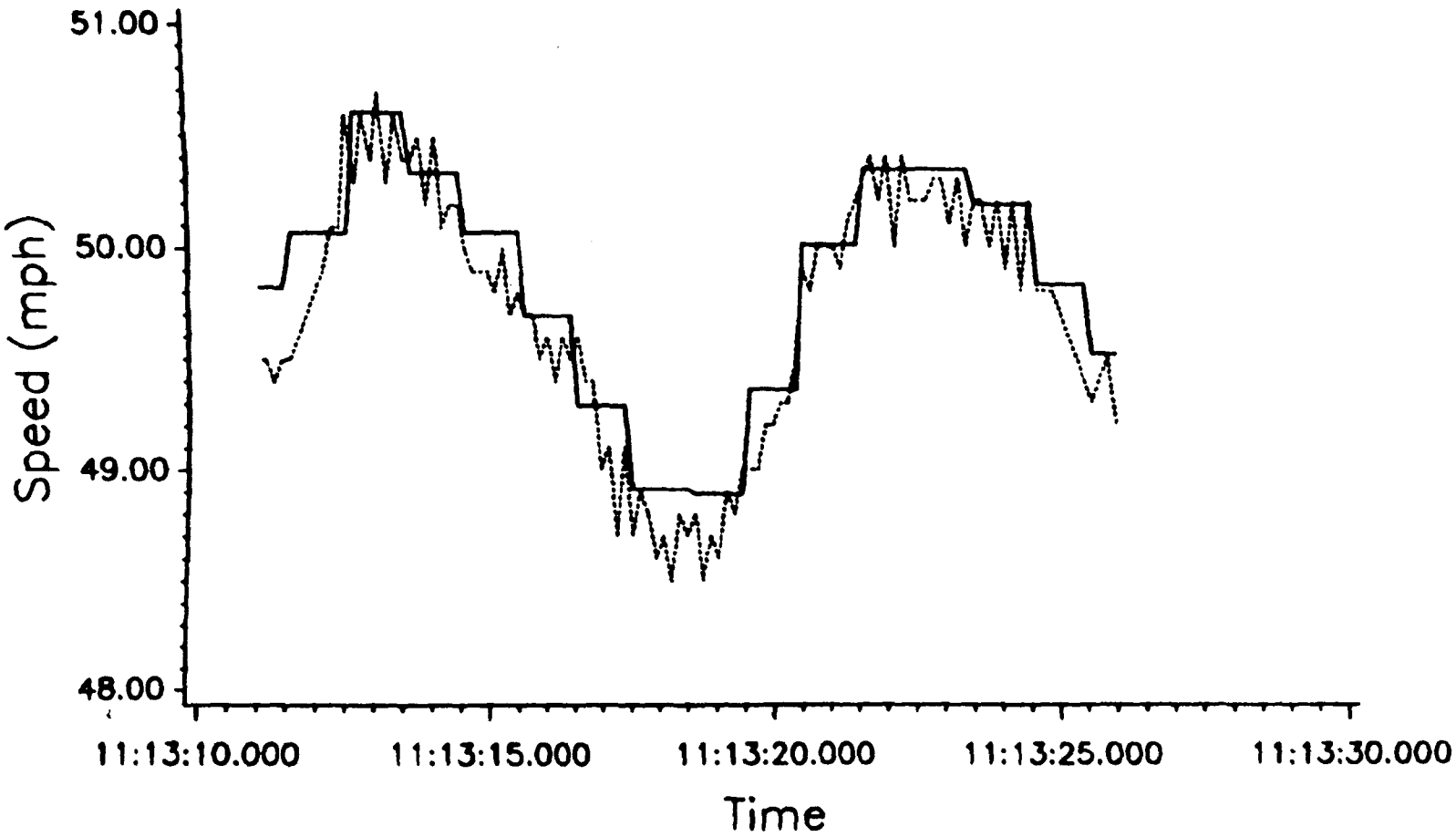


Figure 2-9. High Speed Accuracy for OEM Speed Sensor

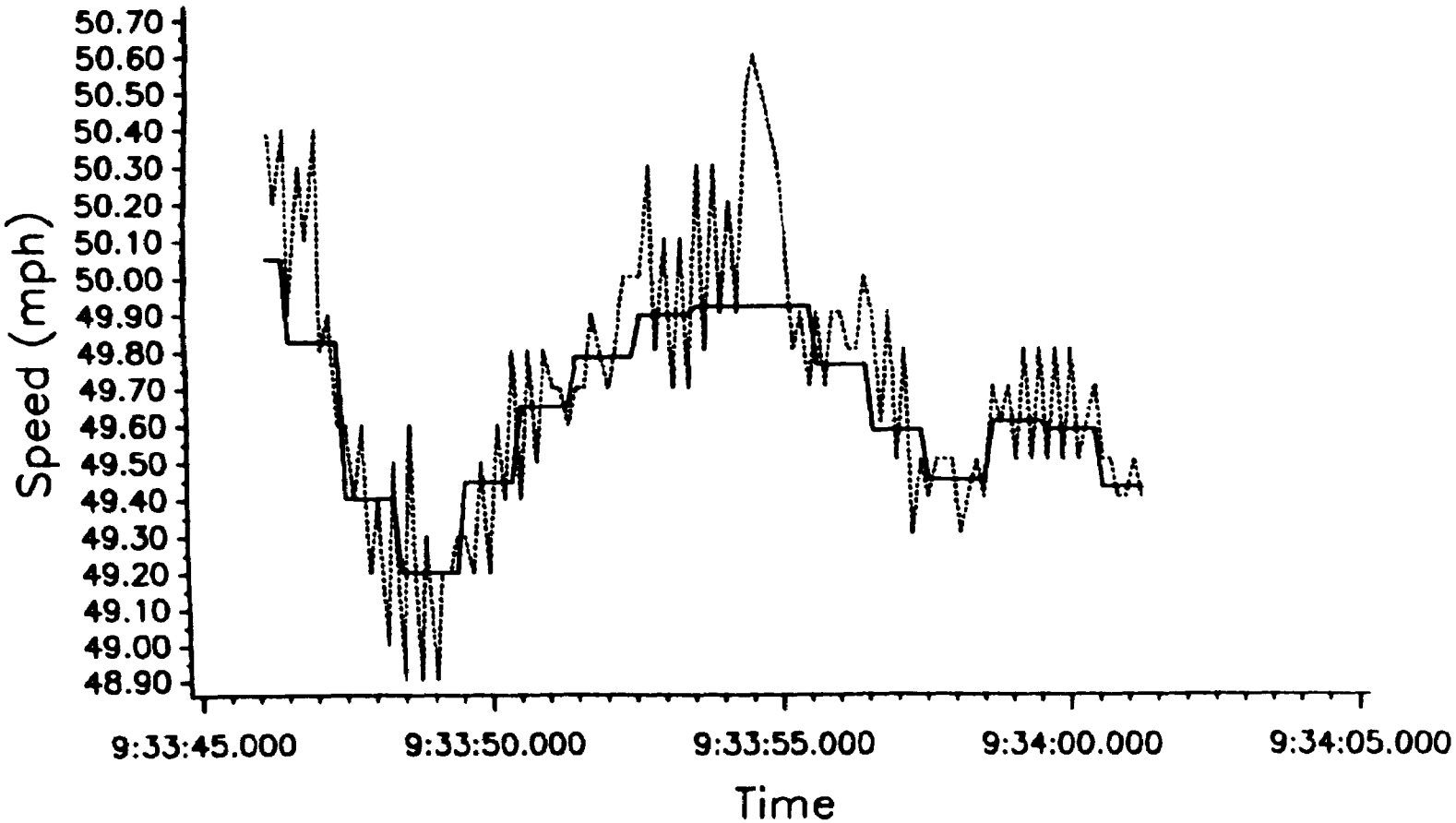


Figure 2-10. High Speed Accuracy for Speedometer Cable Sensor

Table 2-5

Constant Speed Performance of 3-Parameter Datalogger vs. Fifth Wheel

Sensor Type	Drive	Nominal Speed (mph)	Average |Speed Difference| (mph)	Maximum |Speed Difference| (mph)
Magnets	2	1	0.03	0.07
		2	0.02	0.06
		5	0.02	0.03
		10	0.06	0.08
		20	0.07	0.10
		50	0.16	0.21
OEM Sensor	2	1	0.03	0.08
		2	0.02	0.05
		5	0.02	0.04
		10	0.07	0.10
		20	0.10	0.13
		50	0.13	0.20
Speedometer Cable	2	1	1.5[a]	9.6[a]
		2	1.0[a]	2.8[a]
		5	0.6[a]	2.0[a]
		10	0.10	0.24
		20	0.05	0.11
		50	0.07	0.25

[a] Poor performance caused by speedometer cable jerking on this vehicle (see text).

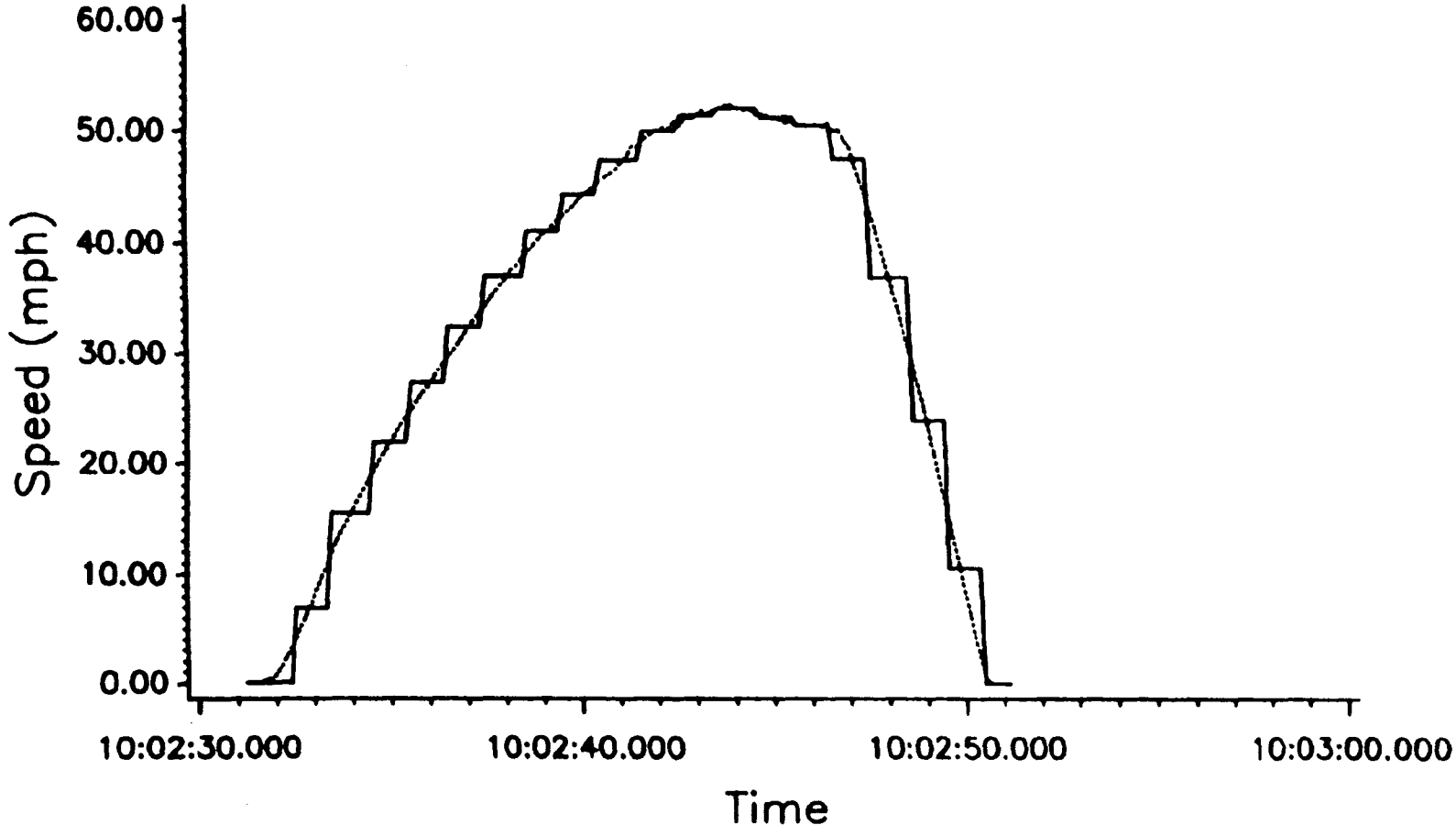


Figure 2-11. Transient Performance for Magnet Speed Sensor

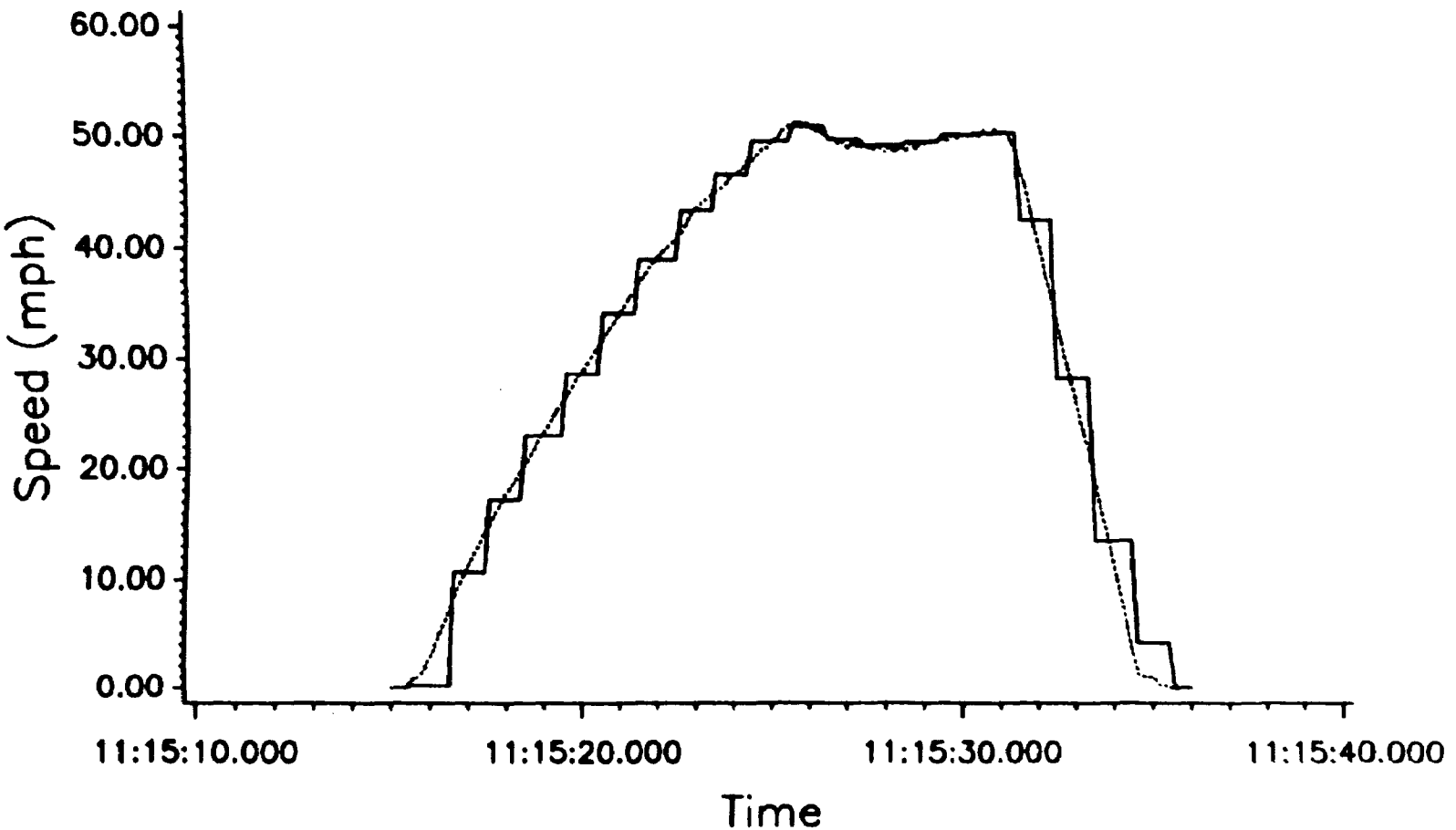


Figure 2-12. Transient Performance for OEM Speed Sensor

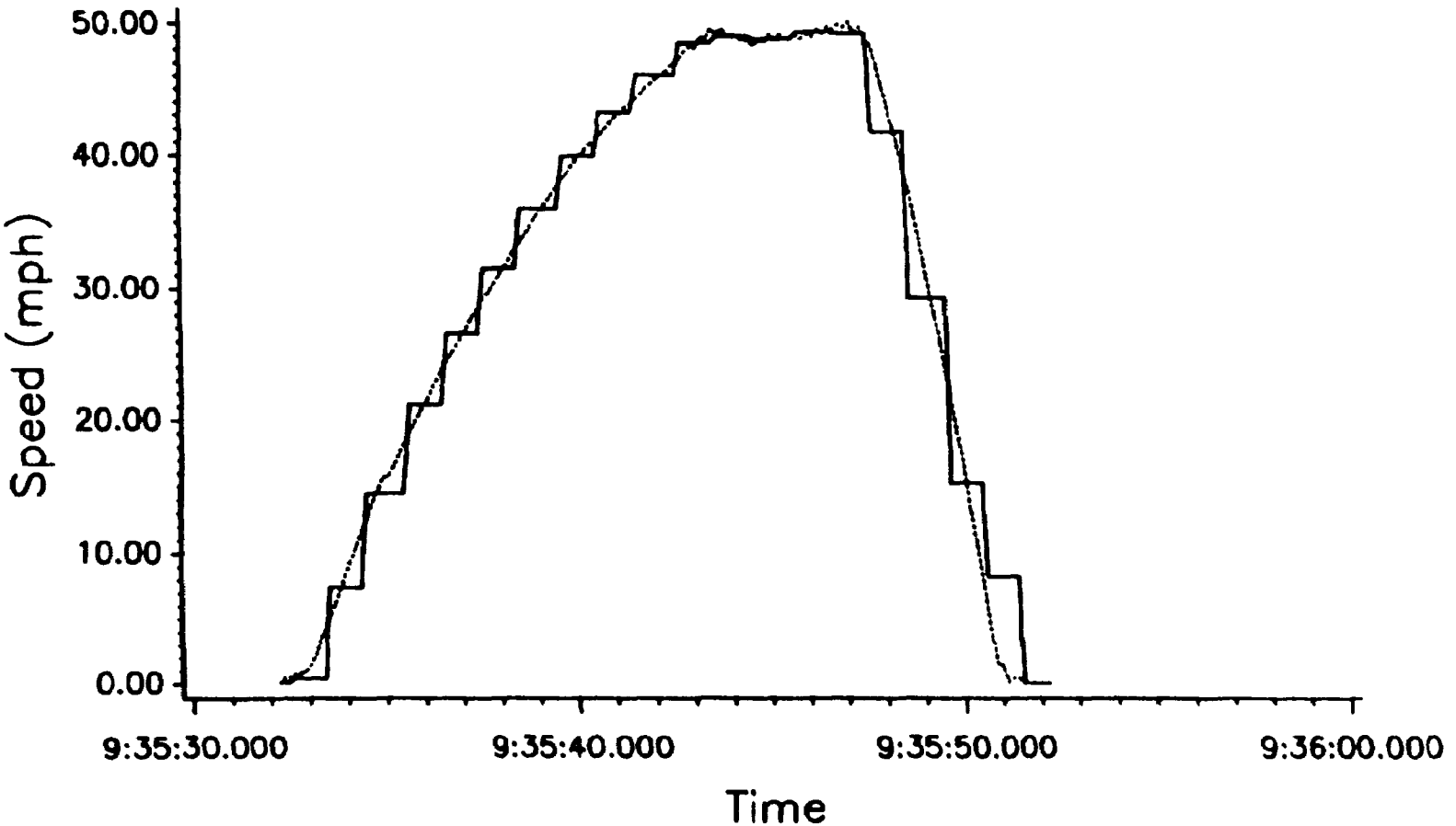


Figure 2-13. Transient Performance for Speedometer Cable Sensor

During high accelerations and decelerations, accurate measurement of speed is more difficult than at constant speed. Under these conditions, both the fifth wheel and the datalogger have inputs with rapidly changing pulse rates to determine the average speed over the integrating time period. In addition, a small difference in the relative time scales of the fifth wheel and the datalogger can mean a significant difference in the logged speeds. Table 2-6 shows the average absolute speed difference between the 1-second averages of the 3-parameter datalogger and the fifth wheel for each of the Drives 3. These values are larger than the same statistics shown in Table 2-5 for constant speed operation. Examination of the comparable 1-second speed values for the two instruments showed that the largest speed differences were seen at speeds below 10 mph, which occurred at the beginning and end of the drive. The largest four of these for each Drive 3 are shown in Table 2-6.

2.1.6 Pilot Testing

Vehicle tests were used to ensure the completeness of the logged values, the proper operation of the software, and the compatibility of the datalogger circuit with the three types of speed sensors to be used in this project. Radian made these tests using dataloggers installed on the eight Radian employee vehicles given in Table 2-7.

On-car testing of dataloggers was used to determine the performance of the loggers in actual use conditions. Radian employee vehicles were selected to provide a range of model years and the type of speed sensors required. The dataloggers were left on the vehicles for a period of one week, during which the Radian employees drove their vehicles as they normally would. At the end of the one-week period, the dataloggers were retrieved from the vehicles and examined to determine if they had worked properly.

Additional pilot testing of the 3-parameter dataloggers took place on four private vehicles in the Spokane pilot study. This on-site study (4) was conducted in

Table 2-6

Transient Performance of 3-Parameter Datalogger vs. Fifth Wheel

Sensor Type	Drive	Average |Speed Difference| (mph)	Largest Four |Speed Difference| (mph)
Magnets	3	0.42	2.0, 1.2, 0.88, 0.66
OEM Sensor	3	0.65	3.5, 3.1, 2.1, 0.97
Speedometer Cable	3	0.83	6.3, 2.0, 1.5, 1.4

Table 2-7

Radian Employee Vehicles Used for Austin Pilot Testing

Vehicle	Type of Speed Sensor
1990 Mazda 626	OEM Wire
1971 Ford Bronco	Magnets
1989 Chevrolet S-10 Blazer	OEM Wire
1988 Honda Accord	Magnets
1979 Buick LeSabre	Magnets
1985 Buick Century	OEM Wire
1980 Chevrolet Malibu	Speedometer Cable
1979 Buick LeSabre	Speedometer Cable

Spokane under EPA contract 68-C1-0079 and was part of the preparation activities for this study.

2.2 6-Parameter Data Collection

The 6-parameter datalogger took less than half of the observations in the study; however, the datalogger was designed to collect three more parameters than the 3-parameter datalogger: throttle position, coolant temperature, and equivalence ratio, as well as vehicle speed, engine RPM, and engine load. The datalogger was designed around the Campbell Scientific CR10 datalogging system and, accordingly, was too large to be placed under the hood and could not withstand underhood temperatures. Therefore, it was mounted in the trunk of vehicles. Since this location meant it was far from the engine control unit connectors, wiring had to be run from the front of the vehicle to the trunk.

The objective for this datalogging system was not to install the datalogging system rapidly, but instead to acquire a set of data which more thoroughly described engine and vehicle operation than the 3-parameter datalogger. Because installation of the datalogging system took much longer than an hour, the owners of the vehicles were not asked to wait while their vehicle was being instrumented. Instead, they were given a rental car to drive for the remainder of the day. Because of the longer installation time and more intrusive method of installation of the 6-parameter datalogger, it was expected that a lower percentage of people would be willing to participate in the study.

2.2.1 6-Parameter Logger Measurements

The critical and noncritical measurements for the 6-parameter datalogger are given in Table 2-8. To meet the primary objectives of this project, the critical measurements were vehicle speed, time of day, and the dates the engine was turned on

Table 2-8

Summary of Physical Measurements for the 6-Parameter Datalogger

Measurement	Measurement Classifcation	Measurement Site	Measurement Frequency
Vehicle Speed	Critical	ECU/Diagnostic Connection	Once per second when engine is on
Date	Critical	Data Logger Memory	Once per second when engine is on
Time	Critical	Data Logger Memory	Once per second when engine is on
Engine RPM	Noncritical	ECU/Diagnostic Connection	Once per second when engine is on
Throttle Position	Noncritical	ECU/Diagnostic Connection	Once per second when engine is on
Manifold Absolute Pressure	Noncritical	ECU/Diagnostic Connection	Once per second when engine is on
Manifold Air Flow	Noncritical	ECU/Diagnostic Connection	Once per second when engine is on
Coolant Temperature	Noncritical	ECU/Diagnostic Connection	Once per second when engine is on
Equivalence Ratio	Noncritical	NGK UEGO Oxygen Sensor in Exhaust System	Once per second when engine is on

and off. Together, these three measurements determined how people took trips, when vehicles were at rest, and how people drove the vehicle during trips.

Vehicle speed was a critical measurement collected once per second when the engine was running. Depending on the vehicle manufacturer, the speed of the vehicle was determined from the ECU of the vehicle or a speed sensor.

The date and time of the readings were also critical measurements. Determination of these was based on the time stored in the datalogger. For the GM dataloggers, this was Eastern Standard Time, and for the non-GM dataloggers it was local time for the two cities.

All other measurements were noncritical. Engine RPM was recorded once per second whenever the engine was running. The engine RPM was sensed by monitoring the appropriate channel on the engine ECU from the manufacturer's interface box. Engine load was determined by measuring manifold absolute pressure (MAP) or mass air flow (MAF). The throttle position and the coolant temperature were determined by monitoring the ECU.

Equivalence ratio was measured by an oxygen sensor installed in the exhaust system. Equivalence ratio (ϕ) is a measure of air/fuel (A/F) ratio relative to the stoichiometric A/F ratio (the theoretical weight to weight ratio of the air/fuel mixture required for complete combustion). The measured equivalence ratio is given by:

$$\text{Measured } \Phi = \frac{\text{Stoichiometric A/F}}{\text{Measured A/F}}$$

2.2.2 Quantitative Quality Assurance Objectives for the 6-Parameter Datalogger

Table 2-9 lists the units used for the 6-parameter datalogger measurements. The datalogger software and hardware were developed by the vehicle manufacturers. The precision, accuracy, and completeness of the various parameters were designed by the specific vehicle manufacturers and they differed from manufacturer to manufacturer. Radian did not participate in designing any of the hardware or software for the 6-parameter data collection; therefore, the precision, accuracy, and completeness of the various measurements cannot be documented by Radian.

2.2.3 6-Parameter Datalogging Equipment Design

The 6-parameter dataloggers can be divided into two categories:

- The General Motors (GM) datalogger; and
- The non-GM datalogger.

The GM datalogger was designed and built by the instrumentation group of General Motors. The datalogger was connected to the vehicle diagnostic connector to determine the values of the various parameters that needed to be recorded. 12 volts DC power also had to be attached to the datalogger so that it could record the engine parameters while the engine was running. The logger itself was also directly connected to the oxygen sensor to record the values for equivalence ratio.

The non-GM dataloggers were developed by six different manufacturers: Ford, Chrysler, Mazda, Mitsubishi, Nissan, and Toyota. Each of these dataloggers had a manufacturer-specific interface box that was connected to the vehicle ECU or to the diagnostic port on the vehicle. From this connection, the interface box interpreted the signals for engine speed, engine RPM, throttle position, coolant temperature, and

Table 2-9

6-Parameter Datalogger Measurements

Measurement	Measurement Classification	Reporting Units
Speed	Critical	mph
Engine RPM	Noncritical	rpm
Throttle Position	Noncritical	mv
Manifold Absolute Pressure	Noncritical	kPa
Mass Air Flow	Noncritical	kg/hr
Coolant Temperature	Noncritical	°C
Equivalence Ratio	Noncritical	≡ 1.000 for stoichiometric

manifold absolute pressure or mass air flow. The oxygen sensor signal was also directly connected the interface box. The interface box received the signals from the vehicle sensors and interpreted them for the Campbell Scientific CR10 datalogger. The CR10 datalogger then used a manufacturer-specific software program to convert the electrical impulses into engineering units for the various parameters. These values were stored in the Campbell Scientific memory modules.

The equivalence ratio (ϕ) was determined by using an NGK UEGO wide-range oxygen sensor placed between the catalytic converter and the muffler on most vehicles. Thus, the measurement of equivalence ratio includes combustion by the catalytic converter, as well as by the engine. The output signal voltage from the oxygen sensor control unit was cut in half by a resistor network. Thus, the voltage going into the CR10 was 1.500 volts for an equivalence ratio of 1. The relationships used by the 6-parameter datalogger to convert CR10 input voltage to equivalence ratio were:

For lean conditions ($A/F \geq 14.6$ wt/wt, $\phi \leq 1$):

$$\phi = -1.6364 * V + 3.4546$$

For rich conditions ($A/F < 14.6$ wt/wt, $\phi > 1$):

$$\phi = -0.8839 * V + 2.3259$$

where V = the CR10 input voltage (volts)

The value of the equivalence ratio from these expressions was stored in the datalogger memory. These relationships are linear approximations of the true curved relationship of the oxygen sensor for equivalence ratio vs. voltage as given by the NGK specifications sheet.

Figure 2-14 shows a wiring diagram for the non-GM 6-parameter datalogger. Communications were only possible with the CR10 datalogger and the memory modules. These were achieved by connecting an RS232 cable with an appropriate interface device from the PC to the CR10 datalogger or memory module.

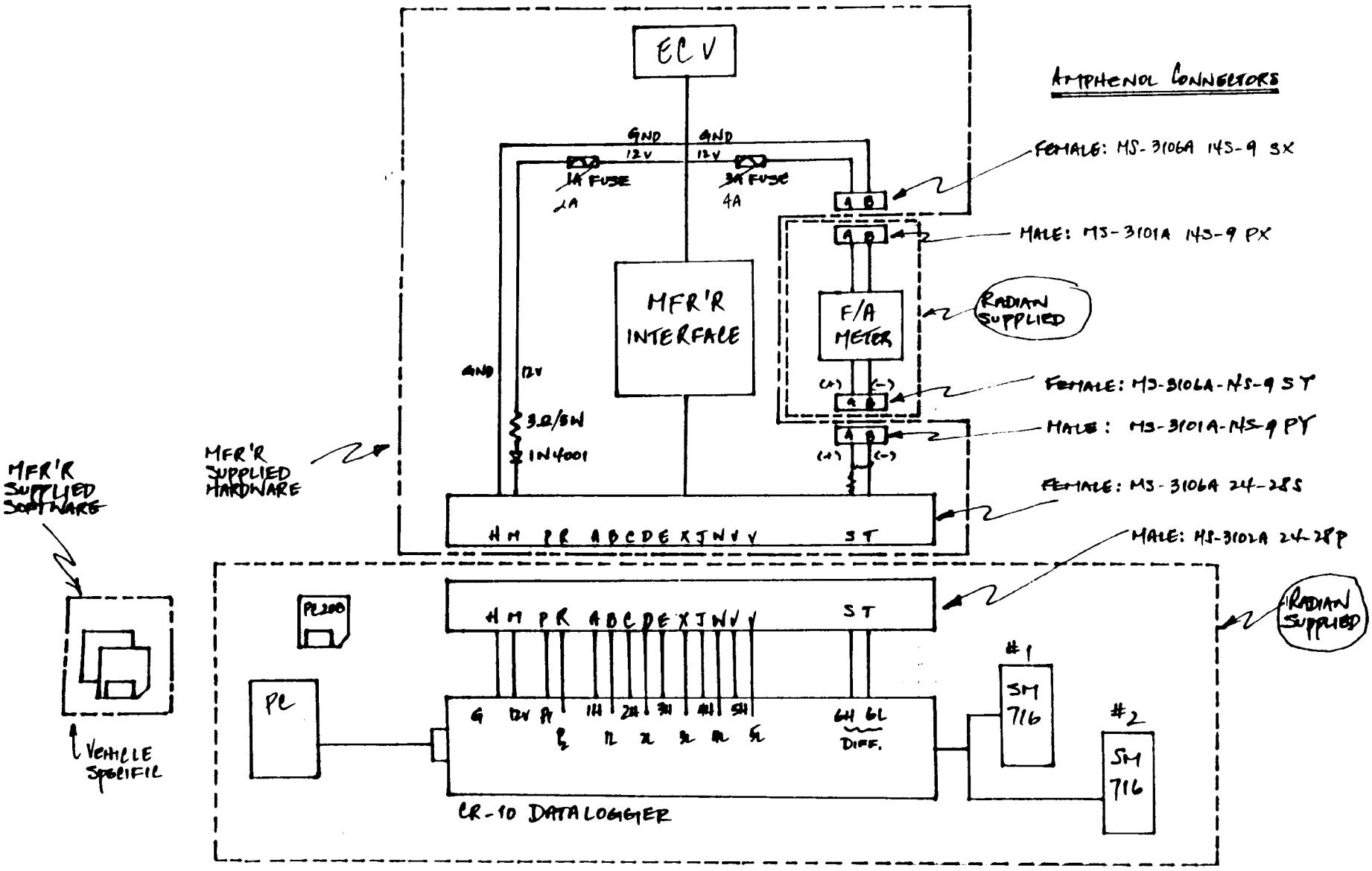


Figure 2-14. Wiring Diagram for the 6-Parameter Non-GM Datalogger

Special Campbell Scientific software, called PC208, was used for these communications. In addition, manufacturer-specific software was also required.

Applications

Tables 2-10 and 2-11 list the vehicles that could be used for the 6-parameter installation.

Data Conversion Software

Each 6-parameter datalogger system had manufacturer-specific software to analyze the signals coming from the vehicle and convert them into engineering units so that they could be stored on the datalogger. In each system, the engine parameters were recorded for each second the engine was running.

For the GM system, the software received the signals from the vehicle ECU and then converted the signals into engineering units and stored them on the datalogger. These stored values could then be downloaded from the datalogger to a PC. The software could also initialize the datalogger to erase the memory of a previous trip.

For the non-GM dataloggers, software could reside in two different places. There could be specific software on the manufacturer interface box and on the CR10 datalogger. The interface box interpreted the electronic signals coming from the vehicle. The box then converted these signals into a form understandable by the CR10 datalogger. The software on the CR10 datalogger could then be used for the following:

- To record the data in memory;
- To display engineering units by a laptop PC as the vehicle was being driven;

Table 2-10. List of Domestic Models Used for the 6-Parameter Installation

General Motors

Yr	Model		Engine Type	VIN Check Digits
89	6000		2.8L PFI	---A---W-K-------
89	6000		3.1L PFI	---A---T-K-------
89	6000	+	3.3L 3300	---A---N-K-------
89	88	+	3.8L 3800	---H---C-K-------
89	98	+	3.8L 3800	---C---C-K-------
89	Beretta		2.8L PFI	---L---W-K-------
89	Bonneville	+	3.8L 3800	---H---C-K-------
89	Calais		2.3L Quad 4	---N---D-K-------
89	Calais		2.3L Quad 4 H.O.	---N---A-K-------
89	Calais	+	3.3L 3300	---N---N-K-------
89	Camaro (Z28, IROC)	+ *	5.0L PFI	---F---F-K-------
89	Camaro (Z28, IROC)	+ *	5.7L PFI	---F---8-K-------
89	Cavalier (Z24)		2.8L PFI	---J---W-K-------
89	Celebrity		2.8L PFI	---A---W-K-------
89	Celebrity		3.1L PFI	---A---T-K-------
89	Century		2.8L PFI	---A---W-K-------
89	Century		3.1L PFI	---A---T-K-------
89	Century	+	3.3L 3300	---A---N-K-------
89	Cierra		2.8L PFI	---A---W-K-------
89	Cierra		3.1L PFI	---A---T-K-------
89	Cierra	+	3.3L 3300	---A---N-K-------
89	Corsica		2.8L PFI	---L---W-K-------
89	Corvette	+ *	5.7L PFI	---Y---8-K-------
89	Cutlass Supreme		2.5L TBI	---W---R-K-------
89	Cutlass Supreme		2.8L PFI	---W---W-K-------
89	Cutlass Supreme		3.1L PFI	---W---T-K-------
89	Firebird (Trans Am)	+ *	5.0L PFI	---F---F-K-------
89	Firebird (Trans Am)	+ *	5.7L PFI	---F---8-K-------
89	Grand Am		2.3L Quad 4	---N---D-K-------
89	Grand Am		2.3L Quad 4 H.O.	---N---A-K-------
89	Grand Am	+	3.3L 3300	---N---N-K-------
89	Grand Prix		2.5L TBI	---W---R-K-------
89	Grand Prix		2.8L PFI	---W---W-K-------
89	Grand Prix		3.1L PFI	---W---T-K-------
89	LeSabre	+	3.8L 3800	---H---C-K-------
89	Park Avenue	+	3.8L 3800	---C---C-K-------
89	Regal		2.5L TBI	---W---R-K-------
89	Regal		2.8L PFI	---W---W-K-------
89	Regal		3.1L PFI	---W---T-K-------
89	Skylark	+	3.3L 3300	---N---N-K-------
89	Sunbird		2.8L PFI	---J---W-K-------

* = Use ALDL pin E instead of M, and connect diag. line to pin B.
+ = LV8 is stored in data in place of MAP

Table 2-10. (Continued)

Yr	Model	Engine Type	VIN Check Digits
90	6000	3.1L PFI	---A---T-L-------
90	6000	+ 3.3L 3300	---A---N-L-------
90	88	+ 3.8L 3800	---H---C-L-------
90	98	+ 3.8L 3800	---C---C-L-------
90	Beretta	2.3L Quad 4 H.O.	---L---A-L-------
90	Beretta	3.1L PFI	---L---T-L-------
90	Bonneville	+ 3.8L 3800	---H---C-L-------
90	Calais	2.3L Quad 4	---N---D-L-------
90	Calais	2.3L Quad 4 H.O.	---N---A-L-------
90	Calais	+ 3.3L 3300	---N---N-L-------
90	Camaro (Z28, IROC)	5.0L PFI	---F---F-L-------
90	Camaro (Z28, IROC)	5.7L PFI	---F---8-L-------
90	Cavalier (Z24)	3.1L PFI	---J---T-L-------
90	Celebrity	3.1L PFI	---A---T-L-------
90	Century	3.1L PFI	---A---T-L-------
90	Century	+ 3.3L 3300	---A---N-L-------
90	Cierra	3.1L PFI	---A---T-L-------
90	Cierra	+ 3.3L 3300	---A---N-L-------
90	Corsica	2.3L Quad 4 H.O.	---L---A-L-------
90	Corsica	3.1L PFI	---L---T-L-------
90	Corvette	5.7L PFI	---Y---8-L-------
90	Cutlass Supreme	2.3L Quad 4	---W---D-L-------
90	Cutlass Supreme	2.3L Quad 4 H.O.	---W---A-L-------
90	Cutlass Supreme	2.5L TBI	---W---R-L-------
90	Cutlass Supreme	3.1L PFI	---W---T-L-------
90	Firebird (Trans Am)	5.0L PFI	---F---F-L-------
90	Firebird (Trans Am)	5.7L PFI	---F---8-L-------
90	Grand Am	2.3L Quad 4	---N---D-L-------
90	Grand Am	2.3L Quad 4 H.O.	---N---A-L-------
90	Grand Am	+ 3.3L 3300	---N---N-L-------
90	Grand Prix	2.3L Quad 4	---W---D-L-------
90	Grand Prix	2.3L Quad 4 H.O.	---W---A-L-------
90	Grand Prix	2.5L TBI	---W---R-L-------
90	Grand Prix	3.1L PFI	---W---T-L-------
90	LeSabre	+ 3.8L 3800	---H---C-L-------
90	Lumina	2.3L Quad 4	---W---D-L-------
90	Lumina	2.3L Quad 4 H.O.	---W---A-L-------
90	Lumina	2.5L TBI	---W---R-L-------
90	Lumina	3.1L PFI	---W---T-L-------
90	Park Avenue	+ 3.8L 3800	---C---C-L-------
90	Regal	2.5L TBI	---W---R-L-------
90	Regal	3.1L PFI	---W---T-L-------
90	Skylark	+ 3.3L 3300	---N---N-L-------
90	Sunbird	3.1L PFI	---J---T-L-------

+ = LV8 is stored in data in place of MAP

Table 2-10. (Continued)

Yr	Model	Engine Type	VIN Check Digits
91	6000	3.1L PFI	---A---T-M-------
91	6000	+ 3.3L 3300	---A---N-M-------
91	88	+ 3.8L 3800	---H---C-M-------
91	Beretta	2.3L Quad 4 H.O.	---L---A-M-------
91	Beretta	3.1L PFI	---L---T-M-------
91	Bonneville	+ 3.8L 3800	---H---C-M-------
91	Calais	2.3L Quad 4	---N---D-M-------
91	Calais	2.3L Quad 4 H.O.	---N---A-M-------
91	Calais	+ 3.3L 3300	---N---N-M-------
91	Camaro	3.1L PFI	---F---T-M-------
91	Camaro (Z28, IROC)	5.0L PFI	---F---F-M-------
91	Camaro (Z28, IROC)	5.7L PFI	---F---8-M-------
91	Cavalier (Z24)	3.1L PFI	---J---T-M-------
91	Celebrity	3.1L PFI	---A---T-M-------
91	Century	3.1L PFI	---A---T-M-------
91	Century	+ 3.3L 3300	---A---N-M-------
91	Cierra	3.1L PFI	---A---T-M-------
91	Cierra	+ 3.3L 3300	---A---N-M-------
91	Corsica	2.3L Quad 4 H.O.	---L---A-M-------
91	Corsica	3.1L PFI	---L---T-M-------
91	Corvette	5.7L PFI	---Y---8-M-------
91	Cutlass Supreme	2.3L Quad 4	---W---D-M-------
91	Cutlass Supreme	2.5L TBI	---W---R-M-------
91	Cutlass Supreme	3.1L PFI	---W---T-M-------
91	Cutlass Supreme	3.4L DOHC	---W---X-M-------
91	Firebird	3.1L PFI	---F---T-M-------
91	Firebird (Trans Am)	5.0L PFI	---F---F-M-------
91	Firebird (Trans Am)	5.7L PFI	---F---8-M-------
91	Grand Am	2.3L Quad 4	---N---D-M-------
91	Grand Am	2.3L Quad 4 H.O.	---N---A-M-------
91	Grand Am	+ 3.3L 3300	---N---N-M-------
91	Grand Prix	2.3L Quad 4	---W---D-M-------
91	Grand Prix	2.5L TBI	---W---R-M-------
91	Grand Prix	3.1L PFI	---W---T-M-------
91	Grand Prix	3.4L DOHC	---W---X-M-------
91	LeSabre	+ 3.8L 3800	---H---C-M-------
91	Lumina	2.3L Quad 4	---W---D-M-------
91	Lumina	2.5L TBI	---W---R-M-------
91	Lumina	3.1L PFI	---W---T-M-------
91	Lumina Z34	3.4L DOHC	---W---X-M-------
91	Regal	2.5L TBI	---W---R-M-------
91	Regal	3.1L PFI	---W---T-M-------
91	Skylark	+ 3.3L 3300	---N---N-M-------
91	Sunbird	3.1L PFI	---J---T-M-------

+ = LV8 is stored in data in place of MAP

Table 2-10. (Continued)

Chrysler

VEHICLE LINE	BODY	MODEL YEAR AVAILABILITY 89	90	91	ENGINE FAMILIES AVAILABLE SPANNING THESE MODEL YEARS
SPIRIT	A	YES	YES	YES	EDF,EDM,EDT,EFA
ACCLAIM	A	YES	YES	YES	EDF,EDM,EDT,EFA
NEW YORKER	C	YES	NO	NO	EFA
N.Y. LANDAU	C	YES	YES	NO	EFA,EGA
N.Y. SALON	C	NO	YES	YES	EGA
DYNASTY	C	YES	YES	YES	EDM,EFA,EGA
DAYTONA	G	YES	YES	YES	EDR,EDM,EDT,EFA
DAYTONA SHELBY	G	YES	YES	YES	EDR,EDT,,EFA
LEBARON	H	YES	NO	NO	EDF,EDM,EDT,EDR
LEBARON	A	NO	YES	YES	EDM,EFA
LANCER	H	YES	NO	NO	EDF,EDM,EDT,EDR
LEBARON	J	YES	YES	YES	EDR,EDM,EDT,EFA
ARIES	K	YES	NO	NO	EDF,EDM
RELIANT	K	YES	NO	NO	EDF,EDM
OMNI	L	YES	YES	NO	EDF
HORIZON	L	YES	YES	NO	EDF
SHADOW	P	YES	YES	YES	EDF,EDM,EDT
SUNDANCE	P	YES	YES	YES	EDF,EDM,EDT
FIFTH AVENUE	Y	NO	YES	YES	EGA,EGH
IMPERIAL	Y	NO	YES	YES	EGA,EGH
LIGHT DUTY TRUCK					
CARAVAN	S	YES	YES	YES	EDM,EDT,EFA,EGA
GRAND CARAVAN	S	YES	YES	YES	EDT,EFA,EGA
VOYAGER	S	YES	YES	YES	EDM,EDT,EFA,EGA
GRAND VOYAGER	S	YES	YES	YES	EDT,EFA,EGA

ENGINE SALES CODE CHART

EDF = 2.2L TBI
EDM = 2.5L TBI
EDT = 2.5L TURBO I
EDR = 2.2L TURBO IV
EFA = 3.0 MMC
EGA = 3.3L MPI
EGH = 3.8L MPI

Table 2-10. (Continued)

Ford/Mercury/Lincoln

ESCORT

Year	1989	1990	1991
Engine Type	1.9L SOHC	1.9L SOHC	1.9L SOHC
MAP/MAF	MAP	MAP	MAF
ECU Location	By steering column	By steering column	In center counsel

TEMPO/TOPAZ

Year	1989	1990	1991
Engine Type	2.3L HSC	2.3L HSC	2.3L HSC
MAP/MAF	MAP	MAP	MAP
ECU Location	By steering column	By steering column	By steering column

TAURUS/SABLE/CONTINENTAL

Year	1989	1990	1991
Engine Type	3.0L/3.8L*	3.0L/3.8L*	3.0L/3.8L*
MAP/MAF	MAP	MAP	MAF
ECU Location	Behind glove box	Behind glove box	Behind glove box

THUNDERBIRD/COUGAR

Year	1989	1990	1991
Engine Type	3.8L	3.8L	3.8L
MAP/MAF	MAP	MAP	MAF
ECU Location	Passengerside kick panel	Passengerside kick panel	Passengerside kick panel

CROWN VICTORIA/GRAND MARQUIS/TOWN CAR

Year	1989	1990	1991**	1992
Engine Type	5.0L	5.0L	5.0L/4.6L	4.6L
MAP/MAF	MAP	MAP	MAP/MAF	MAF
ECU Location	Driverside	Driverside	Driverside	

*** The Continental does not come in a 3.0L model.**

**** The Town Car had a 4.6L engine in 1991 and was MAF.**

Table 2-11. List of Foreign Models Used for the 6-Parameter Installation

MITSUBISHI

90 Galant 2wd SOHC
89 Mirage 3 or 4 Dr. SOHC Engine
90 Mirage 3 or 4 Dr. SOHC Engine

89 Dodge/Plymouth Colt 3 or 4 Dr. SOHC Engine
90 Dodge/Plymouth Colt 3 or 4 Dr. SOHC Engine
89 Eagle Summit 3 or 4 Dr. SOHC Engine
90 Eagle Summit 3 or 4 Dr. SOHC Engine

NISSAN

89, 90 Sentra
89, 90, 91 Maxima

TOYOTA

89, 90, 91 Camry

MAZDA

89, 90, 91 626
89, 90, 91 Mx6
90, 91 Protege
90, 91 Miata

- To turn the logger on and off with the engine;
- To dump data from the memory to the PC; and
- To initialize the datalogger by erasing memory.

For both kinds of 6-parameter dataloggers, the final format of the file had exactly the same format. These files were in ASCII and were in a format compatible with SAS.

2.2.4 Pilot Testing

Several activities were conducted to prepare for the installation of the 6-parameter dataloggers in Spokane and Baltimore. These activities included training Radian and Automotive Testing Lab personnel by the vehicle manufacturers to install the dataloggers, and a final checkout and installation practice in Austin of each of the manufacturer's dataloggers.

In December of 1991, the Radian 6-parameter installation leader and the key mechanic from Automotive Testing Labs for 6-parameter installation spent a week in Michigan being instructed by individual member companies on the procedures for each of the 6-parameter dataloggers for General Motors, Ford, Chrysler, Mitsubishi, Nissan, Mazda, and Toyota. This training involved all aspects of the hardware and software that needed to be understood by installation personnel in the field.

In this study, we have assumed that MVMA/AIAM member companies verified the accuracy and precision of their datalogging systems through laboratory function tests and test track speed accuracy checks. No activities specifically aimed at these checks were part of this project.

After the dataloggers were developed by each manufacturer, they were sent to the Radian office in Austin, Texas. On-car functionality checks were then performed on all the dataloggers from GM, Ford, and Chrysler. One manufacturer-specific vehicle was recruited for each manufacturer, and the datalogger was installed on the vehicle. The dataloggers were then checked in both idle and city driving modes. For the Chrysler vehicle, a Radian employee vehicle was equipped with an oxygen sensor. For all the other tests, the oxygen sensor was installed on a piece of exhaust pipe mounted on the tailpipe. For at least one manufacturer, the datalogger was kept on the vehicle for a one-week period and data were collected periodically from the vehicle to see how the datalogger was functioning. These functionality checks were also used to train Radian staff and to develop the procedures followed in the field. Several issues were identified for each manufacturer and resolved before the on-site installations began in Spokane. For Mazda, Toyota, Nissan, Mitsubishi, and Honda, no pilot testing was done. In most cases, manufacturer representatives were available on site to resolve installation problems.

3.0 FIELD PROCEDURES

A large number of field procedures were followed to ensure the success of the data collection project. Procedures were specified in the Quality Assurance Project Plan (3) to ensure that the maximum number of good quality data sets would be obtained, that private vehicle owners would be happy to participate in the project, that a representative sample of the vehicle population would be obtained in each city, and that all necessary information about the vehicles that were sampled would be documented for the purposes of data quality checking and data analysis. The field procedures can be broken down into three general activities: field administrative procedures, datalogger installation procedures, and datalogger removal procedures. The field administrative procedures deal primarily with the handling of the vehicle owners and the vehicles, while the datalogger procedures deal primarily with the technical aspects of instrumenting vehicles.

3.1 Field Administrative Procedures

Figure 3-1 shows a flowchart that describes the general installation procedure. After the I/M test was performed, vehicles with GVWs of less than 8500 pounds that received passes or waivers were selected as target vehicles if they met any of these criteria:

- The vehicle passed the I/M inspection at a predetermined selection time for a 3-parameter datalogger installation;
- The vehicle met the characteristics of a refusal replacement vehicle for a 3-parameter datalogger installation; or
- The vehicle met year/make/model criteria for a 6-parameter datalogger installation.

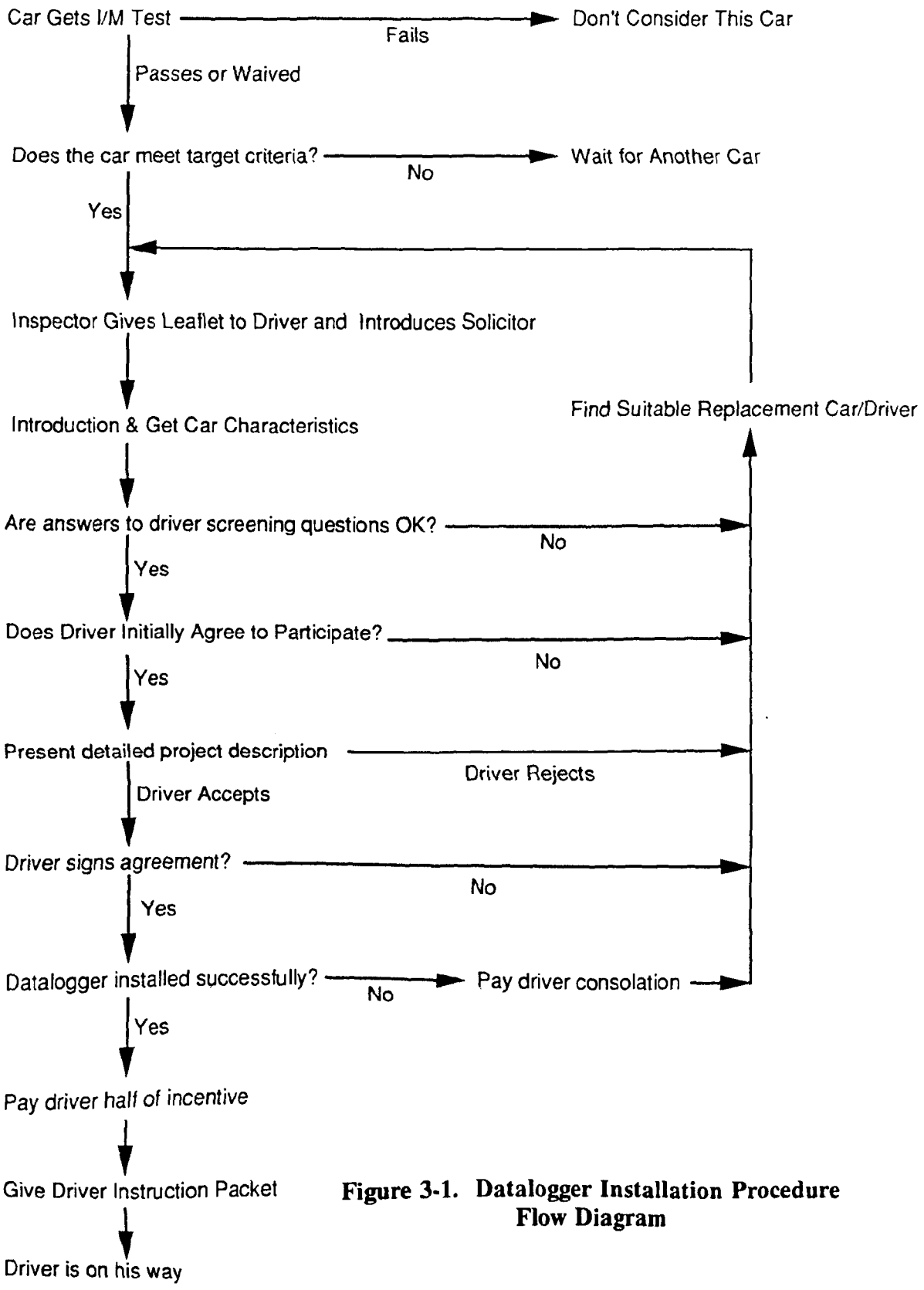


Figure 3-1. Datalogger Installation Procedure Flow Diagram

If the vehicle was selected as a target vehicle, the I/M inspector handed the driver an information leaflet and introduced the driver to the Radian solicitor. The information leaflet contained a basic description of the driving pattern project. The solicitor asked some screening questions to determine if the vehicle's usage pattern was suitable for participation in the program. If the vehicle's usage pattern was suitable, the solicitor then asked the driver to participate in the program. The solicitor described the program in some detail, answered any questions, and asked if the driver was interested in participating. If the driver did not want to participate in the program, this brought the solicitor's interview to an end, and the driver left the installation premises. If the driver was interested in participating, the solicitor offered an incentive to the driver and asked him or her to sign an instrumentation agreement.

The logger was installed, calibrated, and checked on the vehicle. The name, address, and telephone number of the owner was documented to maintain contact during the datalogging period. After the installation was complete, the solicitor gave the owner an information packet that described the project, gave the driver the installation crew's telephone numbers in case of problems, and set up an appointment for removing the datalogger.

If a 3-parameter datalogger was installed, the driver waited for the installation to be completed. If a 6-parameter datalogger was installed on the vehicle, the driver was assigned a loaner vehicle, and an appointment was set up to exchange his vehicle for the rental car.

Vehicles that participated in the driving patterns project and that had loggers installed on them were assigned a unique number. Vehicles in Spokane were assigned a number like S001, and vehicles in Baltimore were assigned a number like B001. Each vehicle packet consisted of a booklet containing all the forms and sheets required for the installation and removal process:

- Cover Sheet;
- Vehicle Selection Sheet;
- Vehicle Study Participation Agreement;
- 3-parameter Logger Installation Notes;
- 3-parameter Logger Calibration Sheet;
- 3-parameter Logger Removal Report;
- Usage Questionnaire;
- 3-parameter Data Downloading Sheet;
- 6-parameter Logger Installation Notes;
- 6-parameter Logger Identification and Sensor Verification;
- 6-parameter Logger Software Check;
- 6-parameter Logger Removal Report;
- Usage Questionnaire;
- 6-parameter Data Downloading Sheet (non-GM); and
- 6-parameter Data Downloading Sheet (GM).

The introductory leaflet and each of the forms are described in the following sections.

3.1.1 Introductory Leaflet

If a vehicle passed the I/M inspection and satisfied the vehicle selection criteria, the I/M inspector handed the driver an introductory leaflet at the end of the inspection. The purpose of this leaflet was to introduce the drivers to the vehicle instrumentation program in a general way so that the solicitor would not have to explain all the details to them. The leaflet did not reveal that the test program was a measure

of their driving behavior to avoid biasing driving patterns. This concept was understood by all personnel at the instrument installation site, including I/M personnel.

The leaflet was attractive so that people understood that this test program was a serious effort and that it was being conducted in a professional manner. A sample leaflet is shown in Figure 3-2.

3.1.2 Cover Sheet

Each vehicle packet had a cover sheet to show which vehicle information the packet contained. An example of the cover sheet is shown in Figure 3-3. To facilitate vehicle tracking, a vehicle packet was used for every vehicle solicited, whether or not the vehicle actually participated in the test program. In this way, at the end of the test program the targeted vehicles could be compared with the participating vehicles, and the history of vehicle selection and the reasons for vehicle nonparticipation could be determined.

3.1.3 Vehicle Selection

Vehicles to be solicited for datalogger installation were selected from vehicles that either passed or received a waiver during the I/M inspection. Random vehicle selection was desired to help ensure that a representative cross-section of the vehicle population and driver population was made. However, because of the practicalities of vehicle instrumentation and the distribution of vehicle year, make, and model in the population, modifications to straight random sampling had to be made. Accordingly, vehicles for 3-parameter dataloggers were selected in a quasi-random manner; vehicles for 6-parameter dataloggers were selected as they became available.

CLEAN CARS / CLEAN AIR

The effort to produce clean vehicles and clean air in our cities has come a long way. Today's vehicles produce only 1/5 of the emissions of those just two decades ago.

However, we still have a long way to go. Our cities' air should be cleaner still, to enhance our quality of life, and to protect our own health, as well as our children's.

The U.S. Environmental Protection Agency (EPA) has led the fight for clean air and cleaner vehicles for the past 20 years. The EPA's Volunteer Vehicle Test Program (VVTP) currently under way will help us find better ways of controlling pollution from cars and trucks, while maintaining or even improving vehicle performance. And your cooperation in this program will help in the effort to improve the quality of the air we breathe.

Following the state inspection of your vehicle, you may be asked by EPA representatives from Radian Corporation to participate in the VVTP. Data-collecting instruments will be installed on participants' vehicles. In return, participants will receive a monetary incentive.

The installation of our test equipment is simple (one example is shown below). All installations are performed by experienced automotive technicians from Automotive Testing Laboratories—nationally recognized experts in installing test equipment on private automobiles. The total installation takes about one hour.

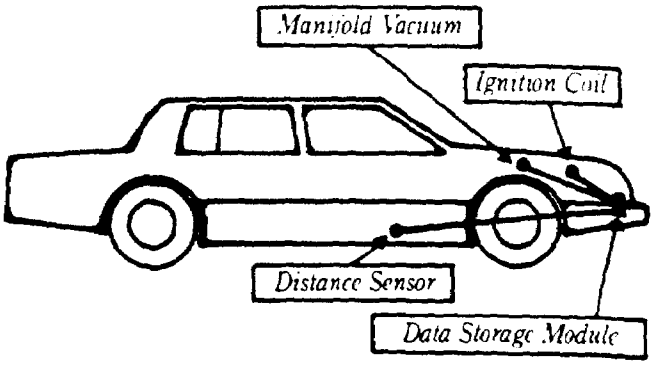


Figure 3-2. Introductory Leaflet

Vehicle Sample No. B ___ ___ ___

Solicitor

Datalogger Type: 3-parm 6-parm

Vehicle Selection Method:

Time of Day

Replacement for Vehicle Sample No. ___ ___ ___ ___

Model Year: _____

Make: _____

Model: _____

Polaroid
Photo
of Vehicle

Space for attaching
Owner Information

Figure 3-3. Cover Sheet

For any given I/M station, it is well known that the number of vehicles inspected per day increases toward the end of the month. This is shown graphically in Figure 3-4, which shows the number of passes and waivers per day for Stations 3 and 4 in Maryland. The spikes pointing downward every seventh day represent the number of passes and waivers were issued on Saturdays; on Saturdays these I/M stations are only open from 8 a.m. to noon.

Other than this small value seen on Saturdays, the number of cars inspected in a given week is relatively constant. The number of cars inspected on the first complete weeks of the month are about the same. The number of cars inspected on the third week is greater, and during the last week the daily number of passes and waivers is the highest.

To sample this vehicle population representatively, more vehicles should be sampled during the last two weeks of the month than at the beginning of the month. However, because this would have required additional staff on site to perform the installations at the I/M station, this more representative sampling procedure was not used. Instead, a procedure that targeted the same number of datalogger installations every day was used.

Examination of the number of vehicles inspected for a given hour of the day during weekdays showed that the highest use of the I/M lanes occurs between 10:00 a.m. and 2:00 p.m. This is demonstrated in Figure 3-5, which shows the relative position of a car in relationship to the other cars inspected on a given day and the time the car is inspected. The figure shows that in May of 1991 at this particular station in Maryland 50% of the cars were inspected by a little after noon. Since each line in the graph represents a different weekday in an entire month, the figure shows that the profile of inspection rates from day to day is repeatable. Specifically, the average inspection time profile differs from the most extreme daily inspection time profile by about 40 minutes.

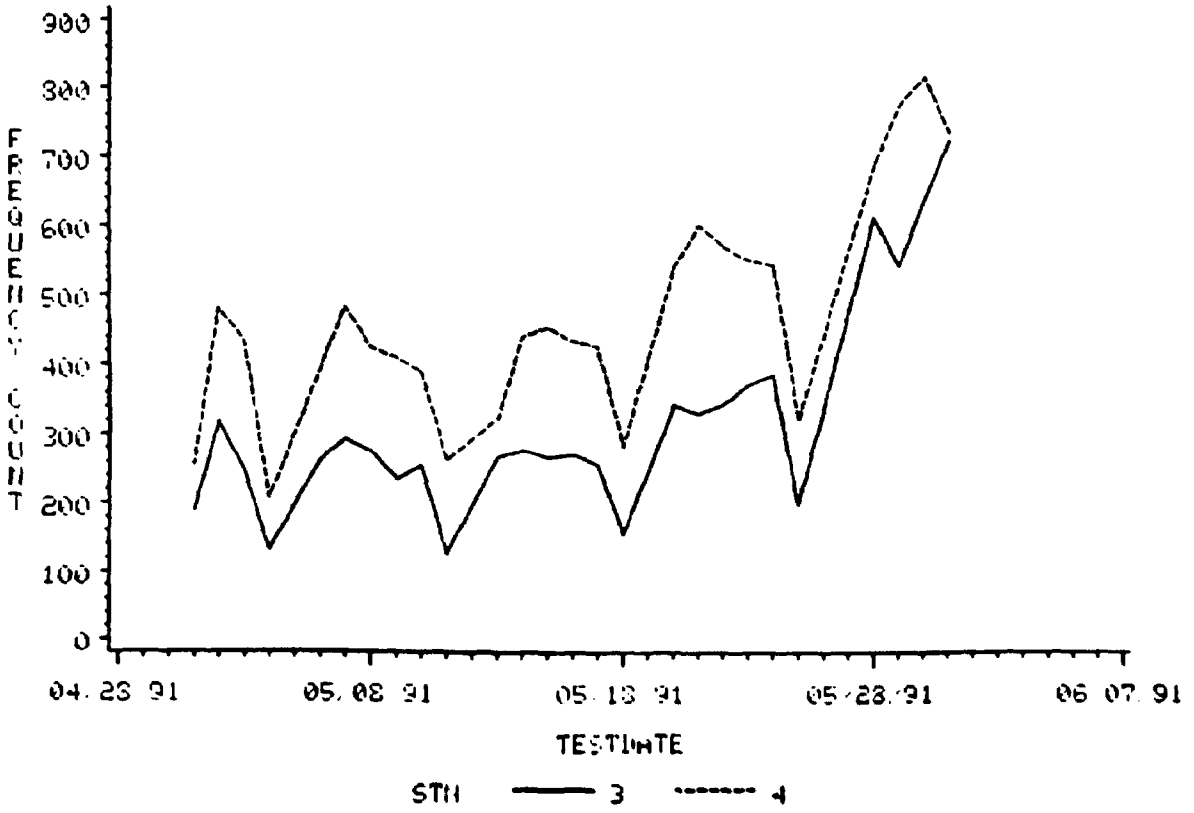


Figure 3-4. Passes and Waivers Issued Per Day

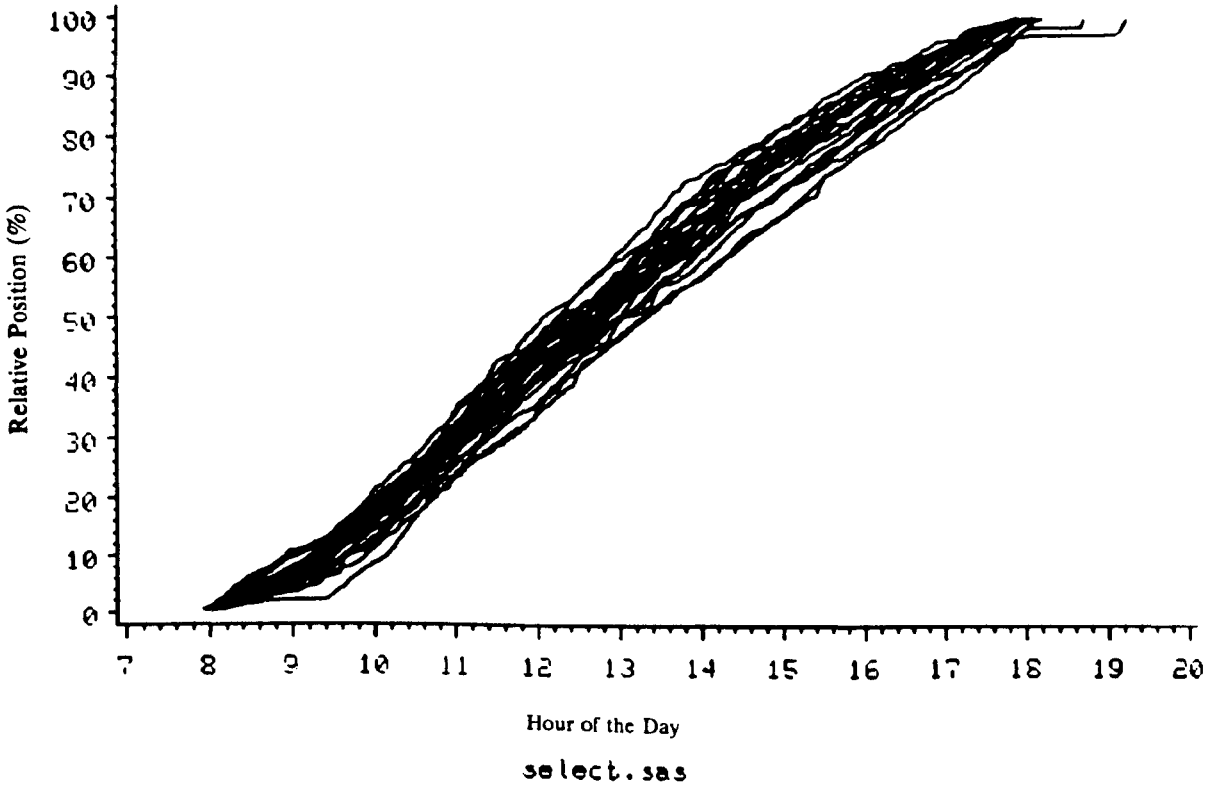


Figure 3-5. Inspection Time Profile for Baltimore

To get a representative sample of the cars that had passed or had been given a waiver, a random sampling of all cars on a given day should be made. This could be done if it was known in advance how many cars on a given day would be inspected and passed or waived. However, selection of these vehicles would involve counting every car that came through the I/M lanes. An alternative to this procedure was to use historical data on the distribution of times when cars were inspected to determine the times of the day to select vehicles.

If the time is randomly selected, according to historical vehicle flow through the inspection station, the vehicles would be close to being randomly selected. However, the generation of such random times was found to repeatedly produce clumps of times, meaning that up to three vehicles would have to be instrumented in a short time. At other times of the day, no cars would have been selected and the installation crew would be idle.

An alternative approach to determining selection times was more practical and yet did provide a reasonable degree of randomness in the vehicles selected. In this quasi-random approach, the historical inspection rate data for the month and station in question was used to select times when the number of cars inspected between consecutive times was constant. However, the time used to select the first car of the day was randomly selected (based on historical inspection rates) from the first portion of cars corresponding to the number of cars expected between consecutive selection times.

The result of this technique was a set of selection times for each day that were relatively evenly spaced. The times were closer in the middle of the day than in the morning or late afternoon because the inspection rate was higher in the middle of the day. The times from day to day were "dithered" in time (shifter earlier or later) as a group because of the random time selected for the first car. Each list of times was randomly assigned to instrumentation days.

The list of selection times derived by this method for Spokane and Baltimore is shown in Table 3-1. The times for Spokane were based on Spokane inspection records for February 1991. The times for each of the two Baltimore inspection stations were based on inspection records for March 1991 for each of the respective stations.

The result of this approach was that, while daily times were not random, the times for the three-week instrumentation period were random. The advantage to the instrumentation activities was that the work load was smoothed out so that more vehicles could be instrumented by the same small crew. This also enabled the installation staff to be ready for vehicles to be instrumented since they knew the selection times in advance.

Because of the restrictions on the models that could be instrumented with 6-parameter dataloggers, it was unlikely that a sufficient number of randomly-selected vehicles would have fit the instrumentation requirements; therefore, the most workable approach was to solicit 6-parameter target vehicles:

- When they appeared in the I/M lanes; and
- When a 6-parameter vehicle was not currently undergoing an installation.

To meet the target number of 6-parameter installations, three vehicles on Monday, Tuesday, Thursday, and Friday and four vehicles on Wednesday had to be instrumented. Thus, in terms of random selection times, a 6-parameter vehicle was selected in the morning, midday, and afternoon of most days.

3.1.4 Replacement Vehicle Selection

Every reasonable and pleasant effort was made to convince the driver of the carefully selected 3-parameter vehicle that he and the vehicle should participate in

Table 3-1

3-Parameter Vehicle Selection Times

Station	Date	Day	Times							
Spokane	3 Feb 92	Monday	9:13	10:37	11:54	1:16	2:36	4:00		
Spokane	4 Feb 92	Tuesday	9:45	11:04	12:22	1:43	3:06	4:32		
Spokane	5 Feb 92	Wednesday	9:41	10:48	11:44	12:52	2:01	3:06	5:42	
Spokane	6 Feb 92	Thursday	10:03	11:19	12:40	2:00	3:23	4:55		
Spokane	7 Feb 92	Friday	9:30	10:52	12:08	1:31	2:52	4:17		
Spokane	8 Feb 92	Saturday	9:49	11:09	12:30					
Spokane	9 Feb 92	Sunday								
Spokane	10 Feb 92	Monday	8:58	10:26	11:42	1:05	2:25	3:49		
Spokane	11 Feb 92	Tuesday	9:45	11:03	12:22	1:43	3:05	3:31		
Spokane	12 Feb 92	Wednesday	10:12	11:16	12:16	1:26	2:32	3:38	4:52	7:27
Spokane	13 Feb 92	Thursday	10:25	11:41	1:03	2:23	3:48	5:55		
Spokane	14 Feb 92	Friday	9:26	10:48	12:04	1:27	2:47	4:12		
Spokane	15 Feb 92	Saturday	10:01	11:18	12:40					
Spokane	16 Feb 92	Sunday								
Spokane	17 Feb 92	Monday	President's Day							
Spokane	18 Feb 92	Tuesday	9:56	11:14	12:33	1:54	3:17	4:40		
Spokane	19 Feb 92	Wednesday	9:50	10:56	11:51	1:03	2:10	3:14	4:27	6:01
Spokane	20 Feb 92	Thursday	10:08	11:23	12:44	2:04	3:28	5:03		
Spokane	21 Feb 92	Friday	9:33	10:55	12:12	1:34	2:55	4:21		
Spokane	22 Feb 92	Saturday	9:18	10:42	11:59					

Table 3-1 (Continued)

Station	Date	Day	Times							
Baltimore	5 Mar 92	Thursday	9:26	10:53	12:11	1:37	3:04	4:48		
Baltimore	6 Mar 92	Friday	8:22	10:21	11:39	1:03	2:28	4:01		
Baltimore	7 Mar 92	Saturday	8:59	10:26	11:41					
Baltimore	8 Mar 92	Sunday								
Baltimore	9 Mar 92	Monday	8:13	10:17	11:36	12:59	2:24	3:57		
Baltimore	10 Mar 92	Tuesday	8:37	10:27	11:45	1:10	2:34	4:09		
Baltimore	11 Mar 92	Wednesday	9:34	10:59	12:18	1:43	3:12	4:57		
Baltimore	12 Mar 92	Thursday	8:23	10:22	11:40	1:04	2:29	4:02		
Baltimore	13 Mar 92	Friday	9:46	11:07	12:28	1:52	3:22	5:13		
Baltimore	14 Mar 92	Saturday	9:03	10:29	11:44					
Baltimore	15 Mar 92	Sunday								
Baltimore	16 Mar 92	Monday	8:44	10:26	11:46	1:12	2:42	4:25		
Baltimore	17 Mar 92	Tuesday	9:32	11:03	12:22	1:48	3:25	5:14		
Baltimore	18 Mar 92	Wednesday	9:19	10:52	12:11	1:36	3:12	4:58		
Baltimore	19 Mar 92	Thursday	8:52	10:31	11:50	1:16	2:47	4:31		
Baltimore	20 Mar 92	Friday	8:13	10:08	11:29	12:53	2:23	4:03		
Baltimore	21 Mar 92	Saturday	9:18	10:43	11:51					
Baltimore	22 Mar 92	Sunday								
Baltimore	23 Mar 92	Monday	9:24	10:56	12:15	1:41	3:17	5:04		
Baltimore	24 Mar 92	Tuesday	9:48	11:15	12:37	2:03	3:43	5:34		
Baltimore	25 Mar 92	Wednesday	8:37	10:21	11:42	1:08	2:38	4:20		

the study. However, if the targeted vehicles that refused to participate in the program were simply dropped, the potential existed for a bias in the vehicles instrumented. To attempt to remove such biases, a procedure was used to select replacement vehicles for those 3-parameter vehicles that were targeted but that, for some reason, could not be in the vehicle instrumentation study. The basic technique used was that solicited but nonparticipating vehicles and drivers were characterized in a general fashion and that replacement vehicles and drivers with the same characteristics were solicited as soon as possible from those that received passes or waivers from the I/M inspectors.

Table 3-2 shows the four characteristics considered for each refusal replacement and the levels that each characteristic could have. The characteristics were designed to quickly categorize the vehicle and driver. That is, at a glance the solicitors were able to determine the characteristics of the driver they were speaking to and of the vehicle. The solicitors used their own judgement to determine the classification of driver and vehicle that refused to participate and the classification of a replacement vehicle. The solicitor did not ask the driver his age or determine the model year of the vehicle. The idea here was not necessarily to get an exact replacement of a vehicle or driver that refused, but to avoid replacing an unusual vehicle or driver with common ones, and vise versa. For example, an old person driving an old pickup should not be replaced with a young person driving a new sports car, since the driving characteristics of these two classifications could be very different.

For 6-parameter target vehicles, refusals were not replaced according to any category, since they were not randomly selected. Any other qualifying vehicle was sought.

Table 3-2

3-Parameter Replacement Vehicle Characteristics

Driver Age	<25
	26-65
	>65
Vehicle Age	New (1990+)
	Middle (1980-1989)
	Old (1979-)
Vehicle Type	Luxury, Sedan, Station Wagon
	Pickup, Van, Utility
	Sports Car
Origin	Domestic
	Foreign

3.1.5 Interactions With Drivers

After the target vehicle was inspected by the I/M staff, the first instrumentation person the driver met was the solicitor. The job of the solicitor was to determine if the vehicle was eligible for participation, convince the driver that he or she should participate in the vehicle instrumentation program, answer the driver's questions, and offer the driver the incentive package. While doing this, the solicitor filled out the Vehicle Selection Sheet in the data packet. This is shown in Figure 3-6.

The first thing the solicitor entered on the sheet was an estimated classification of the driver's age, the vehicle's age, the vehicle type, the vehicle's origin, and the vehicle's license number. This was done immediately in case the driver immediately refused to participate in the program and drove off. In this way, the solicitor had the information needed to choose a suitable replacement. The license number was used to get the vehicle identification number (VIN) so that details of the vehicle and engine could be obtained by decoding the VIN.

The solicitor then described the program to the driver to try to get his participation. The solicitors established themselves as official EPA representatives. They said that they were studying automotive emissions.

The solicitor then administered the screening questions. If the answers to all screening questions were acceptable, the solicitor told the driver that his vehicle was eligible to participate in the test program. The solicitor then briefly reviewed what would happen. That is, the vehicle would be instrumented that day. The instrumentation would be left on the vehicle for approximately one week. At the end of the week, the instrumentation would be removed at the driver's home or place of work. Alternatively, the driver could bring the vehicle back to the crew at the I/M station to have the instrument removed. If it was necessary, the solicitor pointed out that experienced mechanics performed the installation and removal. The solicitor explained

Figure 3-6

VEHICLE SELECTION SHEET

Solicitor

Driver Age:	<25	26-65	>65
Vehicle Age:	Old (70s)	Middle (80s)	New (90s)
Vehicle Type:	Luxury Sedan Stn Wagon	Pickup Van Utility	Sports Car
Origin:	Domestic		Foreign

Solicitor's First Contact Date: _____ Time: _____

License Number: _____

Eligibility Questions:

Is the vehicle in acceptable condition for this study?	Yes	No
Are you the owner of record of this vehicle? Fleet vehicle.	Yes	No
Is this your normal, everyday car? (no cream puffs, collector's cars, mechanic's specials)	Yes	No
Will you be using your car for any long trips or getting it worked on during the next week?	Yes	No
Is your car running normally?	Yes	No
6-parm only: Model Year _____ Make _____ Model _____	Yes	No

Your vehicle is eligible for this study. Are you interested in hearing about the project? Yes No

Present detailed program description.

GMs: VIN _ _ _ ☐ _ _ _ ☐ _ ☐ _ _ _ _ _ _ _ Yes No

to the driver that both parties would sign a promise that Radian would repair any damages, as stated in the agreement. Finally, half of the incentive would be paid before the installation was done if the driver agreed to participate in the program. At this point in the approach to the driver, interaction became flexible. The solicitor had to listen to the drivers attentively to be aware of their concerns and interests, but the solicitor was not to stray from the established protocol. The solicitor told the driver that installation of the instrumentation on the vehicle would not affect the performance or safety of the vehicle while it was on, nor after it was removed.

At some point, but never before the screening questions were asked, the solicitor offered the driver an incentive to participate in the program. The amount of the offer depended on the type of datalogger that was to be installed, and for the 6-parameter datalogger, depended on the manufacturer of the vehicle. For 3-parameter dataloggers, the incentive that was offered was $100. In a few instances, owners of vehicles asked for a little bit more money for their participations, and they were accommodated. The incentive offer for the 6-parameter dataloggers was a bit more flexible, because these 6-parameter dataloggers could only be installed on certain specific makes and models and model years of vehicles. The initial offer for 6-parameter dataloggers was $175 and, in most cases, this was sufficient to convince the drivers to participate in the program. In some cases, the amount was raised to $200 to convince people to participate and, in a few cases, amounts as high as $450 were required to get participation. Half of the incentive was paid at datalogger installation and half was paid at datalogger removal.

Some drivers were not able to decide themselves whether to have the vehicle instrumented. Some wanted to call their spouses. In these instances, the solicitor encouraged the driver to use the mobile telephone to make the communication.

When the driver agreed to participate, as indicated by signing the agreement, the solicitor showed the driver to the waiting room and drove the vehicle to the mechanic.

3.1.6 Vehicle Condition Check

If the mechanic for any reason believed that a solicited vehicle was not in safe operating condition, it was not to be accepted for participation in the program. No vehicle was rejected, however, because of poor mechanical condition.

3.1.7 Final Vehicle Acceptance

Acceptance in the program was demonstrated by the owner's signature on the vehicle study participation agreement shown in Figure 3-7. The agreement was also signed by the solicitor as a representative of Radian. The document showed the amount of incentive for the total package and the amount paid at installation. After the owner signed the incentive agreement, the mechanic proceeded to install the datalogger on the vehicle.

While the owner waited, the owner filled out the instrument removal appointment sheet that documented specific information about the owner and the vehicle for the purpose of maintaining communications and to set up a removal appointment. This sheet is shown in Figure 3-8.

In the case of the 6-parameter logger installations, the drivers left their cars at the I/M station for the installation of the datalogger. Drivers were provided with rental cars to drive for the remainder of the day while the instrumentation was taking place. Appropriate paperwork was filled out for the rental car.

Figure 3-7

VEHICLE STUDY PARTICIPATION AGREEMENT

1. _____ (OWNER) agrees to accept a total payment of $_____ from Radian Corporation (RADIAN) (EPA's authorized representative) in consideration for allowing the instrumentation of the OWNER's vehicle for an 8 day period. The first payment of $_____ will be made on _____. The final payment of $_____ will be made upon removal by RADIAN of the installed equipment. The OWNER agrees to meet with RADIAN for the purposes of instrument removal and to receive the final payment. In the event that RADIAN mechanics cannot instrument the OWNER's vehicle, RADIAN will pay the OWNER $20.

2. The OWNER is not liable for any damage to the instrumentation incurred during normal vehicle operation. The OWNER will receive the final payment in full, regardless of the condition of the instrumentation, given that the instrumentation has not been disturbed or handled in any way. Manipulation or removal of the instrumentation by anyone other than RADIAN mechanics will cause forfeiture of the second payment.

3. RADIAN assumes responsibility for damage to the instrumented vehicle incurred during the installation and removal of the instrumentation devices. In addition, RADIAN assumes responsibility for any damage clearly caused by the instrumentation during normal vehicle operation.

4. Any damage or vehicle operation problems detected must be reported to RADIAN personnel within one week after instrument removal. RADIAN retains the option to either provide prompt reimbursement to the OWNER for the fair market value of the damages or to use RADIAN's contractors for the repairs. Any repair to the OWNER's vehicle made in connection with this study shall be warranted by RADIAN for thirty (30) calendar days following completion of the repair work.

5. The OWNER agrees to accept RADIAN's decision as final with regard to both repair estimates and repairs. Other than RADIAN's warranty on workmanship described above, the OWNER understands and agrees to waive his/her right to make additional claims (of any kind or nature) against RADIAN one week after the date of final payment or repair as described in paragraph 4.

X_____
OWNER's Signature

X_____
RADIAN Representative's Signature

_____
OWNER's Printed Name

_____
Date

_____
Address

_____
Home Telephone Number

_____
Work Telephone Number

Figure 3-8

Owner's Copy

MY INSTRUMENT REMOVAL APPOINTMENT

Name: _____

S M T W T F S Date: _____ Time: _____

My phone number at the appointment time: _____

I will meet the removal team at:

If I am unable to keep this appointment and want to schedule another appointment, I can contact the mobile removal team at (509) 993-4340.

OWNER

Name	
Street Address	
City, State	
Day Phone	
Evening Phone	

License Plate Number: _____

Appointment for Datalogger Removal:

Name: _____

S M T W T F S Date: _____ Time: _____

Phone number at time of appointment: _____

Location:

Map Coordinates: _____

Just before the driver left the I/M facility after the vehicle was instrumented, he or she was given a driver information packet. The first sheet in the packet, shown in Figure 3-9, described the test program and gave instructions on the care of the datalogger and telephone numbers for reach the installation crew. The top half of the appointment sheet in Figure 3-8 was given to the owner to help him remember the appointment. The bottom half was stapled to the bottom half of the cover sheet. Finally, the owner was given a copy of the agreements he had signed.

3.1.8 Handling of Driver/Owner Problems

It was anticipated that some drivers or vehicle owners would encounter problems with having the datalogger on their vehicles and would need to talk to the installation or removal teams. We wanted the owners of the vehicles to be as unworried about the dataloggers being on their vehicles as possible, so that they would drive their vehicles normally. When necessary, the mobile mechanic was dispatched to help drivers with datalogger problems.

3.2 Datalogger Installation Procedures

While the datalogger installation procedures were outlined in the Quality Assurance Project Plan (3), those procedures were not detailed enough to ensure reliable and consistent installation and removal of dataloggers on vehicles. Accordingly, a procedures manual was written for use by installation and removal personnel in the field. This procedures manual contained detailed instructions and application guides for installing RPM and speed sensors, as well as the datalogger itself, on the vehicles in the field. Both 3-parameter and 6-parameter dataloggers were covered in the procedures manual. The sections that follow highlight some of the important features of the 3-parameter and 6-parameter datalogger installation and removal procedures.

Figure 3-9

THE VOLUNTEER VEHICLE TEST PROGRAM

Congratulations, you have been selected as a participant in the Volunteer Vehicle Test Program. This program is sponsored by the US Environmental Protection Agency and the Motor Vehicle Manufacturers Association, and is being administered by Radian Corporation, in cooperation with state and local authorities.

Your assistance is critical to the success of the program. The information obtained from your vehicle will be used to develop new emissions standards for cars and trucks in the U.S. Thus, your participation in the program today will put cleaner and better performing vehicles on the road tomorrow.

The Program -- Radian is willing to offer you monetary compensation for allowing us to install data collection devices on your vehicle. Our experienced mechanics will install instruments on your vehicle, in most cases, while you wait. During instrument installation, our mechanics will need to drive your vehicle around the block for checkout purposes. The instruments will remain on the vehicle for 7 full days before our mechanics come and remove them. Removal of our equipment will occur at a mutually agreed upon time and place. At that time, our representatives will ask you a few follow-up questions and provide you with the final payment for your cooperation.

Instrumenting Your Vehicle -- Our monitors are passive, data-collecting devices - that is, nothing should interfere with the normal operation of your car or truck. No changes will be made to the engine, electrical, or exhaust systems without prior permission from you, the vehicle owner. The presence of the devices should in no way affect the performance, efficiency, or safety of your vehicle.

Problems with Your Vehicle -- In the unlikely event that your vehicle has operations problems while the instrument is in place, and there is reason to suspect that our equipment or installation is at fault, our mobile mechanics can be reached at the number provided below. If necessary, a mechanic will be dispatched to you and your vehicle immediately.

Though the equipment presents no risk to you, **you should not touch, disturb or handle the instrument in any way** while it is on your vehicle. Such handling may disturb the instrument and invalidate the data. Manipulation or removal of our equipment by anyone other than our own mechanics may cause forfeiture of the second cash payment.

Questions -- If you have any further questions while the instrument is in place, you can call either of the following numbers for assistance:

For instrument removal appointment changes: (509) 993-4358

If no answer: (509) 993-4340

3.2.1 3-Parameter Logger Installation

The mechanic was the person in charge of installing the dataloggers on the private vehicles. He was assisted by the mechanic's assistant, who also calibrated the datalogger after it was installed. When the mechanic completed the installation, he completed the 3-Parameter Logger Installation Notes sheet, which is shown in Figure 3-10. The purpose of the checklist was to inspect specific aspects of the installation and to make a note of what was done to the vehicle so that the it could be restored to its original condition when the datalogger was removed.

3.2.1.1 Sensor Installation

The speed sensor was chosen from among the available Rostra Precision Controls (RPC) components to fit the model, make, and model year of the vehicle being instrumented. In general, the speed sensors were attached to the speedometer cable at the transmission, inductively coupled to magnets installed on the drive shaft, or tied in electrically to the output of the OEM speed sensor. The installation mechanic determined the type of speed sensor to be used on a vehicle by examining the vehicle and by consulting the RPC speed sensor application guides.

All older model vehicles and some late model vehicles use speedometer cables. Where these can be easily unscrewed at the transmission, the after-market speed sensors were used. Speed sensors were not installed on the speedometer cable at the back of the speedometer gauge because of the possibility of disturbing dashboard components and because of the difficulty of reaching this location on many vehicles. The speedometer cable installation was done in some cases by accessing the speedometer cable under the hood when an OEM cruise control was on the vehicle. Late-model vehicles that do not have speedometer cables are equipped with OEM speed sensors, and the wire from the speed sensor to the ECU was tied into with a Scotch-Lok.

Figure 3-10

3-PARAMETER LOGGER INSTALLATION NOTES

Mechanic's Assistant

DISTANCE SENSOR

Type: Speedometer Cable Adapter (RPC _____)
Driveshaft Magnets (RPC 4165)
OEM Speed Sensor Wire

Point of Attachment:

RPM SENSOR

Type: Thexton Coil Adapter No.: _____
Other: _____

Comments:

VACUUM SOURCE

Comments:

Vehicle location of vehicle parts removed during the installation:

RPM signals were sent to the datalogger from the tachometer terminal of the coil. Commercially available adapters from Thexton were used to access this signal. On late model cars, the Thexton adapters fit between the connector on the distributor and the wiring harness connector. A mechanic checked the signal from the RPM connector with a tachometer to ensure that the tachometer terminal of the coil had been selected for transmitting the signal to the datalogger.

The mechanic selected an appropriate source of manifold vacuum to route to the vacuum port on the datalogger. The mechanic checked the vacuum signal with a standard vacuum gauge. An existing vacuum line was disconnected and a tee inserted to provide a source for the datalogger. An additional tee was placed in the vacuum line that leads from the existing line to the datalogger for the calibration check of the pressure transducer in the datalogger against the mechanic's vacuum gauge.

3.2.1.2 Box Installation

The 3-parameter logger was installed at a location distant from heat and moving parts that was not subject to much vibration and that could not be struck directly by rocks, water, dirt, or oil. The datalogger was attached to the vehicle under the hood in a suitable location with tie wraps.

3.2.1.3 Wires

Wires and vacuum lines were routed from sensors to the datalogger to avoid areas where damage could occur from hot parts and moving parts. Leads were securely tie-wrapped to existing parts of the vehicle so that they were not damaged. Standard crimp connectors were used to join sensors to datalogger input wires. Color-coded wires were used to avoid confusion about the inputs to the datalogger. The power for the datalogger was from a wire run directly to the +12 volts on the battery. An in-line power fuse on the +12 volt line protected the vehicle's electrical system. Datalogger

ground was also connected directly to the negative terminal of the battery. The connection points for the 3-parameter logger wiring harness are shown in Table 3-3.

3.2.1.4 Troubleshooting

If the datalogger was installed properly, it worked when powered up. If the datalogger did not work, then normal troubleshooting procedures were performed to make sure that all systems were operating properly. If the datalogger could not be made to work, there was no point in letting the vehicle participate in the test program, and the datalogger and sensors were removed.

3.2.1.5 3-Parameter Logger Calibration and Calibration Check

Because of differences in the RPM and speed sensors, and because of individual differences between vehicles, the RPM and speed sensors were calibrated after installation. Calibration of the datalogger was performed by the mechanic's assistant with the mechanic or the solicitor's assistant driving the car.

The datalogger was checked for calibration and proper operation on the vehicle by plugging an RS-232 adaptor cable into the datalogger and running the cable inside the passenger compartment and connecting to a laptop PC. Checks were made against the mechanic's instruments and against the vehicle's instruments as the vehicle was driven and the engine was run.

The first thing that the calibrator did after connecting the PC to the datalogger was to make certain the datalogger was in the calibration (CAL) status. Then he entered the essential information about the vehicle identification. He was prompted by software to enter sample ID, VIN, model year, make, model, transmission type, and beginning odometer reading.

Table 3-3

3-Parameter Logger Wiring Harness Connection

Color	Connection Point
Red	Battery + (12 volt)
Black	Battery - (Ground)
Blue	Speed Signal • Speedometer Cable Adaptor (Blue wire) • Magnetic Pickup (Blue wire) • OEM Vehicle Speed Sensor Wire
Gray	Speed Return Signal • Speedometer Cable Adaptor (Gray wire) • Magnetic Pickup (Gray wire)
White	Ignition Coil Tachometer Terminal

The clock chip in the datalogger was set to Central Standard Time in the laboratory before field work began. The clock chip has an internal battery good for 3 years at 85°C; however, the date and time setting was checked after installation of the datalogger against the watch of the calibrator to ensure it was reasonably correct. These data were entered with the rest of the 3-parameter logger calibration data on the 3-Parameter Logger Calibration Sheet, shown in Figure 3-11.

The calibration of engine RPM required the mechanic's assistant to answer questions on the PC provided by the datalogger software. The information to be supplied was the number of cylinders in the engine, the number of coils on the engine, and whether the engine was a conventional Otto or a Wankel engine configuration. No diesel engines were instrumented in this study. From the answers to these questions, the software calculated a conversion factor to be used to convert the pulses obtained from the tachometer terminal of the ignition coil to RPM readings.

Once these questions were answered, a calibration check of RPM was made by comparing the mechanic's hand-held tachometer with the RPM indication shown on the laptop computer. The RPM was checked at idle and at fast idle. The values given by the datalogger and by the mechanic's tachometer were recorded on the calibration sheet.

In a few instances, it was found that these RPM values disagreed by a substantial amount. In this situation, the installers checked the datalogger installation, checked the answers to the datalogger questions about engine configuration, checked the tachometer switch settings, and, if necessary, tried another datalogger. In some cases, an RC filter was inserted in the RPM input wire to the datalogger. This filter caused the waveform voltage to be shifted down. In many problem cases, this caused the RPM input circuit to trigger properly and to produce an accurate and reliable RPM reading. In Spokane, for installations where a good RPM signal could not be obtained, the dataloggers were removed from the vehicles, because the start and end of trips depended

Figure 3-11

3-PARAMETER LOGGER CALIBRATION SHEET

Solicitor

Datalogger Number _____ has been installed in the vehicle.

Put datalogger in CAL mode.

Vehicle Sample No. : S ___ B ___ (get from Cover Sheet)
VIN: _____ (Fill for 1981+ cars)
Model Year: _____ (get from label under the hood)
Make: _____
Model: _____
Transmission: Automatic Manual: 3 4 5 6
Odometer: _____

Mechanic's Assistant

Measurement	Vehicle's Instruments	Mechanic's Instruments	Toler-ance	Datalogger Reading
Date				
Time (CST)				
Vacuum at Idle			±1	
RPM at Idle			±67	
RPM at Fast Idle			±67	
Speed (> 30 mph)			±6 %	

Perform WOT acceleration from <10 mph to 35-60 mph. Local Time _____

Explanation of calibration drive abnormalities and corrective action:

Put datalogger in RUN mode before releasing vehicle to driver.

critically on a good RPM reading. On the other hand, because of the improved trip sensing logic in Baltimore, vehicles could be safely released. There, trip starts and ends were reliably detected with the redundance provided by the MAP and speed sensors.

The manifold vacuum was checked at idle by monitoring the datalogger via the PC. At the same time, the mechanic obtained a manifold vacuum reading by tying into the tee on the vacuum line leading into the datalogger. These comparable values were recorded on the calibration sheet and should have been reasonably close to each other. Because of errors in the mechanic's vacuum gauge and changes in atmospheric pressure, they were not exactly the same. These MAP checks were only calibration checks since the response of the pressure transducer on the datalogger could not be changed. The information that a MAP sensor was reading incorrectly during this calibration check would have been used to delete the MAP values from the data for that vehicle. Since MAP was not a critical parameter for the study, an incorrectly reading MAP sensor would not have been a sufficient reason for removing the datalogger from the vehicle at the end of installation. The critical speed data would still be good.

The speed sensor was calibrated by driving the vehicle over a measured distance of about 800 feet on pavement. During the calibration phase of the speed sensor, the datalogger counted pulses that the speed sensor put out for the measured distance. The calibrator told the datalogger when the datalogger should begin and stop counting the pulses for this short drive. The speed at which the vehicle drove was not important. At the end of the drive, the software asked the calibrator the distance the vehicle had driven and, based on that distance, a calibration factor was calculated by and stored in the datalogger. Then the vehicle was driven across a second measured distance to check the calibration. The distance that the datalogger indicated the vehicle had driven had to agree to within 1.0% of the true distance.

Finally, the vehicle was driven on the street, and the indicated speed on the vehicle speedometer was compared with the speed indicated on the laptop. Those

two speeds had to agree within 5-10 percent. The speedometer could read incorrectly because of tire sizes, which may have been different from those originally on the vehicle. This was only a calibration check of the speed as measured by the datalogger, since vehicle speedometers are known to be inaccurate to a degree.

The final part of the datalogger calibration involved doing a wide-open throttle acceleration of the vehicle. This provided a measure of the vehicle's ultimate performance for comparison with acceleration versus speed profiles in the data analysis phase. In addition, this provided a check of the MAP sensor since MAP should be about 100 kPa during a wide open throttle acceleration and about 30 kPa at idle. Usually, a 0-40 miles/hour acceleration was performed.

3.2.1.8 Memory, Data, Downloading Check

After the installation calibration drive, the data collected during the drive were downloaded to the laptop PC and inspected to see if they were reasonable. This was the final datalogger check before the vehicle was released to its owner. The datalogger status flag, which differentiates calibration driving from owner driving, was switched from CAL to RUN just before giving the vehicle to the owner.

3.2.2 6-Parameter Logger Installation and Checkout

The MVMA/AIAM wanted to have a certain distribution of manufacturers represented with the 6-parameter datalogger installations. To accomplish this, a list of target make, model year, and models for each manufacturer was maintained. As vehicles were instrumented, the list was updated to indicate that certain slots had been filled. Any remaining slots that were open showed the types of vehicles that could be used to fill the quota.

In addition, since the 6-parameter dataloggers were specific to certain manufacturers and their vehicles, a current inventory list of the vehicle-specific datalogger systems on hand was maintained.

Seven domestic and foreign vehicle manufacturers participated in the driving modes project. As a vehicle entered the I/M lane and was selected to be a candidate vehicle for the 6-parameter datalogger, the vehicle characteristics were compared with the list of vehicles that could be instrumented. If all the vehicle characteristics matched those of a vehicle that could be instrumented with a 6-parameter logger, the solicitor tried to persuade him to participate in the project. If the driver agreed, the solicitor filled out the top half of the 6-Parameter Logger Identification and Sensor Verification form shown in Figure 3-12.

The solicitor then drove the vehicle to the 6-parameter installation area. The mechanic's assistant filled out the bottom part of Figure 3-12, in which the details of the selection characteristics used to identify the 6-parameter vehicle were noted. Before the instrumentation process began, the error codes on the vehicle were checked to make sure that all vehicle sensors were operating properly. If error codes were found, the vehicle was not instrumented. An initial determination was made that the vehicle exhaust system was in proper working order.

For each 6-parameter vehicle, the speed, RPM, MAP, coolant temperature, and throttle position sensors were installed first. Once these were confirmed to be working appropriately, the vehicle system was tested for the oxygen sensor channel. This procedure was done before going to the muffler shop and before the oxygen sensor boss was installed on the vehicle tailpipe. The oxygen sensor signal in the power cables was connected to the manufacturer control box using the Amphenol connectors provided. The oxygen sensor itself was then placed in a piece of exhaust pipe that was slid on the end of the vehicle tailpipe. The oxygen sensor readings were checked in the monitor mode to see if the equivalence ratio was near 1. For GM vehicles, the data were

Figure 3-12

6-PARAMETER LOGGER IDENTIFICATION AND SENSOR VERIFICATION

Solicitor

Vehicle Sample No.: S ___ B ___ (get from Cover Sheet)
VIN: _____ (Fill for 1981+ cars)
Model Year: _____ (get from label under the hood)
Make: _____
Model: _____
Transmission: Automatic Manual: 3 4 5 6
Odometer: _____

Mechanic's Assistant

Vehicle Selection Parameters:

	GM	FORD	CHRY	MITS	MAZD	NISS	TOYT
Year							
Make							
Model							
Engine							
VIN							
2/4 Wheel Drive							
S/D Cam							
Box Test							
Electronic Dash							

Check Error Codes Before Installation:

Check Error Codes After Installation:

downloaded to check the oxygen sensor readings. If the oxygen sensor readings were found to be satisfactory, the vehicle was taken to the muffler shop for the boss installation. After the installation, the oxygen sensor was installed into the boss and connected to the datalogger system, and the vehicle exhaust system was tested to be free of exhaust leaks. The vehicle was then taken on a short drive. All the vehicle parameters were then examined to see if they were satisfactory.

After the Spokane installations and before the Baltimore installations began, the oxygen sensor responses were checked against air and 0.1 percent oxygen in nitrogen, which simulates an exhaust gas from an engine running near the stoichiometric air/fuel ratio. The voltage from the oxygen control box was measured. The air calibration check was performed on 18 oxygen sensors that were available, and the 0.1 percent oxygen check was performed on four oxygen sensors. One oxygen sensor had been sent to Ford and another to Toyota, and they could not be checked before the vehicle installations. Table 3-4 shows the logger number, oxygen sensor serial number, and the voltages recorded for the oxygen sensors. According to data provided by NGK, the oxygen sensor voltage for air should be between 4.25 and 4.75 volts, and the voltage for oxygen concentration of 0.1 percent should be near 3.000 volts.

The next sections describe the installation process for each manufacturer.

3.2.2.1 GM Vehicle Instrumentation

Before proceeding with the GM installation, the GM datalogger's interfacing with the vehicle was tested by directly connecting the GM datalogger to the vehicle ALDL connector. If the communication was successful, the power cable was installed to the fuse box ignition ON power. Next, the ALDL cable was connected to the diagnostic connector under the steering wheel. The ground cable was installed next to the power cable in front and also to the datalogger box in the trunk.

Table 3-4

Oxygen Sensor Calibration Check
(Performed on March 4, 1992)

Datalogger Box #	Manufacturer	Oxygen Sensor #	Oxygen Sensor Voltage with Air	Oxygen Sensor Voltage with 0.1% Oxygen
Blue 5	Ford	1925-1228	4.354	3.003
Blue 15	Mitsubishi	1925-1222	4.278	3.007
Blue 6	Ford	1925-1224	4.312	3.006
Orange 21	Nissan	1925-1227	4.205	3.007
Orange 18	Nissan	1926-1226	4.226	-
Red 1	Chrysler	1925-1223	4.238	-
Red 2	Chrysler	1925-1221	4.263	-
Blue 4	Ford	1925-1220	4.286	-
Blue 3	Ford	1925-1216	4.226	-
Green 16	Mazda	1925-1217	4.321	-
Green 17	Mazda	1925-1219	4.286	-
Yellow 8	GM	1925-1231	4.234	-
Yellow 12	GM	1925-1213	4.226	-
Yellow 11	GM	1925-1212	4.228	-
Yellow 10	GM	1925-1211	4.426	-
Yellow 13	GM	1925-1214	4.243	-
Yellow 14	GM	1925-1215	4.278	-
Yellow 9	GM	1925-1232	4.233	-
Blue 7	Ford	1925	-	-
White 20	Toyota	1925	-	-

Figure 3-13 shows the 6-Parameter Logger Installation Notes form. This form was filled out after all the wiring was connected between the vehicle andthe datalogger box. The locations of all the vehicle parts removed during the installation were also noted.

The 6-parameter datalogger software check was performed by using the 6-Parameter Logger Calibration Sheet shown in Figure 3-14. The vehicle was driven at a known speed over a fixed driving route. The time, speed, and RPM of the vehicle were recorded and compared with the values stored in the datalogger. After the data had been checked, the datalogger was initialized and the vehicle was given to the owner.

3.2.2.2 Mitsubishi Vehicle Instrumentation

The procedures described above in the GM section for vehicle identification, sensor verification, wire installation and software check were followed. The forms presented in Figure 3-12, 3-13, and 3-14 were used. The Mitsubishi datalogger was a Campbell Scientific CR10-based system. The primary connections were to the ECU and the multi-use connector. The connection to the ECU provided 12 volts of power to the Mitsubishi interface box, and the connection to the multi-use connector provided speed, RPM, throttle position, and coolant temperature information to the interface box. The MAP was measured by using a vacuum sensor mounted on the air intake plenum in the engine compartment. Once the basic wiring was determined to be working properly, the oxygen sensor was installed. After the oxygen sensor was connected to the interface box, the final software check was performed by using the form described in Figure 3-14. The vehicle was driven on a specified route and the 6-parameters were monitored during the drive. After the values were confirmed to be appropriate in both the monitoring mode as well as in the downloaded data, the vehicle was given to the owner.

Figure 3-13

6-PARAMETER LOGGER INSTALLATION NOTES

Mechanic's Assistant

Datalogger System Color/Number _____

GM FORD CHRY MITS MAZD NISS TOYT

Connection Location:

Power
Ground
Speed
RPM
THR
Circle: MAP MAF LV8
CTS

Wire Routing:

Vehicle location of vehicle parts removed during the installation:

Oxygen Sensor Box should be ON
Oxygen sensor location: Upstream of Muffler Downstream of Muffler

Figure 3-14

6-PARAMETER LOGGER CALIBRATION SHEET

Mechanic's Assistant

Non-GM only: Check that memory modules are empty.
Non-GM only: Check that FILL & STOP switch is ON.
Non-GM only: Name of program installed on CR10: _____
Non-GM only: Record values at idle:

Time		
Speed		
RPM		
THR	Idle:	WOT:
Circle: MAP MAF LV8		
CTS		
PHI		

GM and non-GM: Drive the vehicle at a known speed and record:

Measurement	Vehicle's Instruments	Datalogger Reading
Date		
Time		
Speed		
RPM		

Comments:

GM and Non-GM: Reset datalogger after test drive.

Non-GM only: Connect memory modules.

3.2.2.3 Ford Vehicle Instrumentation

The procedures described in the above sections for vehicle instrumentation were followed. All the Ford connections were made through a tee connector into the ECU of the vehicle. The ECU was removed and the tee connector was put into its place. The ECU was then connected to the tee harness. This was the only connection and this harness was connected directly into the Ford manufacturer's box, which received all the sensor information and power from this connection. After the vehicle was instrumented and the idle mode test was performed, the oxygen sensor was installed. The final software check was performed using the form described in Figure 3-14.

3.2.2.4 Chrysler Vehicle Instrumentation

All the Chrysler connections were made through a diagnostic connector, which was found next to the battery in the engine compartment. The harnesses were routed underneath the vehicle and up through the rubber grommet in the vehicle trunk. This harness connected to the manufacturer interface box in the trunk. The box and the oxygen sensor were then connected to each other and to the CR10. All the procedures described in the above sections were followed before the vehicle was released to the owner.

3.2.2.5 Mazda Vehicle Instrumentation

All the procedures discussed in the above sections were followed. The Mazda-specific installation procedures required the connection of a manufacturer-supplied ECU in place of the original vehicle ECU. The speed sensor cable, which was connected to the speedometer cable, was used to determine the speed of the vehicle. All the other sensors (MAP, RPM, coolant temperature, and throttle position) were determined from the ECU. The oxygen sensor was directly connected to the

manufacturer interface box. Depending on the particular model of the vehicle, the ECU box had to be configured to a particular setting.

After the oxygen sensor was installed and the software check was performed the vehicle was released to the owner.

3.2.2.6 Toyota Installation Procedures

The primary connection for the Toyota installation involved the replacement of the original ECU with the manufacturer-supplied ECU box. All the vehicle parameters were determined from this ECU box. Connections also had to be made for the 12-volt power to the manufacturer interface box. Because of the large size of the Toyota interface box, it was installed on the back seat of the vehicle. After all the harnesses were connected, each signal had to be calibrated on the manufacturer-specific box. The calibration process was required for both zero and span values. When this calibration process was completed and the oxygen sensor was installed on the vehicle, it was released to the owner.

3.2.2.7 Nissan Vehicle Instrumentation

The procedures specified for vehicle identification, sensor verification, datalogger installation, and software check described in the sections above were followed. Nissan provided a special ECU box with a model-specific EPROM chip that had to be substituted for the original ECU. In addition, connectors were used to supply 12-volt power as well as a link to the diagnostic connector for Nissan vehicles. After the initial wires were connected, the vehicle parameters were checked at idle. After the proper values were monitored for all five vehicle parameters, the oxygen sensor was installed, followed by the final 6-parameter software check. Before the vehicle was released to the owner, the datalogger was reset so that only owner driving was collected on the memory modules.

3.3 Datalogger Removal Procedures

The dataloggers were removed from the vehicles during appointments with vehicle owners. At the appointed time, a Radian van rendezvoused with the driver and vehicle to remove the datalogger. To minimize the inconvenience to the owner of the vehicle, owners were offered the option of having dataloggers removed at their house or workplace, but most preferred to return to the I/M station to have the equipment removed.

3.3.1 3-Parameter Logger Removal

First, the datalogger and speed transducer were checked for proper operation before they were removed from the vehicle. This was done by connecting the datalogger to the laptop PC as it was during the datalogger calibration. The datalogger status flag was changed from RUN to CAL. The displayed date and time were checked. The vehicle was then taken for a short drive to check the displayed vehicle speed on the PC against the vehicle's speedometer. These two values were recorded on the 3-Parameter Logger Removal Report, shown in Figure 3-15. This check was made to ensure that the speed transducer was still working or to determine if it had been degraded in some way, for example, if some of the magnets had fallen off the rotating shaft. Finally, during the drive a wide-open throttle acceleration was performed to aid data analysis.

The datalogger was then carefully removed from the vehicle. While the mechanic was removing the datalogger from the vehicle, the assistant discussed the vehicle's usage with the owner to determine how the vehicle had been driven during the week the datalogger was collecting data. The purpose of this the usage information form (shown in Figure 3-16) was to determine if there was any reason to throw out the data collected by the datalogger. Finally, the owner was paid the remainder of the incentive. The data from the logger memory were downloaded to the PC hard disk. The file name

Figure 3-15

3-PARAMETER LOGGER REMOVAL REPORT

Removal Leader

Data Points Collected: _____

Put datalogger in CAL mode.

Odometer: _____

Measurement	Vehicle's Instruments	Datalogger Reading
Date		
Time (CST)		
Speed (> 30 mph)		
RPM at Fast Idle		

Perform WOT acceleration from <10 mph to 35-60 mph. Local Time _____

Explanation of removal drive abnormalities:

Hit Alt X to exit PROCOM

Datalogger Number _____ (get from logger case before removal!)

Remove datalogger from vehicle.

Figure 3-16

USAGE INFORMATION

Removal Leader

During the last week:

Was the vehicle driven?

Did you go on any long trips?

Who drove the vehicle?

Did you have your car worked on?

used was the last eight characters of the VIN. For reliability, downloading was done in the hotel at the end of the day. To do the downloading, the datalogger removed from the vehicle was powered by a 12-volt supply. Immediately after the data were transferred onto the PC hard disk, the raw data file was compressed, and two copies on floppies of the compressed hard disk file were made. One floppy was archived on site. The second copy was mailed with all the other floppies from dataloggers retrieved that day to Austin. The 3-Parameter Data Downloading Sheet, shown in Figure 3-17, was filled out to document details of the data retrieval.

3.3.2 6-Parameter Logger Removal

For the GM dataloggers, the removal team confirmed that the datalogger was in the data collecting mode before it was removed. Figure 3-18 shows the 6-Parameter Datalogger Removal Report. The cables and connectors were removed from the vehicle and the vehicle was returned to its original state. The datalogger installation notes were consulted to make sure that all vehicle parts were returned to original condition.

For the non-GM dataloggers, the removal team first removed the memory modules and connected the computer to the CR10 datalogger. They monitored the 6 parameters in idle mode and noted the readings on the form described in Figure 3-18. In addition, the vehicle was taken on a short drive to note the speed and RPM of the vehicle. The vehicle instrument readings were compared with the datalogger readings during the drive. If all parameters read properly, all the cables were removed from the vehicle and the battery was disconnected from the CR10.

For both the GM and the non-GM dataloggers, the oxygen sensor was removed from the exhaust system and new exhaust system components after the catalytic converter were installed.

Figure 3-17

3-PARAMETER DATA DOWNLOADING SHEET

Removal Leader

Datalogger Number _____ (get from datalogger case!)

Dump data to PC hard disk.
Name the Raw Data file with the last 8 characters of the VIN:

_ _ _ _ _ _ _ _ _ • 3RD

Record the size of the •3RD file as seen on the hard disk:

_____ Mbytes

Compress the file using PACK to create a new file.
Name the ComPressed file with the last 8 characters of the VIN:

_ _ _ _ _ _ _ _ _ • 3CP

Make a copy of this file on each of two 3.5" 1.44 Mbyte floppies.
Label each floppy with:

Filename•3CP
Vehicle Sample ID
Today's Date

Fed Ex one floppy to Austin.
Archive the other floppy on site.

Figure 3-18

6-PARAMETER LOGGER REMOVAL REPORT

Removal Leader

Odometer: _____

Datalogger System Color/Number: _____

(Get number from the system box, not the datasheet!)

GM:

Date: _____ Time (local): _____

Make sure PRODAS is in COLLECT mode.

Remove cables and GM datalogger.

Non-GM:

Counter: _____

Disconnect memory modules.

Record values at idle:

Speed	
RPM	
THR	
Circle: MAP MAF LV8	
CTS	
PHI	

Drive the vehicle and record:

Measurement	Vehicle's Instruments	Datalogger Reading
Date		
Time (local)		
Speed		
RPM		

Remove cables and non-GM datalogger from vehicle.

The owner was also paid the balance of the incentive originally agreed on. At this time, the Usage Information form shown in Figure 3-16 was also completed.

3.3.3 Data Handling

As data were downloaded in the hotel room from the dataloggers onto the portable PC, the data were put in a SAS-compatible format for loading onto a mainframe computer.

Each of the datalogger systems had software that read the logger's memory, converted the information in memory into engineering units for each parameter measured, and sent it to the portable PC. Thus, the format of the data in the downloaded files on the PC could be controlled by modifying the downloading software. Because the 3-parameter and 6-parameter loggers were measuring different parameters in different ways, the downloaded data files were different. The downloaded data file formats for the two types of dataloggers are described below.

3.3.3.1 3-Parameter Data Downloading

As the data were downloaded from the datalogger to the PC, the data were automatically put into the SAS-compatible format, shown in Figure 3-19. The first twenty-four lines in the downloaded data file give information about the vehicle to which the data in the following seven columns apply. These columns of data in the downloaded file provide the operational information about the vehicle.

These seven parameters are self-explanatory except for the last two. Status denotes whether the data for the observation was taken while the datalogger was in the calibration mode and the vehicle was being driven by the instrumentation staff or whether the data were being obtained by the regular driver of the vehicle. Parity tells whether the data on each observation line of the file passes a parity check. This is used

Figure 3-19. 3-Parameter Downloaded Data Format

```
dd

Vehicle Identification :
------- -------------- -
Sample ID = b130
Motor Vehicle ID = 1fabp44e2kf117098
Model Year = 1989
Make = ford
Model = mustanglx
Transmission = automatic
Odometer Reading = 45277


Speed Calibration :
----- ----------- -
1192 pulses is equivalent to 800 feet


RPM Calibration :
--- ----------- -
Piston engine
Number of Cylinders = 8
Number of coils = 1

03/11/92        12:24:54        .       .       .       cal
.       .       0.00    833     78.6    cal     .
.       .       0.00    1233    31.6    cal     .
.       .       0.00    667     37.3    cal     .
.       .       0.00    700     42.2    cal     .
.       .       0.00    700     47.8    cal     .
.       .       0.00    700     47.0    cal     .
.       .       0.00    700     47.0    cal     .
.       .       0.00    700     47.0    cal     .
.       .       0.00    700     47.0    cal     .
.       .       0.00    733     48.6    cal     .
.       .       0.00    733     48.6    cal     .
.       .       0.00    1000    55.9    cal     .
.       .       0.00    967     52.7    cal     .
.       .       0.00    867     49.5    cal     .
.       .       0.00    733     47.8    cal     .
.       .       0.00    733     49.5    cal     .
.       .       0.00    800     48.6    cal     .
.       .       0.00    1433    71.3    cal     .
.       .       0.00    1433    65.7    cal     .
.       .       0.00    833     44.6    cal     .
.       .       0.00    667     48.6    cal     .
.       .       0.00    667     48.6    cal     .
```

Date	Time	Speed	RPM	MAP	Status	Parity
(12/25/91)	(HHMMSS)	(m/s)	(rpm)	(kPa)	(RUN or CAL)	(• or parity_error)

to greatly improve the reliability of the data on each line and can be used to spot errors in the logged data. Other than this information, no other data were recorded in the downloaded files.

3.3.3.2 6-Parameter Data Downloading

The final phase of the data handling process was downloading the 6-parameter data from the dataloggers. This was done by following the instructions on the form described in Figures 3-20 and 3-21. For the non-GM dataloggers, the CR10 memory modules were connected to the PC through an appropriate interface. The vehicle files were named so that the identity of the memory modules and the vehicle sample number could be identified. The 6-parameter downloaded data have no values in the file which specified the vehicle to which the data applied. All the files downloaded for a particular vehicle for memory module 1 and memory module 2 were concatenated to produce one file that contained all the data for that particular vehicle. The file was converted to the final output format and was examined using an editor. Figure 3-22 shows the format of the downloaded 6-parameter data. Once a file was found to be reasonable, it was compressed so that it could fit onto a 1.44 Mb floppy. Two copies of the compressed data were made. One was sent to Austin and one was filed with the data packet on site.

Figure 3-21 was used for downloading the files from the GM datalogger. The output format of the file was available directly from the datalogger software. The file was examined to make sure that all the data were available on the file. The data file was compressed and two copies were made of the compressed data file.

Figure 3-20

6-PARAMETER DATA DOWNLOADING SHEET
(GM only)

Removal Leader

Datalogger System Color/Number _____
(Get number from the system box, not the datasheet!)

Read and Convert data using PRODAS.

Name the raw data file with the last 8 characters of the VIN:

_____ • PRN

Examine the •PRN file.

Record •PRN file size in /PRODAS/DATA directory: _____bytes

Compress the •PRN file with GMPACK to make a •6CP file.

Make a copy of this file on each of two 3.5" 1.44 Mbyte floppies.
Label each floppy with:

Filename•6CP
Vehicle Sample ID
Today's Date

Initialize the GM datalogger.

Fed Ex one floppy to Austin.
Archive the other floppy on site.

Figure 3-21

6-PARAMETER DATA DOWNLOADING SHEET
(non-GM)

Removal Leader

Datalogger System Color/Number _____
(Get number from the system box, not the datasheet!)

Connect Memory Module 1 to PC with the SC 532 interface.

Collect all data files using SMCOM.
Name Memory Module 1 files with Vehicle Sample Number: 1 _ _ _ _

Repeat procedure for Memory Module 2. Name these 2 _ _ _ _ files.

Use CONCAT to concatenate the •DAT files into:
_ _ _ _ _ _ _ _ • DAT using the last eight VIN digits.

Use SPLIT to convert the •DAT file to a •PRN file. _____ bytes

Examine the •PRN file with the SEE editor. Is it reasonable?

Use SIXPACK to compress the •PRN file into a •6CP file.

Make a copy of this file on each of two 3.5" 1.44 Mbyte floppies.
Label each floppy with:

Filename•6CP
Vehicle Sample ID
Today's Date

Reset memory modules.

Fed Ex one floppy to Austin.
Archive the other floppy on site.

Figure 3-22

6-Parameter Downloaded Data Format

Julian Date	Time HHMM	Time SS	Speed (mph)	RPM	Throttle Position	Load	Coolant Temperature	ϕ
85	1641	52	1	925	1	98	31	1.023
85	1641	53	0	925	1	96	31	1.022
85	1641	54	0	925	1	98	31	1.022
85	1641	55	0	925	1	98	31	1.022
85	1641	56	0	925	1	97	31	1.024
85	1641	57	0	925	1	98	32	1.024
85	1641	58	0	925	1	96	32	1.023
85	1641	59	0	925	1	96	32	1.027
85	1642	0	0	925	1	96	32	1.001
85	1642	1	0	925	1	96	32	0.998
85	1642	2	0	900	1	94	33	0.995
85	1642	3	0	925	1	96	33	0.999
85	1642	4	0	900	1	96	34	1.002
85	1642	5	0	900	1	95	34	1.010
85	1642	6	0	925	1	94	34	1.011
85	1642	7	0	925	1	96	34	1.015
85	1642	8	0	875	1	93	34	1.018
85	1642	9	0	900	1	92	34	1.026
85	1642	10	0	900	1	95	34	1.010
85	1642	11	0	900	1	94	35	1.025
85	1642	12	0	900	1	94	35	1.016
85	1642	13	0	900	1	96	35	1.018
85	1642	14	0	925	1	95	35	1.027
85	1642	15	0	900	1	94	36	1.029
85	1642	16	0	900	1	94	36	1.017
85	1642	17	0	925	1	91	36	1.025
85	1642	18	3	1425	10	154	36	0.999
85	1642	19	8	1625	15	161	36	0.993
85	1642	20	12	1825	21	180	37	1.001
85	1642	21	17	2250	26	189	37	0.975
85	1642	22	22	2000	26	205	37	1.001
85	1642	23	26	2075	26	196	37	1.002
85	1642	24	29	2100	21	168	37	1.048
85	1642	25	30	1625	13	142	37	1.067
85	1642	26	30	1225	1	56	37	1.051
85	1642	27	29	1125	1	50	38	1.196
85	1642	28	27	900	1	46	38	1.251
85	1642	29	25	950	1	55	38	1.277
85	1642	30	22	775	1	65	38	1.287
85	1642	31	17	750	1	82	39	1.155

4.0 FIELD RESULTS

The results of the field efforts in Spokane and Baltimore are presented in this section. First, a review of the reasons that EPA chose Spokane and Baltimore for the driving pattern study are reviewed. Next, a summary of the facilities at the inspection/maintenance stations and the activities of the installation and removal staff are presented. The final part of this section reviews the success rates for solicitation and datalogger instrumentation for the 3- and 6-parameter dataloggers. Tables are presented which show the identity of the vehicles that were solicited, as well as those that were instrumented in this study.

4.1 Selection of Cities

EPA selected two cities, Spokane, Washington and Baltimore, Maryland, for the driving modes study. The selection was based on a number of factors. For the instrumented vehicle study, the primary factor was the presence of a centralized inspection/maintenance (I/M) program in the two cities. A centralized I/M station provided a convenient location to sample vehicles representatively in a situation where drivers would be aware of exhaust emissions of their vehicles. Driving in Spokane consists of city driving on flat as well as hilly terrain, and Baltimore presented a variety of city driving conditions, both on city streets and on the highway. The I/M program in the State of Maryland uses 10 locations all over the state for testing vehicles. Two locations, one in the Baltimore city area and one in the Baltimore county area, represented by Locations 3 and 4, were used in this study. The Spokane I/M program is conducted through only one location, which was used in this study.

The desirable characteristics of the survey sites were considered before the cities were chosen for the measurement of driving patterns. The characteristics considered were:

- Nonattainment area,
- Centralized I/M;
- Transportation Planning System Model;
- Terrain;
- Altitude;
- Precipitation;
- Road System; and
- Traffic.

It was appropriate to use an emissions nonattainment area for the study; however, the question arose whether ozone nonattainment areas, CO nonattainment areas, or areas which attain neither the CO nor the ozone NAAQS should have been considered. No reason could be given as to how driving in an attainment or a nonattainment area would affect driving behavior.

From a practical point of view, the survey site that had centralized I/M made the procurement of instrumented vehicles easier. For the chase car study, a survey site with a good urban transportation planning system model was needed.

The terrain and altitude of a survey site affects the way engines operate and vehicles are driven. Since most vehicles are driven at low altitudes, it seemed appropriate to choose low-altitude survey sites. Since the presence of many steep hills can affect vehicle driving patterns, and most large cities are relatively flat, it was appropriate to chose a city which is relatively flat.

The presence of precipitation on the road may affect driving patterns, so cities expected to have a large amount of precipitation during the period of the study were ranked lower.

The characteristics of the traffic and road systems of the survey site may greatly affect driving patterns. The driving characteristics in a city that has congested traffic will be significantly different from those in a city that has relatively open traffic. Trips in large, spread-out cities will tend to be longer than those in small, compact cities. For example, driving patterns in downtown Boston would be different than in Los Angeles.

Table 4-1 lists the nonattainment areas within the continental United States that have centralized I/M programs. The table contains information about the I/M program, the altitude, and precipitation in these 25 areas. This information, along with other information specific to the collection of data by the chase car technique, was considered in the selection of candidate cities for the measurement of vehicle driving patterns.

All 25 areas use centralized I/M programs; however, only 20 use centralized I/M exclusively. For example, in New Jersey vehicles may be inspected at the centralized state station, or for a higher fee they may be inspected at decentralized stations. While most vehicles go to the state stations, it is possible that the vehicles inspected at the decentralized stations are driven differently than those inspected at the centralized stations. Consequently, the five areas that have a combination of centralized and decentralized I/M (New Jersey; Washington, DC; Jacksonville, Florida; Miami, Florida; Tampa, Florida) were less attractive as candidate sites than those that have only centralized inspection.

All of the sites except Tucson, Arizona and Spokane, Washington have altitudes below 1300 feet. The higher altitudes of these two cities may cause different

Table 4-1

Attributes of Nonattainment Areas with Centralized I/M Programs

Nonattainment Area	Model Years of Light-Duty Vehicles Tested for Emissions	I/M Program Type	Altitude	Average Per Cent of Days With > 0.01 Inch Precipitation	Average Monthly Precipitation	Average Number of Days With > 1 Inch Snow	Comments
		(C = Centralized) (D = Decentralized)	(feet)	(%)	(inches)	(days) (OCT NOV DEC JAN FEB)	
STATES							
Connecticut (e.g. Hartford)	68+	C	169	36	3.7	0 1 4 3 3	Frequent snow
Delaware (e.g. Wilmington)	68+	C	74	32	3.2	0 1 1 2 2	•
New Jersey	All	C + D	160	34	3.4	0 0 2 2 2	Partly decentralized I/M
METROPOLITAN AREAS							
Baltimore MD	79+	C	148	32	3.1	0 0 1 2 2	•
Washington suburbs MD	79+	C	10	32	2.9	0 0 1 2 1	Suburbs
Washington DC	All	C + D	10	32	2.9	0 0 1 2 1	Partly decentralized I/M
Jacksonville FL	75+	C + D	26	25	2.9	0 0 0 0 0	Partly decentralized I/M
Miami FL	75+	C + D	7	28	3.2	0 0 0 0 0	Partly decentralized I/M
Tampa FL	75+	C + D	19	20	2.3	0 0 0 0 0	Partly decentralized I/M
Memphis TN	All	C	258	30	4.1	0 0 1 1 1	•
Nashville TN	79+	C	590	34	3.8	0 0 1 1 1	•
Cleveland OH	75+	C	777	46	2.6	0 2 4 4 4	Frequent precip, frequent snow
Louisville KY	All	C	477	35	3.2	0 0 1 2 1	•
Louisville suburbs IN	76+	C	477	35	3.2	0 0 1 2 1	Suburbs
Chicago suburbs IN	76+	C	801	34	2.4	0 1 3 3 3	Frequent snow
Chicago IL	68+	C	658	32	1.9	0 1 3 3 3	Frequent snow
E.St.Louis IL	68+	C	535	30	2.2	0 1 1 2 2	Suburbs
Milwaukee WI	76+	C	672	33	1.8	0 1 3 4 3	Frequent snow
Minneapolis MN	76+	C	834	22	1.2	0 2 3 3 3	Frequent snow
Phoenix AZ	67+	C	1112	12	0.6	0 0 0 0 0	•
Tucson AZ	67+	C	2584	13	0.8	0 1 0 0 0	Higher altitude
Medford OR	71+	C	1298	53	2.7	0 1 1 1 1	Frequent precip
Portland OR	71+	C	21	59	5.0	0 0 1 1 1	Frequent precip
Seattle WA	68+	C	19	63	5.1	0 1 1 2 1	Frequent precip
Spokane WA	68+	C	2357	43	2.0	0 2 5 6 3	Higher altitude, frequent precip, frequent snow

driving behavior because vehicles will not respond to driver demands as do the majority of vehicles operated at lower altitudes. Also, the terrain of the 25 areas was considered in the final selection of survey sites.

Precipitation can produce differences in measured driving patterns by allowing wheel spin and by inducing drivers to drive more carefully than they would on dry pavement. On the other hand, since wet or snowy roads are part of the environment in which most vehicles are occasionally driven, it was reasonable to measure driving behavior under wet conditions during part of the study; however, because the data in this study were collected in winter, and the results must be relevant to year-round driving, an excessive number of wet days was to be avoided.

Data collection was expected to occur sometime between October 1991 and February 1992. The average precipitation for the months of October through February at each of the 25 areas is shown in Table 4-1 in terms of the average percentage of days that have measurable precipitation, the average monthly precipitation in equivalent inches of water, and the monthly average number of days where snowfall is more than one inch.

Consideration of the percentage of days with precipitation showed that the list can be broken into three groups: 12-22%, 30-36%, and 43-63%. The amount of precipitation is also shown in the table. Large amounts of rainfall (in comparison with small amounts) were not expected to be a problem because roads will drain and dry; however, days with snow could be a problem, especially in cold climates, because roads could remain slippery for days after the snowfall. Accordingly, the table also shows the average number of days with snowfall by month. In general, the number of days with snowfall is low in October and November, but is high in December, January, and February.

An additional, although perhaps minor, consideration made for either type of study was the presence of a nearby large city that could attract vehicles from the area of interest and thus increase the amount of interstate driving over what would otherwise occur. Baltimore, Maryland was expected to be large enough to have driving patterns like those of cities rather than those of suburbs, although other large cities are nearby.

After taking all considerations into account, EPA selected Spokane and Baltimore. Auxiliary driving pattern studies are being carried out in Los Angeles and Atlanta. The California Air Resources Board is sponsoring a chase car study in Los Angeles. EPA's Office of Research and Development is sponsoring a 3-parameter instrumented vehicle study in Atlanta. The addition of these cities should provide a proper regional representation.

4.2 Activities at Inspection/Maintenance Facilities

In both cities, the project staff consisted of a solicitor, two 3-parameter installers, two 6-parameter installers, and two datalogger removers. However, the staff shared responsibilities as the need arose.

Physical installation and calibration of the 3-parameter datalogger took from 40 minutes to 2 hours, depending on the complexity of the application. The average installation time was about 70 minutes. In most cases, the vehicle owner waited in the station for the vehicle to be instrumented. Installation of the 6-parameter systems took from 1-1/2 to 4 hours. This time included a trip to a nearby muffler shop for welding the oxygen sensor boss on the exhaust system. The average 6-parameter system installation time was about 2 and 1/2 hours.

Instrument removals began one week after instrumentations began. All but eight of the 3-parameter removals and all of the 6-parameter removals took place at the I/M stations. 3-parameter removals took about 30 minutes per vehicle and 6-parameter

removals took approximately two hours per vehicle, including the trip to and from the muffler shop to replace the back portion of the vehicle's exhaust system.

Instrumentations in Spokane began on Monday, February 3 and continued through February 22. Since the station was closed for holiday on February 17, instrumentations were performed for a total of 17 days. The removal team, which began its operations on February 10, continued to work through March 2.

Instrumentations in Baltimore began at the Baltimore County station on Thursday, March 5 and continued through Monday, March 16. During that afternoon equipment and personnel were moved to the Baltimore City station. Installations began the next day and ended on Thursday, March 26. Instrumentations were performed for a total of 19 days. The removal team, which began its operation on March 12, continued to work through April 5.

4.2.1 Spokane, Washington

The instrumentation and removal of 3- and 6-parameter dataloggers took place at the Inspection and Maintenance (I/M) station at South 211 Howe Street. The station is located about four miles east of downtown Spokane in a commercial and residential area. Eligible vehicles with registration addresses having 992 as the first three digits of the zip code must be inspected. This station is the only I/M facility serving greater Spokane and is run by VTTI, Inc.; therefore, most of the eligible vehicles populating Spokane's roadways must obtain inspections at this facility once every two years. Vehicles of commuters living 20 miles east in Coeur d'Alene, Idaho are not inspected at this facility.

A biennial system is used to determine which vehicles are inspected. Even model-year vehicles are inspected in even years. Since this study was performed in 1992, almost all vehicles that came through the I/M facility were of even model years. Since

new vehicles are exempt from inspection for the first year, the newest vehicle coming through the inspection lane was the 1990 model year.

Figures 4-1 and 4-2 show the layout of the Spokane site. The I/M station has four lanes, three of which were used for state inspections during the instrumentation phase of the project. The fourth lane was used solely to install the instrumentation. The station is operated from 9:00 AM to 6:00 PM on Monday, Tuesday, Thursday, and Friday and until 8:00 PM on Wednesday. The station was open from 9:00 AM to 1:00 PM on Saturdays and was closed on Sundays. The instrumentation and removal staff solicited vehicles during all station hours.

The I/M program in the Spokane area is a centralized registration-enforced program. It is a biennial program conducted by using the idle test for pre-1981 vehicles and the two-speed (idle plus 2500 rpm) test for the 1981+ vehicles. There is no tampering inspection. The fee for the test is $16 and the cost waiver requirements are $50 for the pre-1981 vehicles and $150 for 1981+ vehicles. All 1968 and newer vehicles must be tested. Diesel vehicles, motorcycles, and alternatively fueled vehicles are exempt. Vehicles are run at the desired rpm levels, during which the exhaust emissions are tested. The cutpoints for all vehicle types for the I/M test are:

Model Year	HC (ppm)	CO (%)
1968-1974	1000	6.0
1975-1980	600	3.0
1981+ no/cat	600	3.0
1981+ w/cat	220	1.2

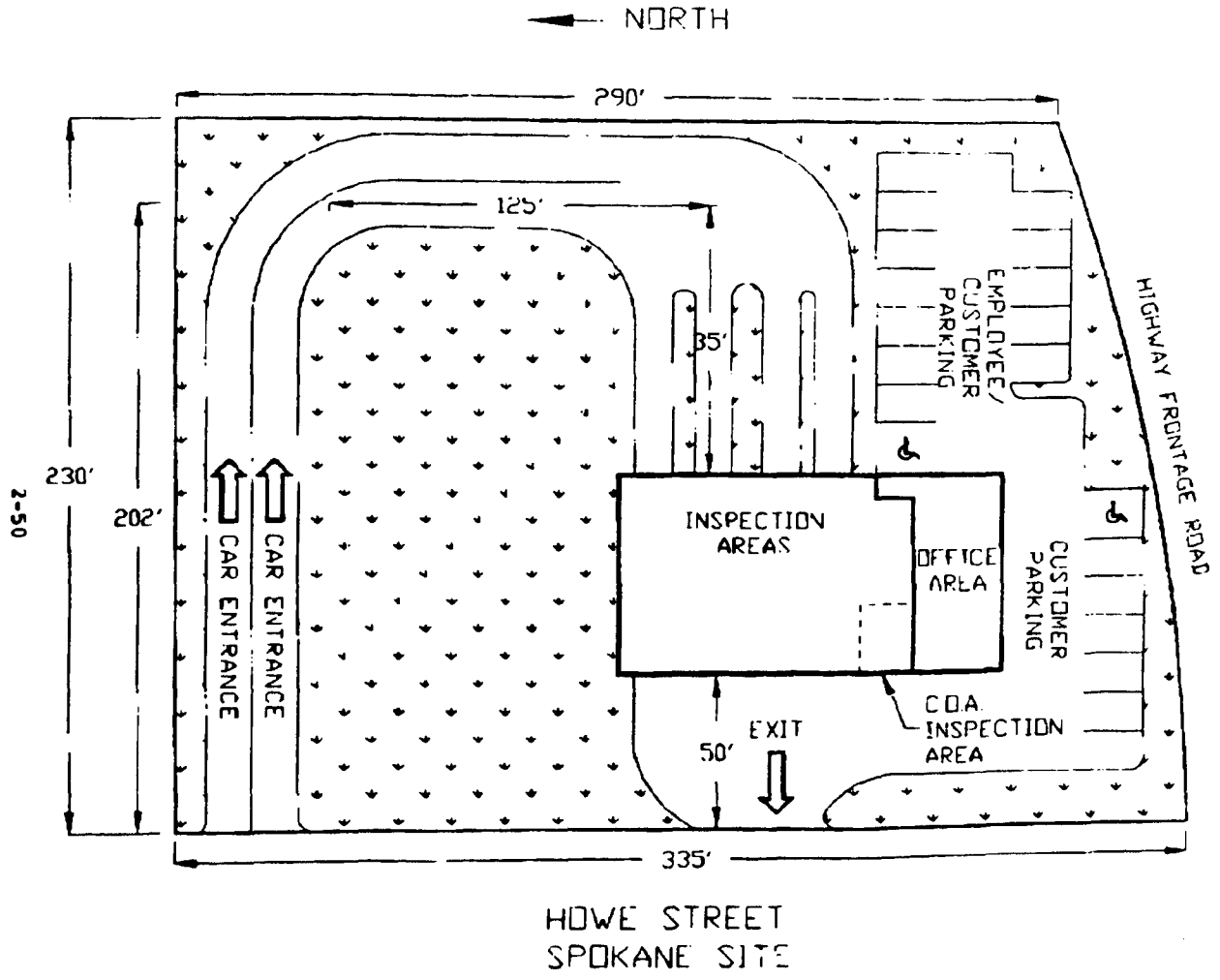
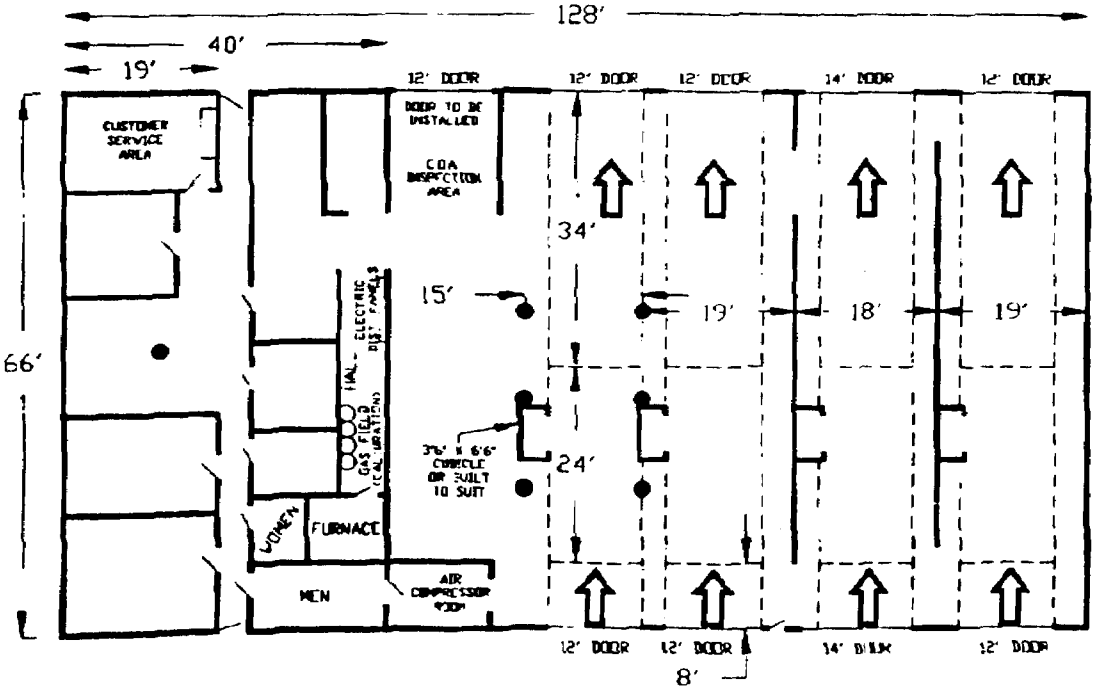


Figure 4-1. Howe Street Spokane Site



HOWE STREET FACILITY
SPOKANE

Figure 4-2. Howe Street Facility - Spokane

4.2.2 Baltimore, Maryland

Maryland inspection stations 3 and 4 were used as locations for recruiting vehicles for the driving modes study. Station 3 is at 1001 Exeter Hall Avenue, Baltimore, Maryland 21218. Station 4 is at 7969 Rossville Boulevard, Baltimore, Maryland 21236. Location 3 is in Baltimore city and Location 4 is in Baltimore county. Station 4 has the highest volume in the Maryland I/M program. Figures 4-3 and 4-4 show the layout of the lanes at the two sites. As can be seen, at both sites the vehicles enter from a single lane or single entrance and move to the different lanes for the I/M inspection.

The Maryland program is a biennial centralized I/M program. All vehicles up to 26,000 lbs. that use gasoline fuel are tested. The hours of operation of the two stations are from 8:00 a.m. to 6:00 p.m. Monday through Friday and 8:00 a.m. to 12:00 noon on Saturday. All 1977 and newer vehicles are covered in this program. Each vehicle is assigned an inspection month as part of the two-year cycle. An inspection notice is sent roughly 30 days before the inspection date for the vehicle. The owner has until the end of the month to bring the vehicle in for inspection. For example, a person who receives a notice on September 1 must have his vehicle inspected by the end of October. The driver can bring in the vehicle at any time during the month of September or October.

The I/M test consists of a visual test for the presence of a catalytic converter, inspection and measurement of the fuel filler inlet restrictor, and the exhaust gas emissions measurement. The exhaust gas measurement is done at idle rpm only. The cutpoints for the I/M test are:

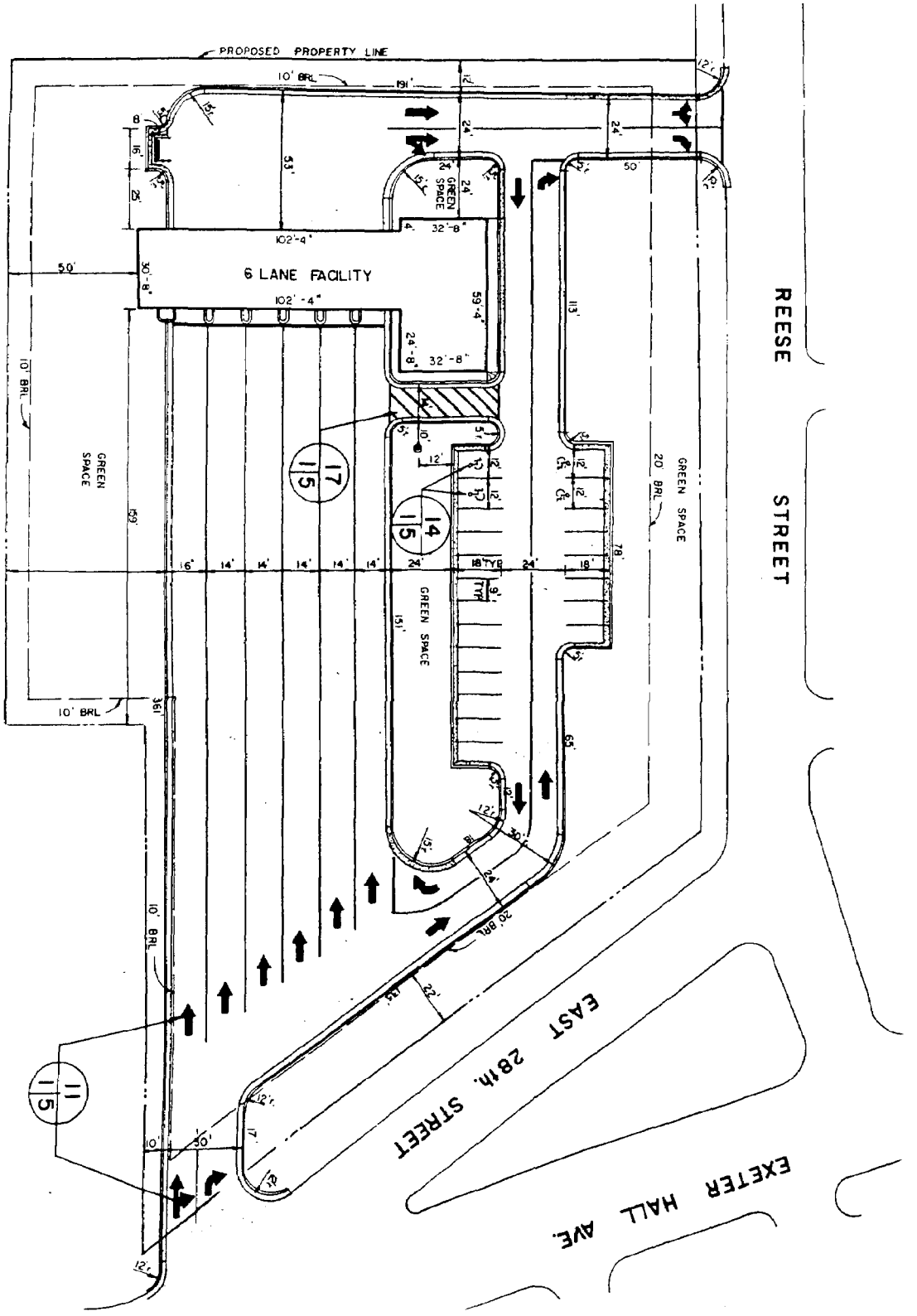


Figure 4-3. Baltimore City I/M Station

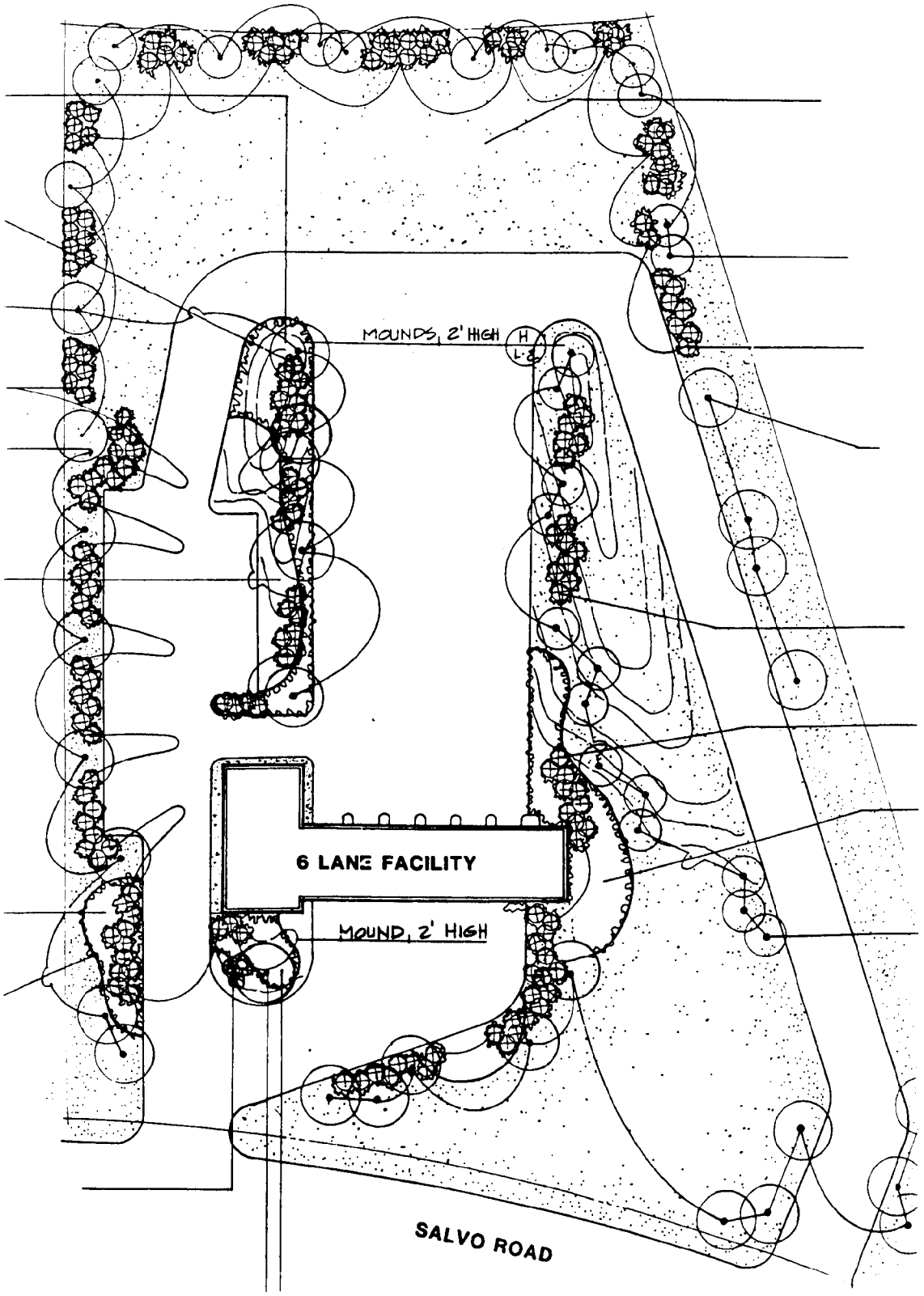


Figure 4-4. Baltimore County I/M Station

Vehicles Under 10,000 lbs		
Model Year	HC (ppm)	CO (%)
1977	500	6.0
1978	430	5.5
1979	400	4.0
1980	220	1.7
1981+	220	1.2

4.3 Vehicle Sampling

The private vehicles to be instrumented in the study were selected from the vehicles that passed through the I/M station at the time of the study. This section describes the vehicles that were instrumented and also those vehicles solicited for participation in the study but that were not instrumented. The method of vehicle selection is also reviewed.

4.3.1 Summary of Vehicles Solicited

Table 4-2 gives a summary of the 247 vehicles solicited in Spokane and the 483 vehicles solicited in Baltimore. The table presents the vehicles in the order in which they were approached at the I/M station.

The sample number in Table 4-2 was assigned to every vehicle approached by the solicitor. The sample numbers are unique to each vehicle and were assigned to a vehicle whether or not the vehicle was instrumented. The sample number begins with an "S" to indicate the sample applies to Spokane or with a "B" to indicate the sample applies to Baltimore. Vehicles with sample numbers B001 to B257 were solicited at the Baltimore County station. All other Baltimore vehicles were solicited at the

Table 4-2
Solicitation Summary

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
S 001	3	T	M	2	D	ELA-068	F	NA	NA	NA	NA	E14BHAH3213		NA
S 002	3	S001	M	2	D	73417-7	P	Y	Y	S	120	1GCGK24M8GJ162254		54239
S 003	6	Q	M	1	F	215-DRE	P	Y	Y	NA	ORG18	JN1HJ01P8LT366371		41290
S 004	3	T	M	1	F	342-DYA	P	Y	Y	S	121	KMHLA31J8HU121264		64011
S 005	3	T	M	1	F	151-CYB	P	Y	Y	M	103	WAUFC58AXLA061766		21809
S 006	6	Q	M	1	D	463-DKS	P	Y	Y	NA	YEL10	1G2AF54T9L6235376		46827
S 007	6	Q	O	1	D	628-DKU	P	Y	Y	NA	YEL14	2G1WL54RXL1169676		22991
S 008	3	T	Y	1	D	769-BOJ	P	Y	Y	W	123	1FAPP36X7JK162901		65465
S 009	3	T	M	1	D	966-DKS	F	NA	NA	NA	NA	1G2WK14W0JF285519		NA
S 010	3	S009	M	1	D	LVH-461	F	NA	NA	NA	NA	1G1AW19W4G6199697		NA
S 011	3	S009	M	1	D	CN-4991(IL)	P	Y	Y	W	142	1G3NT69U9GM372803		45232
S 012	6	Q	O	1	D	757-CYD	P	N	NA	NA	NA	1P3XA5635LF774787		NA
S 013	6	Q	O	1	D	158-DRE	P	N	NA	NA	NA	1G4NV54U0LM079776		NA
S 014	6	Q	M	1	D	Q40-CYD	P	Y	Y	NA	YEL9	3G4AL54N3LS605881		18526
S 015	3	T	M	1	D	SLH-930	P	Y	Y	S	139	HL41G8B367586		83282
S 016	6	Q	M	1	F	238-CMT	P	Y	N1	NA	NA	JM1GD2226L1812401		NA
S 017	3	T	M	1	D	WCH-049	P	N	NA	NA	NA	1G3NT27U4GM376852		NA
S 018	3	S017	M	1	D	HQD-876	P	Y	Y	M	111	GCFBAD246990	No	7877
S 019	6	Q	M	1	F	270-CYG	P	Y	Y	NA	GRN16	JM1BG2265L0111262		.
S 020	3	T	M	1	F	5463(MT)	P	N	NA	NA	NA	.		NA
S 021	3	S020	M	1	F	HMH-681	P	N	NA	NA	NA	1G1AW27XXE6802201		NA
S 022	3	S020	M	1	F	157-BNA	F	NA	NA	NA	NA	1HGCA6280JA000240		NA
S 023	6	Q	M	1	F	737-CYD	P	Y	N2	NA	GRN17	JM1GD2227L1806476		NA
S 024	3	S020	M	1	F	597-DEV	P	Y	Y	W	124	JF2KA83A2JD727208		50355
S 025	3	T	Y	2	F	73829-T	P	Y	Y	W	105	JT4RN50R6J0353266		55206
S 026	3	T	M	1	D	C2D-228	F	NA	NA	NA	NA	A6A057A339724		NA
S 027	3	S026	M	1	D	017-AFN	P	Y	Y	S	133	39128622	No	71084
S 028	6	Q	O	1	D	409-CYB	P	Y	Y	NA	YEL8	1G2HX54C9L1240876		22280
S 029	3	T	Y	1	F	HZT-048	P	Y	N3	NA	NA	WBA-4007548		NA
S 030	3	S029	Y	1	F	CSJ-604	P	Y	Y	S	104	LB110-800914		73371
S 031	3	T	M	1	D	NCY-333	F	NA	NA	NA	NA	.		NA
S 032	3	S031	M	1	D	897-DRG	P	N	NA	NA	NA	KL2TN5462LB317977		NA
S 033	6	Q	M	1	D	.	P	N	NA	NA	NA	1C3XJ41K1LG431532		NA
S 034	3	T	M	1	D	321-BFT	P	Y	N2	NA	NA	2G2AF81R4J9232840		NA
S 035	3	T	O	1	D	009-DRM	P	N	NA	NA	NA	1G4HR54C9JH426908		NA
S 036	3	T	M	2	F	DR-PORK	P	Y	Y	.	108	JT3FJ62G5J0087906		26642
S 037	6	Q	O	1	D	463-DRF	F	NA	NA	NA	NA	1C3XC66R9LD898601		NA
S 038	3	S034	M	1	D	WCH-461	P	Y	Y	W	136	1G4AT27P2EK537437		74264
S 039	3	S035	O	1	D	633-BFR	P	Y	N2	NA	NA	2G3AJ51R5J9306520		NA
S 040	6	Q	O	1	D	038-DRG	P	Y	Y	NA	YEL12	1G3AM54N2L6363462		21252
S 041	3	T	M	1	F	195-CDW	P	Y	Y	S	141	JT2AE92W1J3141485		45352
S 042	6	Q	M	1	D	729-CMT	P	Y	Y	NA	BLU4	2FAPP37X8LB105148		17971
S 043	3	T	M	2	D	73878T	P	Y	Y	W	113	1B7FN14C7JS796743		78526

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
S 044	6	Q	M	1	D	968-CMK	P	N	NA	NA	NA	1FAPP93J0LW139667		NA
S 045	6	Q	O	1	F	856-CMK	P	Y	Y	NA	GRN16	1YVGD22B9L5241604		5037
S 046	3	T	M	2	D	UJ-5074	P	Y	Y	M	106	2FTEF14N6GCA49786		12873
S 047	6	Q	M	1	D	455-DRG	P	Y	Y	NA	RED1	1B3XA4636LF914826		26298
S 048	3	T	O	2	D	117-BFT	P	Y	Y	S	119	AA0BE8S328524		20978
S 049	6	Q	O	1	D	.	P	N	NA	NA	NA	.		NA
S 050	3	S031	M	1	D	472-AGB	P	Y	Y	W	130	1MEBP89C9EG646134		26759
S 051	6	Q	O	1	F	926-CMT	P	Y	Y	NA	GRN17	JM1GD222XL1822669		25800
S 052	6	Q	M	1	D	215-CM0	P	N	NA	NA	NA	1G1LT54G6LE180304		NA
S 053	6	Q	M	1	D	190-CYA	P	Y	Y	NA	BLU6	1FACP52U5LG167445		30663
S 054	3	T	M	2	D	14654-U	P	Y	Y	S	107	1B7HW14T0GS016645		83040
S 055	3	S035	O	1	D	PCD-307	P	Y	Y	S	116	1J089AA196188		47804
S 056	6	Q	M	1	F	292-DRG	P	Y	N2	NA	NA	JA3CR46V2LZ041788		NA
S 057	6	Q	O	1	D	280-DRE	P	Y	N5	NA	NA	1B3XC5639LD718780		NA
S 058	6	Q	O	1	D	345-D41	P	Y	Y	NA	BLU5	1FACP50UXLG149557		9960
S 059	3	T	M	1	D	HZZ-695	P	N	NA	NA	NA	8W82L268781		NA
S 060	3	S059	M	1	.	.	P	N	NA	NA	NA	.		NA
S 061	3	T	M	1	F	357-AIX	P	Y	Y	S	127	JM1BF2227G0145368		68945
S 062	6	Q	M	1	D	31100(ID)	P	Y	N1	NA	NA	1G1LT54G8LY249993		NA
S 063	6	Q	O	1	F	945-CYB	P	Y	Y	NA	WHT19	JT2SV21E2L0336391		29938
S 064	3	S059	M	1	D	865-CED	F	NA	NA	NA	NA	2FABP43F7GX134162		NA
S 065	6	Q	O	1	F	202-BNB	P	NA	N8	NA	NA	JT2AE92E6J3034861		NA
S 066	3	T	M	1	D	996-DEV	P	Y	Y	M	145	1FABP3934EG169705		15865
S 067	3	S059	M	1	D	297-AFY	P	Y	Y	S	146	1C3BH58E1GN168729		40911
S 068	6	Q	M	2	F	666-CYD	P	Y	N2	NA	NA	JT3VN39WXL0023696		NA
S 069	3	T	Y	1	F	501-DRF	P	Y	Y	S	135	JM1BF2327J0116975		65091
S 070	6	Q	O	1	F	7877	P	Y	Y	NA	BLU15	JA3CR46V8LZ036160		29246
S 071	6	Q	O	1	D	650-DRF	P	N	NA	NA	NA	1C3XC66R5LD858645		NA
S 072	3	T	M	1	D	177-CEB	P	Y	Y	.	128	2G2AK37H5E2268581		64645
S 073	3	T	M	1	F	966-CLQ	P	Y	Y	M	126	JF2AN55B4GD439011		108311
S 074	6	Q	O	1	D	599-DKL	P	Y	N2	NA	NA	1LNCM92EXLY703010		NA
S 075	3	T	M	1	D	HMM-404	P	N	NA	NA	NA	1G1AZ37G9ER174613		NA
S 076	3	S075	M	1	D	QLM-026	P	Y	Y	W	114	1FABP22X2GK155745		96676
S 077	6	Q	M	1	D	533-CMK	F	NA	NA	NA	NA	2FACP73F4LX149931		NA
S 078	3	S059	M	1	D	RVL-049	P	Y	Y	M	131	1C3BA54E0EG237812		.
S 079	3	T	M	1	D	734-CMK	P	Y	Y	S	122	1B3BZ18C5GD231063		62889
S 080	6	Q	M	2	D	756-DKS	P	N	NA	NA	NA	1P4FH44R0LX303404		NA
S 081	6	Q	M	1	D	225PK361(CA)	F	NA	NA	NA	NA	1FTCR14X1LPA46236	No	NA
S 082	6	Q	M	1	D	763-DRG	P	Y	Y	NA	BLU7	1MECM50U6LG649782		30183
S 083	3	T	M	1	F	188-CMT	P	N	NA	NA	NA	WAUFB0856EA072906		NA
S 084	6	Q	M	1	D	502-CMP	P	N	NA	NA	NA	1B3XP48K1LN166561		NA
S 085	3	S083	M	1	F	KZZ-703	F	NA	NA	NA	NA	JF2AM53B7CE437554		NA
S 086	3	T	M	2	D	53523-R	P	Y	N3	NA	NA	1FTCR15X1LPA46236		NA

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
S 087	3	S086	M	2	D	018-DRE	P	N	NA	NA	NA	1GNCT18Z2LB118030		NA
S 088	3	S083	M	1	F	202-BNB	P	Y	Y	S	SN03	JT2AE92E6J3034861		32133
S 089	6	Q	M	2	D	807-DKU	P	Y	Y	NA	RED2	1B4FK44R0LX295520		25794
S 090	3	S086	M	2	D	281-CMO	P	Y	Y	W	129	1GNDL15Z6LB143279		28543
S 091	3	T	.	.	.	.	P	N	NA	NA	NA	2G1WN54TXL1156917		NA
S 092	6	Q	.	1	D	591-CMT	P	Y	Y	NA	RED2	1P3XA46K8LF815124		31368
S 093	6	Q	M	1	D	983-ALY	P	Y	Y	NA	YEL11	2G1WN54T4L9218037		94528
S 094	3	T	M	1	D	EBN-30J(NJ)	P	Y	Y	W	109	1G2WK14W3JF252210		43014
S 095	6	Q	M	1	D	703-DKU	P	Y	N6	NA	NA	1G3WS54T9LD395198		NA
S 096	3	T	M	1	D	019-BFQ	P	Y	Y	M	110	1MEBP75X7GK641646		35663
S 097	6	Q	M	2	D	596-DKP	P	Y	Y	NA	RED1	2B4FK4530LR632793		32755
S 098	6	Q	M	1	D	289-CYB	P	Y	Y	NA	YEL13	1G4CW54C8L1624667		17629
S 099	3	T	M	1	D	ENR-837	P	N	NA	NA	NA	1G1AX08X3CT128925		NA
S 100	3	S099	M	1	D	905-CYE	P	Y	Y	.	132	1G1AW19R0G6112873		8983
S 101	6	Q	M	1	D	992-CMK	P	Y	N3	NA	NA	1FAPP959XLW190029		NA
S 102	3	T	M	1	D	192-CYA	P	N	NA	NA	NA	1FAPP9597LW149311		NA
S 103	3	S102	M	1	D	760-BVL	P	Y	Y	.	112	1G1LV14W9JE673479		42696
S 104	3	T	M	1	D	581-CMG	P	N	NA	NA	NA	JE3CU36X4KU069206		NA
S 105	3	S104	M	1	D	ELB-184	P	Y	Y	M	SN08	1FABP0521CW107600		85422
S 106	3	T	M	2	F	TU-2543	P	N	NA	NA	NA	RA32034992	No	NA
S 107	6	Q	.	1	D	012-CYH	P	Y	Y	NA	RED1	1B3XA4639LF838812		23618
S 108	3	S106	M	2	F	UN-1035	P	Y	Y	S	143	JN6ND16Y0GW003899		80882
S 109	6	Q	M	1	F	629-CM0	P	Y	Y	NA	WHT19	JT2SV24E2L3411553		25039
S 110	3	T	M	2	D	653-A1Y	P	Y	Y	S	SN07	JB3BA26KXGU135565		51643
S 111	6	Q	O	1	D	760-CYB	P	Y	N6	NA	NA	1G3WS54TXLD375851		NA
S 112	3	T	M	1	F	235-CYE	P	Y	Y	W	144	1YVGD31BXL5201264		33451
S 113	6	Q	O	1	D	436-CYG	P	N	NA	NA	NA	.		NA
S 114	3	T	M	1	F	440-ADF	P	Y	Y	S	118	KMHLF21J9HU104162		61203
S 115	3	T	M	1	F	(TEMPORARY)	P	Y	N3	W	NA	JA3CU26X3LU017646		NA
S 116	3	S115	M	1	F	259-CMS	P	Y	N3	.	NA	JHMCB7652LC072385		NA
S 117	3	S116	M	1	F	962-DKU	P	Y	Y	W	125	JT2AE94A4L3346545		15625
S 118	3	T	M	2	D	N7KQR	P	Y	Y	M	SN06	1G8CT18B1E0141922		77522
S 119	6	Q	M	1	F	953-CMK	P	Y	Y	NA	ORG18	1N4GB22B6LC764253		21759
S 120	3	T	M	1	F	090-DKP	P	Y	Y	W	139	JT2SV22E0L3407469		31085
S 121	3	T	M	1	F	713-CB0	F	NA	NA	NA	NA	AL10073510	No	NA
S 122	3	S121	M	1	F	345-CMK	P	Y	Y	M	106	JHMSM5423BC116394		23397
S 123	6	Q	M	1	D	265-CMS	P	NA	N6	NA	NA	1G3WH54T6LD351674		NA
S 124	6	Q	M	1	D	014-CU1	F	NA	NA	NA	NA	JHMCB7662LC076249		NA
S 125	6	Q	M	1	D	473-DRF	P	Y	Y	NA	BLU3	1LNLM9848LY702663		33371
S 126	3	T	M	1	D	631-DKP	P	Y	Y	W	102	1Y1SK5467LZ153033		24701
S 127	6	Q	O	1	D	832-CYD	P	Y	Y	NA	YEL14	1G3AJ54N1L6343342		23816
S 128	3	T	M	1	F	166-DRH	P	Y	Y	S	SN04	1NXAE82G3JZ543668		56293
S 129	6	Q	M	1	F	939-CMT	P	Y	Y	NA	GRN16	1YVGD22B6L5224064		27697

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
S 130	3	T	M	1	D	HMH-182	P	Y	Y	M	117	1FABP0757EW169481		51749
S 131	6	Q	M	1	D	677-C4D	P	Y	Y	NA	BLU6	1MECM5344LG630501		14829
S 132	3	T	Y	1	F	828-CMR	P	Y	Y	M	139	JHMAF5332ES007287		47809
S 133	6	Q	O	1	D	244-DRE	P	Y	Y	NA	YEL9	1G2NE54D1LC373895		17511
S 134	3	T	M	1	F	671-BEX	P	Y	Y	W	121	1HGCA554XJA105600		44227
S 135	3	T	M	2	D	34713-J	P	Y	Y	S	123	JB7FM55E2JP049855		34422
S 136	3	T	M	3	D	881-BNB	P	N	NA	NA	NA	1FABP42E9JF199672		NA
S 137	3	S136	M	3	D	721-CLJ	P	Y	Y	W	103	1G2PG9793GP263091		62499
S 138	3	T	O	1	D	HMN-685	P	Y	Y	W	105	3M69FAR476562		80173
S 139	3	T	M	2	F	44368-H	P	N	NA	NA	NA	JM2UC2213E0816360		NA
S 140	3	S139	M	2	F	74007-T	P	N	NA	NA	NA	JN6ND06S6GW105228		NA
S 141	3	S139	M	2	F	035-7UZ	P	N	NA	NA	NA	JA7FL24W0LP020527		NA
S 142	3	T	M	1	F	845-DKP	P	N	NA	NA	NA	2HGED634XLH529405		NA
S 143	3	S142	M	1	F	840-BND	P	Y	Y	S	142	JM1BF2321J0174161		25652
S 144	3	T	M	3	D	GQA-436	P	Y	Y	M	SN05	1FABP28A4DF128103		35167
S 145	6	Q	M	1	D	460-CYA	P	N	NA	NA	NA	1FAC052U1LG214289	No	NA
S 146	3	T	M	1	D	HMH-154	P	Y	Y	M	120	1FABP4634EH101344		81461
S 147	3	S139	M	2	F	31910-J	P	Y	Y	S	113	JM2UF1133J0354042		104786
S 148	6	Q	O	1	D	898-DRG	P	Y	Y	NA	YEL12	2G1WL54T8L1197259		22519
S 149	6	Q	O	1	D	978-CMR	P	N	NA	NA	NA	3G4AH54NXLS613221		NA
S 150	6	Q	O	1	D	619-DRF	P	Y	Y	NA	BLU4	1FACP52UXLG233424		26395
S 151	3	T	M	1	D	HMN-472	P	N	NA	NA	NA	1FABP4637EH151073		NA
S 152	3	S151	M	1	D	WCH-040	P	Y	Y	W	111	1G3CX69B6G1323859		53668
S 153	6	Q	M	1	F	145-DYR	P	Y	N7	NA	NA	JT2VV22W8L0101238		NA
S 154	3	T	M	1	F	838-AFV	P	Y	Y	M	124	SMG-2023538		76753
S 155	3	T	Y	1	D	362-DCP	F	NA	NA	NA	NA	1ZVPT20C5L5206320		NA
S 156	3	S155	Y	1	D	223-DKP	P	Y	Y	S	136	1ZVPT20C1L5138646		46113
S 157	6	Q	M	1	D	4P-4322A	P	N	NA	NA	NA	2G1WN54T2L1150707		NA
S 158	3	T	Y	1	D	428-BVH	P	Y	Y	M	124	1B3BA64E3EG128750		68905
S 159	3	T	O	1	D	HMM-985	P	N	NA	NA	NA	1G4AL19E4ED440542		NA
S 160	3	S159	O	1	D	158-CEB	P	Y	Y	W	104	1FABP52UXJG185500		52065
S 161	6	Q	O	1	D	273-CMS	P	N	NA	NA	NA	1G3AJ54N5L6319366		NA
S 162	6	Q	M	1	D	661-CM0	P	NA	N6	NA	NA	1G3WR54TXL0373223	No	NA
S 163	3	T	M	2	D	15313-T	P	Y	Y	S	108	1GCEK14L5EJ110666		98850
S 164	6	Q	M	1	D	795-CYB	P	Y	Y	NA	YEL8	1G3HY54C9LH309730		25283
S 165	3	T	M	1	F	764-CMK	P	Y	Y	.	137	1N4GB22B9LC742425		21799
S 166	3	T	M	2	D	HE-9011	F	NA	NA	NA	NA	F15YKB54013		NA
S 167	3	S166	M	2	D	UN-2888	P	Y	Y	W	138	1GCBS14E3G2140458		29650
S 168	3	T	M	1	F	958-CMH	P	N	NA	NA	NA	JG1MS2460LK743586		NA
S 169	3	S168	M	1	F	268-DRE	P	Y	Y	M	140	JF1AX9424JG316659		62257
S 170	6	Q	M	1	D	712533(ID)	F	NA	NA	NA	NA	.		NA
S 171	3	T	M	2	D	761-CDS	P	N	NA	NA	NA	1B4FK40K6JX292532		NA
S 172	3	S171	M	2	D	016-CEA	P	Y	Y	W	116	2B4FK41K2JR589231		59394

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
S 173	3	T	M	3	F	LVE-645	P	N	NA	NA	NA	JN1HZ14S2GX141618		NA
S 174	3	T	M	1	D	LPS-022	F	NA	NA	NA	NA	6K92L160868		NA
S 175	3	S173	M	2	F	516-AFW	P	Y	Y	S	134	JN1PS26S4EW633444		92332
S 176	3	S174	M	2	D	CNP-636	P	Y	Y	S	114	256690C110112	No	82386
S 177	6	Q	M	1	D	877-CMT	P	Y	Y	NA	YEL10	1G1LW14T8LE150508		33957
S 178	3	T	M	1	F	143-C4D	P	Y	Y	M	107	JF1AC43B1JC230491		33229
S 179	3	T	M	2	D	98218-N	P	Y	Y	W	119	1GCBS14E5G2149162		72618
S 180	3	T	M	2	F	74547-T	P	Y	Y	S	141	JM2UC2217C0554694		130421
S 181	6	Q	M	1	D	179-CYD	P	Y	Y	NA	YEL13	3G4AH54N7LS609966		33836
S 182	3	T	M	1	F	.	F	NA	NA	NA	NA	.		NA
S 183	6	Q	M	1	D	.	P	Y	N1	NA	NA	1G1LT54G2LE134260		NA
S 184	3	S182	M	1	F	74685	P	Y	Y	S	115	RA42-061277		95909
S 185	3	T	M	1	F	253-CYE	P	.	N	NA	NA	JHMAD5334EC087076		NA
S 186	3	S005	M	1	F	W0G-249	F	NA	NA	NA	NA	JT2AE82E3G3336773		NA
S 187	3	S025	M	2	D	LVB-147	P	Y	Y	W	146	1G8CT18R5G8134828		74266
S 188	6	Q	O	1	D	2024	F	NA	NA	NA	NA	1FACP52U7LG149271		NA
S 189	3	S005	M	1	D	579-CDY	P	Y	Y	M	109	1FAPP23J6JW186397		32962
S 190	3	S030	M	1	F	CZE-800	P	N	NA	NA	NA	SJD-3038E98		NA
S 191	3	S043	M	2	D	33325-J	F	NA	NA	NA	NA	1FTBR10C5JUB67141		NA
S 192	6	Q	M	1	D	435-DRD	P	N	NA	NA	NA	1G3NL54U3LM758872		NA
S 193	3	T	M	2	F	33377-J	P	N	NA	NA	NA	1N6ND11S4JC361129		NA
S 194	3	S193	M	2	F	98228-N	P	Y	Y	S	127	JM2UF2111G0523195		60123
S 195	3	T	M	2	F	VN-1783	P	N	NA	NA	NA	JT4RN50R3G0127582		NA
S 196	3	S043	M	2	D	SMF-573	P	Y	Y	.	126	U15SLFE3261		31573
S 197	3	S195	Y	2	F	74030T	P	Y	Y	S	132	RN47-029466		35410
S 198	6	Q	M	1	D	643-DKS	P	N	NA	NA	NA	1FACP5345LG123282		NA
S 199	6	Q	M	3	D	781-CMH	P	N	NA	NA	NA	1G1FP23T7LL133597		NA
S 200	3	T	Y	1	D	LDH-203	P	Y	Y	S	122	1X115A6114134		43062
S 201	6	Q	O	1	D	422-CM0	P	Y	Y	NA	YEL11	1G3HY54C9L1816555		51226
S 202	6	Q	O	1	D	498-CMT	P	N	NA	NA	NA	1MEPM6047L8619434		NA
S 203	3	T	M	1	D	LVF-557	P	Y	Y	W	112	1FABP3497GW162154		410
S 204	3	S030	M	2	F	556-EAV	P	Y	Y	M	102	5372057163		119512
S 205	3	T	M	2	F	N7-LAX	P	Y	Y	S	110	JM2UF1119G0634121		63103
S 206	6	Q	M	1	D	961-CMK	P	Y	Y	NA	BLU7	2FAPP36X2LB167744		32827
S 207	3	T	Y	1	F	EVT-598	P	Y	Y	S	131	JN1HT14S3DT103884		90561
S 208	3	T	M	1	F	396-BNA	P	N	NA	NA	NA	JF2AN53B3JE427176		NA
S 209	3	S208	M	1	F	HZY-065	P	Y	Y	W	128	17A0987815		102662
S 210	6	Q	M	1	F	738-CYD	P	Y	Y	NA	GRN17	JM1BG2261L0142055		32356
S 211	3	T	Y	1	F	275-AFS	P	Y	Y	S	143	JM1BF2228G0153432		115135
S 212	3	T	M	1	D	911-CDT	P	Y	Y	S	144	1M07VA7159960		67192
S 213	3	T	M	2	F	UN-2620	.	.	N	NA	NA	JM2UF111XG0653535		NA
S 214	3	S213	M	2	F	99716-N	P	Y	Y	W	135	1N6HD11YXJC317900		13807
S 215	6	Q	M	1	F	043-CYA	P	Y	Y	NA	ORG18	1N4GB22BXLC764143		14018

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
S 216	6	Q	O	1	D	466-CYD	P	N	NA	NA	NA	1MECM50U7LG630755		NA
S 217	6	Q	M	1	D	464-CYB	P	Y	Y	NA	YEL12	1G2WJ54T3LF263419		23181
S 218	3	T	Y	1	F	006-CYE	P	Y	Y	S	129	SMK-2089776		88373
S 219	3	T	M	1	D	869-CEB	P	Y	Y	S	130	1W27M8K407920		38511
S 220	6	Q	M	1	D	904-CYB	P	Y	Y	NA	BLU3	1MEPM36X2LK631896		33036
S 221	3	T	M	1	D	526-DKX	P	Y	Y	W	118	1G1AD35P5EJ104025		70033
S 222	3	T	M	2	F	27118P	P	Y	Y	S	117	JM2UF1136K0765114		49467
S 223	3	T	M	1	D	WCG-212	P	N	NA	NA	NA	1Y1SK1943GZ168599		NA
S 224	3	S223	M	1	D	310-BFU	P	Y	Y	W	SN03	1FABP64T8JH140673		66393
S 225	3	T	M	2	D	088-CYE	P	N	NA	NA	NA	2P4FH4538LR660001		NA
S 226	3	S225	M	2	D	33392-J	P	Y	Y	W	142	1FTBR10C9JUB99316		47978
S 227	3	T	Y	3	D	215-BND	P	Y	Y	W	SN07	1FABP40A4JF228320		32750
S 228	3	T	M	2	F	15103-U	P	N	NA	NA	NA	JT4VN63C0J0020668		NA
S 229	3	S228	M	2	F	LN1885	P	Y	Y	S	125	JM2UC1218E0824500		82016
S 230	6	Q	M	1	D	636-DKP	P	Y	N1	NA	NA	1G1LT54G1LY209139		NA
S 231	6	Q	M	1	D	714-CMG	F	NA	NA	NA	NA	2G1WL54R7L9128388		NA
S 232	3	T	M	1	D	HZC-672	F	NA	NA	NA	NA	JP3BA24K7FU109165		NA
S 233	3	S232	M	1	D	110-DRG	P	Y	Y	W	103	1P3BS48KXJN143963		76472
S 234	3	T	M	1	D	HMM-993	P	N	NA	NA	NA	1G1AZ3798ER106983		NA
S 235	3	S234	M	1	D	WRS-240	P	Y	Y	W	123	2G2AF51R0H9223691		110928
S 236	6	Q	M	1	D	HEIDIS	P	Y	Y	NA	YEL19	1G1LV14T1LE144679		27250
S 237	3	T	M	2	F	887-CYD	P	N	NA	NA	NA	JT2SV21E3L3419214		NA
S 238	3	S237	M	1	D	591-BNE	P	Y	Y	W	SN04	1C3CJ41E6JG327477		25280
S 239	3	T	Y	1	D	182-CMN	P	Y	Y	W	SN02	1G1JF77W1GJ208794		102508
S 240	3	T	M	1	F	GOT2SKI	P	Y	Y	M	SN01	JT2ST65L5G7024536		96145
S 241	3	T	M	2	D	785-AFN	P	Y	Y	M	106	1FMDU15Y1ELA53608		57262
S 242	6	Q	O	1	D	533-DDP	P	N	NA	NA	NA	1FACP52U1LG262150		NA
S 243	6	Q	M	1	D	366-CMU	P	Y	Y	NA	YEL11	2G1WN54T9L9201394		13292
S 244	3	T	M	1	D	038-BNQ	P	Y	Y	W	133	1FABP55U8JG122178		61692
S 245	3	T	M	1	D	427-AFZ	P	N	NA	NA	NA	1B3BV41B9CG146685		NA
S 246	3	S245	M	1	D	989-BKH	P	Y	Y	W	124	1FABP52D3JG173298		51306
S 247	3	S031	M	1	D	98-CYL	F	NA	NA	NA	NA	1G3AN69Y1EX334733		NA

N1 VIN not acceptable
N2 No communication with logger
N3 Unable to pick up speed pulses
N5 Error codes
N6 Digital dash
N7 Unacceptable engine family
N8 Unacceptable model year

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
B 001	3	S043	M	2	D	020-171	F	NA	NA	NA	NA	1FTDF15Y4HNA67137		NA
B 002	3	S043	M	2	D	1BA-274	P	Y	Y	W	105	1FTCR10A1MUC48371		21179
B 003	6	Q	O	1	D	.	F	NA	NA	NA	NA	.		NA
B 004	6	Q	O	1	D	NZA-521	P	N	NA	NA	NA	2G4WD14W7K1435099		NA
B 005	6	Q	O	1	D	PBB-481	P	Y	Y	NA	RED2	3B3XA4633MT034156		6710
B 006	6	Q	M	1	D	NWY-629	F	NA	NA	NA	NA	1B3BA76J4KF443588		NA
B 007	3	T	M	1	F	775-AHH	P	Y	Y	M	104	JHMBB7232GC026142		46819
B 008	6	Q	O	1	D	422-AKD	P	Y	Y	NA	YEL12	1G1LT64W8KY218187		35220
B 009	6	Q	.	1	D	WVB-602	P	N	NA	NA	NA	1G2NE14D3KC752033		NA
B 010	3	T	M	1	F	XMG-192	P	Y	Y	W	111	YV1AX885XJ1793960		76160
B 011	6	Q	M	3	D	VAL-JIM	P	Y	Y	NA	RED1	1B3XG24K5KG180041		61720
B 012	3	T	O	1	D	TNC-883	P	N	NA	NA	NA	1FABP57U4JA223282		NA
B 013	6	Q	M	1	F	YVV-221	P	N	NA	NA	NA	1YVGD22B9M5123943		NA
B 014	6	Q	Y	3	D	VTF-944	P	Y	N3	NA	NA	1FABP44A6KF128781		NA
B 015	3	.	M	1	D	547-AMY	F	NA	NA	NA	NA	1FAPP9194KT137977		
B 016	3	B015	M	3	D	WTY-210	P	Y	Y	W	145	1G1FP21S3KL104669		71404
B 017	3	S005	M	1	F	934-ANC	P	Y	Y	M	113	YS3AL75L8M7006092		15011
B 018	3	B012	O	1	D	TYC-278	P	N	NA	NA	NA	1G3HN54C6M1812733		NA
B 019	3	T	M	1	D	YLW-084	P	Y	Y	W	134	1G1FP21S1JL193186		19883
B 020	3	B012	O	1	D	SDC-293	P	N	NA	NA	NA	1G4BR81Y3KA404971		NA
B 021	3	B012	O	1	D	728-ADW	P	N	NA	NA	NA	1G6CD13B2M4277240		NA
B 022	3	B012	O	1	D	BBO-2678	P	N	NA	NA	NA	1G3CW53L4M4318426		NA
B 023	3	T	M	2	D	348-204	P	N	NA	NA	NA	1B7FD04H6GS067280		NA
B 024	3	B012	O	1	D	.	P	N	NA	NA	NA	.		NA
B 025	6	Q	M	1	D	.	F	NA	NA	NA	NA	.		NA
B 026	6	Q	M	1	D	ZKF-718	F	NA	NA	NA	NA	2G1WN54T0L9311377		NA
B 027	3	T	M	2	D	127398-M	P	N	NA	NA	NA	2B6HB23TXHK266154		NA
B 028	6	Q	M	2	D	297412-M	P	Y	N5	NA	NA	2B4FK25K7KR269211		NA
B 029	3	S023	M	2	D	887-123	F	NA	NA	NA	NA	1FTEF15N6JNA59850		NA
B 031	3	B012	O	1	F	KCO-1718	P	N	NA	NA	NA	1G3AJ51W6KG324243		NA
B 032	3	B012	O	1	D	33997	P	N	NA	NA	NA	2MECM74F5MX661232		NA
B 033	3	B023	M	2	D	596-895	F	NA	NA	NA	NA	1GCCT14B5E2173384		NA
B 034	3	B012	O	1	D	RYH-602	F	NA	NA	NA	NA	3B3BK46D3KT993747		NA
B 035	3	B012	O	1	D	VAN-545	P	N	NA	NA	NA	2MEBM75F6KX675910		NA
B 036	3	T	M	2	D	437265-M	P	N	NA	NA	NA	1GNCT18Z5M8146406		NA
B 037	3	S023	M	2	D	WMC-0051	P	Y	Y	W	107	2P4FH413XJR662190		42865
B 038	3	.	M	1	D	WVB-977	P	N	NA	NA	NA	1FABP52U8KA158932		NA
B 039	3	B012	O	1	D	RNT-659	P	Y	Y	W	142	1P3BK46D2KC469869		24327
B 040	.	.	.	.	.	PYX-101	.	.	.	.	.	2FABP74F8KX183167		.
B 041	3	S023	M	2	D	AAG-32T	F	NA	NA	NA	NA	2P4FH51G4GR751156		NA
B 042	3	.	O	1	D	HHS-880	P	Y	Y	S	135	1G6AD6983D9266654		71701
B 043	.	.	.	1	D	299-AFJ	P	.	N	NA	NA	1FACP57U3MA155663		.
B 044	6	Q	O	1	D	00709	P	Y	Y	NA	YEL11	1G2HZ54C2KW215880		29495

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
B 045	6	Q	M	1	F	YTC-431	P	N	NA	NA	NA	JM1BG2262M0228959		NA
B 046	6	Q	M	1	D	REC-404	P	N	NA	NA	NA	1FABP50U8KA177967		NA
B 047	6	Q	M	1	D	RPW-065	P	Y	N1	NA	NA	2G4WB14LXM1861528		NA
B 048	3	B036	M	2	F	TAP-821	P	Y	Y	W	108	1N6SD11S8MC323930		18903
B 049	3	T	M	1	F	.	F	NA	NA	NA	NA	.		NA
B 050	3	S023	M	2	D	81658	P	Y	Y	S	116	1GCEG25HXC7125742		78563
B 051	3	T	M	1	D	MJK-JR	F	NA	NA	NA	NA	1FABP44E1KF114998		NA
B 052	3	B049	Y	1	F	YRE-029	P	Y	Y	W	140	1HGCB7661MA049561		25555
B 053	6	Q	M	1	D	JHU-0593	P	Y	Y	NA	YEL9	1G3NT14DXKM255041		25661
B 054	3	.	M	2	.	286847-M	P	N	NA	NA	NA	1GNCT18R6K0155353		NA
B 055	6	Q	Y	1	F	484-AJW	P	Y	Y	NA	GRN16	JM1GD2224L1810193		34399
B 056	6	Q	M	1	D	.	P	N	NA	NA	NA	.		NA
B 057	3	T	M	1	D	5T05567	F	NA	NA	NA	NA	INTERCHANGEABLE		NA
B 058	3	.	M	1	D	ZPH-57E	P	Y	Y	W	117	1G2AB2705E7332521		81575
B 059	3	B057	M	1	D	01999	P	Y	Y	W	123	1G1JF11W2K7180967		29442
B 060	6	Q	M	1	F	WXN-300	F	NA	NA	NA	NA	1N4GB22S8KC733973		NA
B 061	3	S023	M	2	D	AAH-04J	P	N	NA	NA	NA	1FMCU14T6GUB88128		NA
B 062	3	.	M	1	D	PBN-705	P	Y	Y	W	134	1FAPP14J2MW269094		4365
B 063	3	S023	M	2	D	810954	P	N	NA	NA	NA	1FTCR14A6GPA92258		NA
B 064	3	S023	M	2	D	264-358	P	N	NA	NA	NA	2GCCC14D5C1177157		NA
B 065	6	Q	M	1	D	RYE-253	P	Y	Y	NA	BLU5	1FAPP6046KH126728		34728
B 066	3	B049	M	1	F	YSZ-145	P	Y	Y	S	119	1YVGD31B5M5138706		9633
B 067	3	T	M	1	D	YRZ-855	P	N	NA	NA	NA	1G3EV13L3MU306160		NA
B 068	3	S067	.	1	D	653-ABT	F	NA	NA	NA	NA	1G2FS23EXML205941		NA
B 069	3	B067	M	1	D	.	P	N	NA	NA	NA	.		NA
B 070	3	B067	M	1	D	839-ACX	P	N	NA	NA	NA	JN1MS34P8MW003819		NA
B 071	3	B067	M	1	D	YTZ-547	P	Y	N	NA	NA	1FAPP1283MW223855		NA
B 072	3	T	M	2	D	982-493	P	Y	Y	W	139	1FTCR10A1KUA84004		33205
B 073	6	Q	M	1	D	XCV-403	P	N	NA	NA	NA	1MEBM55U2KA601525		NA
B 074	6	Q	M	1	D	YSZ-538	P	Y	Y	NA	BLU4	1MEPM6042LH679380		15675
B 075	3	T	.	.	.	.	P	N	NA	NA	NA	.		NA
B 076	6	Q	M	1	D	YPX-636	P	Y	Y	NA	BLU4	1FACP57U7MA175592		18855
B 077	3	T	M	1	D	VXA-316	F	NA	NA	NA	NA	1G1AE27P1E7260581		NA
B 078	3	B071	M	1	D	VWH-608	P	N	NA	NA	NA	1G1JC1111K7158004		NA
B 079	3	S023	M	2	D	327-664	P	Y	Y	M	141	1FTBR10T6GUB61390		553
B 080	6	Q	M	1	D	WTX-579	P	N	NA	NA	NA	1LNBM83FXKY727917		NA
B 081	3	.	M	1	D	WVF-128	P	Y	Y	W	129	1G1JC1113KJ171405		46260
B 082	6	Q	M	1	D	YSL-581	F	NA	NA	NA	NA	1G1AW81W6K6214925		NA
B 083	3	T	M	1	D	RBM-985	P	N	NA	NA	NA	1B3BA64E2EG275318		NA
B 084	3	B083	M	1	D	SMZ-544	P	Y	Y	S	128	1G2AB2707E7250564		80424
B 085	3	.	M	1	D	XXR-316	P	N	NA	NA	NA	1FABP29U1GG278824		NA
B 086	3	B071	M	1	D	WXK-557	P	Y	Y	W	114	1FAPP36X9KK201666		60116
B 087	6	Q	O	1	D	KCO-5595	P	N	NA	NA	NA	1G3HN54C6KW357480		NA

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
B 088	3	T	M	2	D	01350	P	Y	Y	W	127	1GCDC14Z8KZ211565		37048
B 089	6	Q	O	1	D	TLV-278	P	N	NA	NA	NA	1G2HX54C4L1219871		NA
B 090	6	Q	Y	1	D	WDG-803	F	NA	NA	NA	NA	1G3WH14TXMD308045		NA
B 091	6	Q	M	1	D	PE00019	F	NA	NA	NA	NA	1G4HP54C1MH431160		NA
B 092	6	Q	O	1	D	YTG-991	F	NA	NA	NA	NA	1G3HN54C7MH335477		NA
B 093	3	.	O	1	D	SFT-453	F	NA	NA	NA	NA	1G1JC5116K7194911		NA
B 094	6	Q	O	1	F	RYR-967	P	N	NA	NA	NA	1N4GB21S8KC733988		NA
B 095	3	T	M	2	D	765-713	F	NA	NA	NA	NA	1FTBR10S3EUB42008		NA
B 096	3	B095	M	2	D	AAF-390	F	NA	NA	NA	NA	.		NA
B 097	3	.	M	1	D	YSZ-722	F	NA	NA	NA	NA	2G1WL54T4M1118073		NA
B 098	3	B095	O	2	D	683-450	P	Y	Y	W	112	1GTBS14R2G2533452		12968
B 099	6	Q	M	1	D	TJD-509	P	Y	Y	NA	YEL10	1G3HY14C3KW311671		37534
B 100	3	T	O	1	D	SAJ-329	F	NA	NA	NA	NA	7E35F526110		NA
B 101	6	Q	M	1	D	025-AKY	P	Y	Y	NA	YEL13	1G3CW54C8K4300538		35425
B 102	3	T	M	1	F	TBN-374	P	N	NA	NA	NA	1N4GB21S5KC782419		NA
B 103	3	T	M	2	D	469-355	F	NA	NA	NA	NA	CE239B869962	No	NA
B 104	3	B051	M	1	D	RJW-112	P	Y	Y	.	110	1G3AJ1137HD381642		50422
B 105	3	T	M	2	F	384-613	P	Y	Y	S	126	JT4RN50R7G0173173		62147
B 106	6	Q	M	1	D	TYK-159	P	N	NA	NA	NA	1G1LT53T4MY110010		NA
B 107	6	Q	M	1	D	ZJR-240	F	NA	NA	NA	NA	1G2WH54T9MF200743		NA
B 108	6	Q	O	1	D	PCB-113	P	N	NA	NA	NA	1G4AL51N1KT476385		NA
B 109	6	Q	O	1	D	PXJ-491	P	N	NA	NA	NA	1G2HX54C9KW206714		NA
B 110	3	B100	M	1	D	NWY-631	P	Y	Y	M	109	1H24KA4409308		6315
B 111	3	T	M	1	F	1A34725	F	NA	NA	NA	NA	INTERCHANGEABLE		NA
B 112	6	Q	O	1	D	KC00531	P	Y	N	NA	NA	1G4NC54N0KM036312		NA
B 113	6	Q	M	1	F	ZEJ-510	P	Y	Y	NA	ORG18	1N4GB2253KC735159		103126
B 114	3	.	M	1	D	YVY-911	P	N	NA	NA	NA	1G3AM19E4EG316495		NA
B 115	3	B114	M	1	D	WFF-409	P	N	NA	NA	NA	1G1AZ3791DB110316		NA
B 116	3	B114	M	1	D	RX00253	P	N	NA	NA	NA	1G4AL19X3GT414184		NA
B 117	3	B114	M	1	D	PEB-223	P	Y	Y	W	106	1G1JC8118H7116530		81318
B 118	6	Q	M	1	D	WPC-937	P	N	NA	NA	NA	1G1JC111XKJ195751		NA
B 119	6	Q	M	1	D	ZJL-454	P	Y	Y	NA	YEL8	1G1JF14T4M7133492		26523
B 120	3	T	M	2	D	431250-M	P	N	NA	NA	NA	2B4GK25KXMR130052		NA
B 121	3	B111	M	1	F	PMA-712	F	NA	NA	NA	NA	YV1AX884XH1244342		NA
B 122	3	.	M	1	F	XLV-069	F	NA	NA	NA	NA	JT2AL22G2B2222699		NA
B 123	3	B111	M	1	F	ITWORKS	P	Y	Y	S	144	TE72-509680	No	100399
B 124	3	T	O	1	D	PLR-789	P	Y	Y	W	118	1B3BP48D5KN589752		17117
B 125	3	T	M	1	D	YVE-420	F	NA	NA	NA	NA	1FAPP36X0MK158001		NA
B 126	3	B125	M	1	D	.	P	N	NA	NA	NA	.		NA
B 127	3	B125	M	1	D	YTG-569	P	N	NA	NA	NA	1G1JC54G6MJ194851		NA
B 128	3	B120	M	2	D	295251-M	P	N	NA	NA	NA	1FMCU14T5KUA42666		NA
B 129	3	.	M	2	F	134413	F	NA	NA	NA	NA	JT4RN67PXH5048277		NA
B 130	3	B125	M	1	D	WTN-186	P	Y	Y	W	137	1FABP44E2KF117098		45568

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
B 131	3	B103	M	2	D	453-026	F	NA	NA	NA	NA	F25HEZ04095		NA
B 132	3	T	M	1	D	XVZ-941	P	N	NA	NA	NA	1G1GZ37G2GR110555		NA
B 133	3	B132	M	1	D	WSV-240	P	N	NA	NA	NA	1G1AZ3799DB142009		NA
B 134	3	B132	M	1	D	RYS-953	P	N	NA	NA	NA	1G3AK47Y7EM450276		NA
B 135	3	B132	M	1	D	XYZ-232	P	N	NA	NA	NA	1G1TB68C9FA154310		NA
B 136	6	Q	O	1	D	RKB-107	P	N	NA	NA	NA	1LNCM81W8MY714626		NA
B 137	3	B125	M	1	D	TGZ-942	F	NA	NA	NA	NA	.		NA
B 138	3	T	M	2	D	235-550	P	N	NA	NA	NA	CLN14A8241066		NA
B 139	3	B132	O	1	D	TVR-667	P	Y	Y	W	143	1G4AL1937F6463396		46927
B 140	6	Q	O	1	D	WTL-100	P	Y	Y	NA	BLU7	1MEPM36X2KK620959		43545
B 141	3	T	M	1	D	NET-237	F	NA	NA	NA	NA	1B3BZ48C6GD222454		NA
B 142	6	Q	M	1	D	VAM-280	F	NA	NA	NA	NA	1FABP52U2KA159753		NA
B 143	3	T	M	1	F	270AMZ	P	Y	Y	S	121	JT2RA44C6B0001018		83805
B 144	6	Q	O	1	F	TJT-292	P	Y	Y	NA	BLU15	JE3CU36X6KU035123		35231
B 145	6	Q	M	1	D	TSB-995	P	Y	Y	NA	YEL9	1G3NT14D2KM235737		16395
B 146	3	T	M	1	F	093-ACR	P	N	NA	NA	NA	JT2ST65C5H7106008		NA
B 147	3	S030	M	1	F	ZFB-153	P	N	NA	NA	NA	1G6DW51Y0J9713286		NA
B 148	3	B142	M	1	D	XPP-662	F	NA	NA	NA	NA	1FABP40A1HF150461		NA
B 149	3	B149	M	1	F	VKV-489	F	NA	NA	NA	NA	JHMSM5429BC042513		NA
B 150	3	B142	M	1	D	WPK-851	P	Y	Y	W	122	1B3YA44K6JG448546		46752
B 151	3	.	M	2	D	340220-M	F	NA	NA	NA	NA	J9F17NH084652		NA
B 152	3	T	M	1	F	SXH-363	P	N	NA	NA	NA	1HGCA6281KA019512		NA
B 153	3	B138	M	2	D	AAG-51V	P	Y	Y	.	146	1GNCT18Z3K0152538		52626
B 154	6	Q	.	1	D	YLL-849	P	Y	N	NA	NA	1G3WH54T6MD326808		NA
B 155	3	T	M	1	D	ZEP-687	.	.	NA	NA	NA	1FABP28M2F1553800	No	NA
B 156	3	T	M	2	D	998-474	P	Y	Y	W	103	1GCFC24H1KE115676		43204
B 157	6	Q	.	1	D	166-AHD	P	N	NA	NA	NA	1G3HN54C9MH308961		NA
B 158	3	T	M	1	D	SWP-680	F	NA	NA	NA	NA	1G3AJ51W8KG342307		NA
B 159	6	Q	O	1	D	19941	P	Y	Y	NA	YEL11	1G2HX54CXKW259695		27252
B 160	3	B120	M	2	D	431478-M	P	N	NA	NA	NA	2B4GK2536MR172629		NA
B 161	3	B120	M	2	D	096-846	P	N	NA	NA	NA	1GTDK14K6KE527575		NA
B 162	3	.	M	1	D	TYV-037	P	N	NA	NA	NA	1MEPM6040MH619227		NA
B 163	3	B146	M	1	F	VRH757	P	Y	Y	W	124	JHMCA5386JC052224		88404
B 164	3	T	O	1	D	RYB-829	P	Y	Y	W	130	1B3BD31D6FG241191		58540
B 165	6	Q	M	2	D	414-713	P	Y	Y	NA	ORG1	2B4GK55R7MR201092		13888
B 166	3	T	O	1	D	SVT-205	P	N	NA	NA	NA	1P3BP36DXHF290238		NA
B 167	6	Q	M	1	F	YSV-199	P	Y	Y	NA	GRN17	1YVGD22B0M5125967		15186
B 168	3	B166	O	1	F	RKY-116	F	NA	NA	NA	NA	1C3BF66P5FX553570		NA
B 169	3	B166	O	1	D	RYC-555	P	Y	Y	W	125	1G4XB69R0FW454358		78872
B 170	3	S110	M	1	F	WVX-385	P	N	NA	NA	NA	WVWEA016XJW311553		NA
B 171	3	.	M	2	D	321457-M	P	N	NA	NA	NA	1FMDU34X1MUC95408		NA
B 172	3	S025	Y	2	F	978-345	P	N	NA	NA	NA	JT2RN81R5K5006631		NA
B 173	6	Q	M	1	D	.	P	N	NA	NA	NA	.		NA

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
B 174	3	.	M	2	D	018-115	P	N	NA	NA	NA	CCU148B158579		NA
B 175	3	T	M	1	F	ZHB-646	P	N	NA	NA	NA	1HGED3659JA026883		NA
B 176	3	.	M	1	D	TSR-546	P	N	NA	NA	NA	1P3BM44C3ED293272		NA
B 177	3	S110	M	1	F	VLF-644	P	N	NA	NA	NA	YV1FX8848H2186523		NA
B 178	3	B153	O	1	F	WVT-348	P	Y	Y	W	131	JH4DA3458KS013350		20744
B 179	3	T	M	1	D	WVT-955	F	NA	NA	NA	NA	1G1BN51E6KA131084		NA
B 180	3	B179	M	1	D	610-ANB	F	NA	NA	NA	NA	1G3WS14W8KD345586		NA
B 181	3	B179	M	1	D	XMF-070	P	N	NA	NA	NA	1Y1SK5149JZ025621		NA
B 182	3	.	M	1	D	.	P	N	NA	NA	NA	.		NA
B 183	3	B179	M	1	D	WVA-200	P	N	NA	NA	NA	1G2NE14U6KC713016		NA
B 184	3	B179	M	1	D	TCM-132	P	Y	Y	W	133	1G4AH51R1HT438622		54376
B 185	3	T	M	2	D	631-875	P	N	NA	NA	NA	1GCCW80H7ER108666		NA
B 186	3	.	M	1	D	SEN-341	F	NA	NA	NA	NA	1G1JC1117H7159408		NA
B 187	6	Q	O	1	D	WVD-342	P	N	NA	NA	NA	1G4AL51N1KT468805		NA
B 188	6	Q	M	1	D	WRS-182	P	N	NA	NA	NA	1G3AJ51N6KG330762		NA
B 189	6	Q	.	1	F	XXR-511	P	N	NA	NA	NA	JN1HJ01P9LT376777		NA
B 190	3	T	Y	1	F	YRD-994	P	Y	Y	W	120	JT2EL34B2M0027569		15264
B 191	3	B120	M	2	D	387-625	P	Y	Y	W	136	1GCDC14H3ME100424		12119
B 192	6	Q	M	1	D	YWJ-196	F	NA	NA	NA	NA	1G1LV13T6MY139222		NA
B 193	3	B185	M	2	D	981-043	P	Y	Y	W	SN09	1GCDC14Z6KE135013		45189
B 194	6	Q	.	1	D	PLY-781	P	N	NA	NA	NA	1G2NE54U6MC527177		NA
B 195	3	T	Y	1	F	.	P	Y	Y	W	SN06	JHMBA7431GC066566		112991
B 196	6	Q	M	1	D	YSV-377	P	Y	Y	NA	YEL11	2G1WN14T9L9302959		15423
B 197	6	Q	M	3	D	TXD-453	F	NA	NA	NA	NA	1G1JF11WXK7174673		NA
B 198	6	Q	M	1	D	862-AMD	P	N	NA	NA	NA	1G4CW54C7K1639319		NA
B 199	6	Q	M	1	D	064-ACS	F	NA	NA	NA	NA	1G2WJ54T1MF245132		NA
B 200	3	T	O	1	D	XXR-189	P	N	NA	NA	NA	1G4JS5116KJ409647		NA
B 201	6	Q	M	1	D	WTP-491	P	Y	N5	NA	NA	1G3HY14C2KW368282		NA
B 202	3	.	M	1	F	WVT-163	F	NA	NA	NA	NA	JM1BD2310E0760014		NA
B 203	3	.	M	1	D	VHE-395	F	NA	NA	NA	NA	1G3AM19EXDD420084		NA
B 204	3	.	M	1	D	XKE-337	P	N	NA	NA	NA	1G4NM27H7FM478057		NA
B 205	3	.	M	1	D	RRH-857	.	.	NA	NA	NA	1G3NT54L4JM259390		NA
B 206	3	T	O	1	D	12820	P	Y	Y	W	SN05	2MEBM75F1KX665883		41294
B 207	3	S076	M	1	D	XXD-452	P	Y	Y	W	SN04	JG1MR2152HK746455		33132
B 208	3	.	Y	1	F	928-AEE	P	Y	Y	S	SN02	JM1FC3312G0121078		111384
B 209	3	T	M	1	D	VDP-360	.	.	NA	NA	NA	.		NA
B 210	3	T	O	1	F	123-AEC	P	Y	Y	M	SN01	JF1AC42B2KC210379		33445
B 211	6	Q	M	1	D	YRA-867	P	N	NA	NA	NA	1MEPM60T2MH631032		NA
B 212	6	Q	.	.	D	PAX-674	P	N	NA	NA	NA	1B3XG24K7KG107124		NA
B 213	6	Q	.	1	D	YYC-671	P	N	NA	NA	NA	1G3AJ51N2KG325381		NA
B 214	6	Q	M	2	D	418626-M	P	Y	N5	NA	NA	1P4GH54R0MX579786		NA
B 215	3	T	M	1	D	VFB-404	F	NA	NA	NA	NA	6D47S8E661372		NA
B 216	6	Q	.	1	D	SFX-142	P	N	NA	NA	NA	3G4AH54NXMS603113		NA

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
B 217	3	B215	M	1	D	ZHV-260	P	Y	Y	M	105	1FABP1323DT120604		63726
B 218	6	Q	.	1	D	YTG-870	F	NA	NA	NA	NA	1G2JC14K9M7585174		NA
B 219	6	Q	.	1	D	YVE-100	P	N	NA	NA	NA	2G4WD54LXM1855715		NA
B 220	6	Q	M	1	D	ZHB-267	F	NA	NA	NA	NA	1B3XA4630MF584988		NA
B 221	6	Q	O	1	D	SLR-603	P	N	NA	NA	NA	1G4HR54C8MH401146		NA
B 222	6	Q	.	1	D	WVT-103	P	N	NA	NA	NA	1G1JC111XKJ215111		NA
B 223	6	Q	M	1	D	XKD-737	F	NA	NA	NA	NA	1G4AH51N7KG408800		NA
B 224	6	Q	.	1	D	XMY-483	P	N	NA	NA	NA	1G2FS23T0ML212461		NA
B 225	3	T	M	1	F	ZFK-055	P	N	NA	NA	NA	YV1FX8848G2051945		NA
B 226	6	Q	M	1	D	YNT-239	F	NA	NA	NA	NA	2G1WL54T1M9113477		NA
B 227	6	Q	.	1	D	970-ALM	P	N	NA	NA	NA	.		NA
B 228	3	B175	M	1	F	WYN-470	P	N	NA	NA	NA	JF1AC45B7HC202556		NA
B 229	3	B175	M	1	F	VRV-952	P	N	NA	NA	NA	1HGED3553JA033488		NA
B 230	6	Q	M	1	D	PZY-943	P	N	NA	NA	NA	1G3AJ51W7KG320122		NA
B 231	3	B225	M	1	F	YJR-728	F	NA	NA	NA	NA	JT2AE86S9E0049002		NA
B 232	6	Q	M	1	D	WWN-287	F	NA	NA	NA	NA	1G3NF54N4KM270366		NA
B 233	3	B175	M	1	F	XZC-169	P	Y	Y	S	104	JN1GB21SXKU537381		41170
B 234	3	.	M	1	D	656-ADW	P	Y	N	NA	NA	1G4EZ13L2M4404077		NA
B 235	6	Q	M	1	D	BBO-5587	P	N	NA	NA	NA	1G4NV54N1MM259987		NA
B 236	3	T	M	1	D	VSX-591	P	Y	Y	.	108	1W19J9B567918		30066
B 237	3	B175	M	1	F	VNT-707	P	N	NA	NA	NA	JM1FC3314J0610704		NA
B 238	6	Q	Y	1	D	ZDG-037	P	Y	Y	NA	RED2	1B3XG24K4KG153848		34873
B 239	3	T	O	1	D	ALO-2624	P	N	NA	NA	NA	2FABP74F1KX108679		NA
B 240	3	.	M	1	F	WTN-515	P	N	NA	NA	NA	JN1HS34P7KW012610		NA
B 241	3	B239	O	1	D	898-AHN	P	Y	Y	W	145	1MEBM55UXKA633641		52045
B 242	3	T	M	1	D	TRG-457	P	N	NA	NA	NA	1G2FS87S9FN215032		NA
B 243	3	B175	M	1	F	XMT-326	P	Y	Y	M	113	YV1AX8852H1723847		66619
B 244	3	B225	M	1	F	PJZ-774	F	NA	NA	NA	NA	KMHLF21J7HU186053		NA
B 245	3	B225	M	1	F	YWJ-392	F	NA	NA	NA	NA	KMHLD11J6HU043837		NA
B 246	3	T	M	2	D	271641-M	F	NA	NA	NA	NA	1GNCT18Z0K0165229		NA
B 247	3	B246	M	2	D	VVX-502	P	Y	Y	W	107	2B4FK5131JR676116		51090
B 248	6	Q	.	1	D	TMV-239	P	N	NA	NA	NA	1FACP50U4LA153137		NA
B 249	6	Q	M	1	D	WVP-840	F	NA	NA	NA	NA	1FABP54Y4KA190602		NA
B 250	3	.	M	1	D	ZHZ-332	F	NA	NA	NA	NA	1FABP132XDT137948		NA
B 251	3	B200	O	1	D	00623	P	N	NA	NA	NA	1LNBM81F7JY847577		NA
B 252	3	B225	M	1	F	835-AMM	P	N	NA	NA	NA	1HGED3546KA028309		NA
B 253	3	T	M	2	F	212-728	F	NA	NA	NA	NA	JT4RN50R2H5105660		NA
B 254	6	Q	O	1	D	TCG-797	P	N	NA	NA	NA	1MEPM6040KH624702		NA
B 255	3	B200	M	1	D	HC00181	P	Y	Y	W	140	1C3BC59KXHF330954		38481
B 256	3	.	M	1	D	XME-131	P	Y	Y	M	111	2FABP38S0HB102197		60767
B 257	6	Q	M	1	D	.	F	NA	NA	NA	NA	.		NA
B 258	6	Q	M	1	F	YSZ-618	P	N	NA	NA	NA	JN1HJ01P4LT430681		NA
B 259	3	B242	M	1	D	VHX-696	P	N	NA	NA	NA	1G1AW19R9D6815769		NA

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
B 260	6	Q	M	1	D	WRL-765	F	NA	NA	NA	NA	1LNLM9845KY673685		NA
B 261	3	T	M	1	F	YTZ-102	P	N	NA	NA	NA	JT8UF11E3M0066028		NA
B 262	3	B225	M	1	F	MHS	F	NA	NA	NA	NA	YV1GA694XJ0054177		NA
B 263	3	B387	M	1	F	ZHT-936	P	Y	Y	M	103	JHMBA3144HC019202		95996
B 264	3	B242	M	1	D	VXF-522	F	NA	NA	NA	NA	2G2AF27X1E1219504		NA
B 265	3	B242	M	1	D	ZHG-206	P	Y	Y	.	116	1FABP30U2GA193321		97951
B 266	6	Q	.	1	D	SDH-424	P	Y	N1	NA	NA	2G4WD54L4M1844158		NA
B 267	3	B253	M	1	D	02380	F	NA	NA	NA	NA	0G87F159842		NA
B 268	3	B242	M	1	D	TAJ-192	P	Y	Y	S	119	1G1AW35K5CR225618		73012
B 269	3	.	M	2	D	218-807	P	Y	Y	S	SN03	1B7HD14T7HS461522		111838
B 270	6	Q	M	1	D	YVV-194	P	N	NA	NA	NA	1G4HR54C3MH445510		NA
B 271	3	T	M	1	F	WTK-331	P	N	NA	NA	NA	JN1GB21S0KU532349		NA
B 272	3	B271	M	1	F	SCE-990	F	NA	NA	NA	NA	YV1AX4951C1381436		NA
B 273	3	S196	M	2	D	989-465	P	Y	Y	W	139	1FTCR11T1JUE26260		27876
B 274	3	.	M	1	F	YTJ-058	P	N	NA	NA	NA	2T1AE94A7MC084133		NA
B 275	3	S110	M	1	F	VXB-579	P	Y	Y	S	125	JT2AL31G7E0225492		72290
B 276	3	B271	M	1	F	SAZ-279	P	N	NA	NA	NA	KMHLF31J8HU117832		NA
B 277	3	S096	M	1	D	SRJ-807	F	NA	NA	NA	NA	1B3BK46K3KC422625		NA
B 278	3	T	M	1	F	VXN-311	F	NA	NA	NA	NA	JN1HU11S0GT124004		NA
B 279	3	B278	M	1	F	VLD-971	P	N	NA	NA	NA	WBADK8301D9206190		NA
B 280	3	B278	M	1	F	RJP-749	P	Y	Y	M	132	YS3AG43S3D1020742		93409
B 281	6	Q	M	1	D	ZKV-901	P	Y	Y	NA	BLU6	2FAPP35X1MB126332		5372
B 282	6	Q	M	1	D	WPA-613	P	Y	Y	NA	RED1	1FABP55UXKA153310		35945
B 283	3	T	M	1	D	VSY-667	F	NA	NA	NA	NA	2XMJP557XJA020762		NA
B 284	3	B261	M	1	F	PVX-136	P	N	NA	NA	NA	YV1FX8848K2314251		NA
B 285	3	B271	M	1	F	PVM-139	F	NA	NA	NA	NA	JT2MX62E1B0022724		NA
B 286	3	B103	M	2	D	10151	P	Y	Y	S	SN07	CRN1498264964		13040
B 287	3	T	M	1	D	ZGK-247	P	Y	Y	S	135	1Z37J9B412061		50242
B 288	6	Q	M	1	D	WXE-726	P	N	NA	NA	NA	1FAPP6045KH163835		NA
B 289	6	Q	M	1	F	90KMAXX	F	NA	NA	NA	NA	JN1HJ01P9KT240079		NA
B 290	6	Q	O	1	D	54417	P	N	NA	NA	NA	1G4HP54C1MH424337		NA
B 291	6	Q	M	1	D	WTK-513	P	Y	Y	NA	BLU5	1FAPP36XXKK176728		46185
B 292	3	T	M	1	D	RBK-888	P	N	NA	NA	NA	1G3BY69Y9FY342666		NA
B 293	3	B261	M	1	F	LHS0090	P	Y	Y	M	127	VF3DA2128KS506151		35297
B 294	6	Q	M	1	D	WVP-659	F	NA	NA	NA	NA	1MEPM6041KH604264		NA
B 295	6	Q	O	1	D	TKB-571	P	N	NA	NA	NA	1G3AJ51N9KG340220		NA
B 296	6	Q	M	1	D	XDT-029	P	N	NA	NA	NA	1LNBM81F0KY640370		NA
B 297	3	B292	M	1	D	NCT-340	P	Y	Y	W	129	1MEBP9237GH654018		53335
B 298	3	B271	M	1	F	YHM-975	P	N	NA	NA	NA	1G1LW14T8LY125235		NA
B 299	6	Q	M	1	D	WSA-922	F	NA	NA	NA	NA	1FAPP36X6KK153561		NA
B 300	3	T	M	2	D	162280-M	F	NA	NA	NA	NA	CGU157U196422		NA
B 301	3	S122	M	1	F	RTJ-407	P	Y	Y	M	138	JHMST5434DS016244		92925
B 302	6	Q	M	1	D	XXB-351	P	Y	Y	NA	YEL13	1G1LT54T2LY160319		33703

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
B 303	3	.	M	1	D	SKK-093	P	N	NA	NA	NA	1G1JC5111H7170086		NA
B 304	3	.	M	1	D	YEX-849	P	N	NA	NA	NA	1G2HZ54C9HW322790		NA
B 305	3	B300	M	2	D	659-744	F	NA	NA	NA	NA	CCL449A162789		NA
B 306	3	B283	M	1	D	NNC-284	F	NA	NA	NA	NA	1MEBP6545DW644243		NA
B 307	6	Q	Y	1	D	WXL-703	F	NA	NA	NA	NA	1G1LV14W6KY180794		NA
B 308	3	B283	M	1	D	XKM-260	P	N	NA	NA	NA	1B3BD49D2FF306621		NA
B 309	3	T	M	1	D	SPD-889	P	N	NA	NA	NA	1FAPP2899JW209976		NA
B 310	3	B283	M	1	D	XMF-329	P	N	NA	NA	NA	1C3BH58E4HN480772		NA
B 311	3	B253	M	2	F	248-767	P	N	NA	NA	NA	1N6ND11Y2GC448136		NA
B 312	3	.	M	2	D	208-009	P	N	NA	NA	NA	F10GEZ01518		NA
B 313	3	B283	M	1	D	ZHG-122	F	NA	NA	NA	NA	1G4AJ69A6EH621456		NA
B 314	3	B283	M	1	D	SMT-854	P	Y	Y	W	110	1G3CX69B9G4332506		55621
B 315	3	T	M	2	D	340-030	P	Y	Y	W	141	1FTEX15H2GKA94158		37404
B 316	6	Q	O	1	D	TTJ-779	P	N	NA	NA	NA	1G3AJ51N7KG332410		NA
B 317	3	T	O	1	D	TDD-547	P	Y	Y	M	124	8G87H169118		89019
B 318	3	S130	M	1	D	TSD-727	P	N	NA	NA	NA	1G2BL81Y5JA200424		NA
B 319	3	S130	M	1	D	WRC-593	P	Y	Y	W	114	1FABP259XHW116408		77229
B 320	6	Q	M	1	D	SYX-874	F	NA	NA	NA	NA	1MEBM55U9KA632819		NA
B 321	3	T	M	1	F	XYL-899	P	N	NA	NA	NA	YV1AX8855G1681639		NA
B 322	3	T	M	1	F	092-AKW	P	N	NA	NA	NA	JN1PB12S4FU631495		NA
B 323	6	Q	M	1	D	PPF-149	P	N	NA	NA	NA	1FABP55U1KA106599		NA
B 324	6	Q	M	1	D	YEJ-185	P	Y	Y	NA	BLU4	1LNBM81F0KY736595		46955
B 325	3	T	M	2	F	007-933	P	Y	Y	S	128	JT4RN50R7H0325017		57739
B 326	6	Q	O	1	D	ZION	F	NA	NA	NA	NA	1C3XY56R3LD910804		NA
B 327	6	Q	O	1	D	256-AGV	P	N	NA	NA	NA	1P3XA5630MF541806		NA
B 328	6	Q	M	1	D	TKC-237	F	NA	NA	NA	NA	2MEPM36X5KB608556		NA
B 329	3	T	O	1	D	SZG-438	P	Y	Y	W	106	1G1GZ11G2HP118178		25410
B 330	6	Q	O	1	D	PBZ-850	P	N	NA	NA	NA	1FABP52U4KA146986		NA
B 331	6	Q	O	1	D	REP-122	P	N	NA	NA	NA	1G3HN54C2KW334147		NA
B 332	6	Q	M	1	D	YTZ-399	F	NA	NA	NA	NA	2G3AJ54N8M2333118		NA
B 333	6	Q	O	1	D	WSZ-617	F	NA	NA	NA	NA	1FABP50D1KG155127		NA
B 334	6	Q	O	1	D	YRZ-186	F	NA	NA	NA	NA	2G4WB54T2M1415297		NA
B 335	3	T	M	1	F	SLC-935	P	N	NA	NA	NA	JN1HB11S5CU006220		NA
B 336	6	Q	O	1	D	YTJ-518	F	NA	NA	NA	NA	1G4AH54N4M6415191		NA
B 337	3	B335	M	1	F	18608HC	P	Y	Y	S	118	JT2MX62EXB0014430		47038
B 338	3	T	M	1	D	VZH-966	P	Y	Y	S	107	1G6AD478XC9150406		21895
B 339	6	Q	O	1	F	WPG-698	P	N	NA	NA	NA	1YVGD22B9M5105315		NA
B 340	6	Q	O	1	D	WTL-002	P	N	NA	NA	NA	1FABP5346KA149225		NA
B 341	6	Q	O	1	D	BB05062	P	N	NA	NA	NA	1B3XP28D2MN554504		NA
B 342	6	Q	M	1	F	RBM-018	P	N	NA	NA	NA	1YVGD22B6M5125617		NA
B 343	3	B321	M	1	F	ZJH-811	P	N	NA	NA	NA	TE51-696464		NA
B 344	3	S160	O	1	D	NYJ-276	P	Y	Y	W	126	1Y1SK5167LZ072182		33818
B 345	3	T	M	1	D	XKL-868	F	NA	NA	NA	NA	8Y89A824642		NA

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
B 346	3	B321	M	1	F	VBA-654	F	NA	NA	NA	NA	JT2MX63E8D0008546		NA
B 347	3	B321	M	1	F	VLY-424	P	N	NA	NA	NA	JM1GD2222J1532651		NA
B 348	3	B321	M	1	F	VTE-646	F	NA	NA	NA	NA	1N4PB21S1HC885474		NA
B 349	3	B309	M	1	D	1A43459	F	NA	NA	NA	NA	INTERCHANGEABLE		NA
B 350	3	B309	M	1	D	YVJ-165	P	Y	Y	M	142	1P3BB26P3GX509455		69134
B 351	3	S244	M	1	D	PXX-020	P	Y	Y	W	137	1G4AJ47A8EH477206		64321
B 352	3	.	M	2	D	217212-M	F	NA	NA	NA	NA	1FMCU14T7JUB25370		NA
B 354	6	Q	M	1	D	WRT-909	P	Y	Y	NA	BLU7	1FAPP36X0KK176575		42858
B 355	3	.	M	1	F	WWF-499	F	NA	NA	NA	NA	JT2EL32D3J0254164		NA
B 356	3	.	M	1	D	.	F	NA	NA	NA	NA	.		NA
B 357	6	Q	M	2	D	391128-M	P	Y	N5	NA	NA	2B4FK25K6KR225698		NA
B 358	6	Q	M	1	D	VXG-781	P	Y	Y	NA	YEL8	1G1AW51W8K6151308		36546
B 359	3	B321	M	1	F	VPS-661	F	NA	NA	NA	NA	1HGCA5620JA059966		NA
B 360	3	S238	M	1	D	YZD-267	F	NA	NA	NA	NA	1FABP3191GT119712		NA
B 361	3	T	M	1	F	416-ABJ	P	Y	Y	S	130	JT2AE92W6J307G220		47393
B 362	3	.	M	1	D	.	P	N	NA	NA	NA	.		NA
B 363	6	Q	M	1	D	ZPB0089	P	Y	Y	NA	YEL14	1G1JF14T2M7136097		17769
B 364	3	S096	M	1	D	.	P	N	NA	NA	NA	.		NA
B 365	3	B321	M	1	F	PXX-127	P	Y	Y	S	122	JT2AE83E4G3279918		92930
B 366	3	T	M	1	D	.	P	N	NA	NA	NA	.		NA
B 367	3	B366	M	1	D	WVP-178	P	Y	Y	W	144	1G2JB6903G7538623		72644
B 368	3	S132	Y	1	F	WCC-990	P	Y	Y	S	109	KMHLF31J3JU420717		55521
B 369	3	T	M	1	F	RXY-721	P	Y	Y	S	143	JT2AE72SXD2040392		56525
B 370	6	Q	M	1	F	WXN-807	P	Y	Y	NA	ORG21	JN1HJ01P7KT248360		31558
B 371	3	B253	M	2	F	771-871	P	Y	Y	M	117	1N6ND06S0EC332168		93910
B 372	6	Q	M	1	D	XXG-371	P	N	NA	NA	NA	1C3BC6637KD543222		NA
B 373	3	T	O	1	D	PXW-449	P	N	NA	NA	NA	1P3BP26C5DF123152		NA
B 374	6	Q	M	1	D	VXL-610	F	NA	NA	NA	NA	1G4AH51N6KT421352		NA
B 375	3	T	M	1	D	TLG-398	P	Y	Y	W	SN08	2G1AW35X3G1114186		94959
B 376	3	B225	M	1	F	SLC-935	P	Y	Y	S	121	JN1HB11S5CU006220		64020
B 377	3	S096	M	1	D	RTK-925	P	N	NA	NA	NA	1G3AJ19R5FG398797		NA
B 378	3	.	M	1	D	VPS-949	F	NA	NA	NA	NA	1FABP55U5KA178079		NA
B 379	3	.	M	1	F	SRE-517	P	N	NA	NA	NA	JM1GC22A4H1100650		NA
B 380	3	S096	M	1	D	NCY-024	F	NA	NA	NA	NA	1B3BD36K4GF152556		NA
B 381	3	S096	M	1	D	PVW-915	P	Y	Y	.	139	1G3HY3735G1874913		45727
B 382	3	.	M	1	F	XBS-139	F	NA	NA	NA	NA	WBADB7401E1194390	No	NA
B 383	3	S096	M	1	D	WVP-988	P	N	NA	NA	NA	1FABP5347JA150060		NA
B 384	3	B271	M	1	F	TAH-525	P	N	NA	NA	NA	JT2MX63E2E0054388		NA
B 385	3	.	M	1	F	VHX-814	F	NA	NA	NA	NA	JN1MN06S1CM004618		NA
B 386	3	B271	M	1	F	XNK-229	P	Y	Y	S	112	JT2AE82E1G3308647		85833
B 387	3	T	M	2	F	NYN-110	F	NA	NA	NA	NA	JN1PB11SXFU629946		NA
B 388	3	.	M	1	F	ZJH-796	P	N	NA	NA	NA	JT2RA64L0D0024499		NA
B 389	3	S154	M	1	F	YNX-083	P	Y	Y	S	102	JT2TE72W2C5109018		154836

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
B 390	6	Q	M	1	D	JHU-0078	P	Y	Y	NA	RED1	1P3BA46K1KF430173		36125
B 391	6	Q	O	1	D	PXC-659	P	N	NA	NA	NA	1G2HX54CXKW263004		NA
B 392	6	Q	M	1	D	ZJE-033	P	Y	Y	NA	GRN10	2G4WB54T1M1805808		34236
B 393	6	Q	M	1	D	TXC-845	P	N	NA	NA	NA	1G4HR54C1MH474455		NA
B 394	6	Q	M	1	D	005-AHZ	P	N	NA	NA	NA	1G3HN54C2KW324623		NA
B 395	3	.	M	1	F	092-AKW	P	Y	Y	S	146	JN1PB12S4FU631495		87957
B 396	6	Q	M	1	D	YAC-514	P	N	NA	NA	NA	2G1WL54T3L9124656		NA
B 397	6	Q	M	1	D	SDH-511	P	N	NA	NA	NA	1G1JF11W0K7173824		NA
B 398	3	T	M	1	F	XME-109	P	Y	Y	.	133	JT2SV21W5H0026106		91220
B 399	6	Q	Y	1	F	WWL-463	F	NA	NA	NA	NA	1N4GB22S1KC768337		NA
B 400	6	Q	O	1	D	BBO-1765	P	N	NA	NA	NA	1G3HN54C0KH300390		NA
B 401	6	Q	O	1	D	XYH-105	F	NA	NA	NA	NA	1G4HP54C1KH536052		NA
B 402	3	T	M	1	D	TPD-264	P	N	NA	NA	NA	1FABP534XJA143314		NA
B 403	6	Q	M	1	D	WNZ-799	F	NA	NA	NA	NA	1G3AJ51W0KG317014		NA
B 404	3	B402	M	1	D	WXF-233	.	.	NA	NA	NA	1B3CA44KXJG365292		.
B 405	6	Q	M	1	D	WSA-278	F	NA	NA	NA	NA	1G1AW81WXK6166023		NA
B 406	3	B402	M	1	D	YDT-448	P	Y	Y	W	120	1G2NE27L1FC748917		92967
B 407	3	T	O	1	D	SDT-657	P	N	NA	NA	NA	1G1JC1110H7162618		NA
B 408	6	Q	M	3	D	CWALKER	F	NA	NA	NA	NA	1G1LW14W4KY160895		NA
B 409	3	B300	M	2	D	122140-M	F	NA	NA	NA	NA	D14AB7S218324		NA
B 410	3	S025	Y	2	F	071513	P	Y	Y	S	SN05	JM2UF1135J0369027		69202
B 411	3	T	M	1	F	YTG-562	F	NA	NA	NA	NA	JH4KA765XMC016078		NA
B 412	6	Q	M	1	F	WSW-521	P	N	NA	NA	NA	JP3CU24X2KU050690		NA
B 413	3	B345	M	1	D	NYJ-949	P	Y	Y	S	136	4J47AAG110524		61080
B 414	6	Q	M	1	D	WVD-341	P	Y	Y	NA	YEL9	1G4HR54C3KH422726		55081
B 415	6	Q	O	1	D	WTK-322	P	N	NA	NA	NA	1G4AH51N2KT474159		NA
B 416	3	T	M	1	F	TAJ-048	F	NA	NA	NA	NA	YS3AK46D8L5004586		NA
B 417	6	Q	M	1	D	YNS-238	P	N	NA	NA	NA	1G3CX54C7L4358932		NA
B 418	3	B416	M	1	F	XYK-724	P	N	NA	NA	NA	JN1FU21P4MT313582		NA
B 419	3	S152	M	1	D	SRK-971	P	Y	Y	S	105	4J47WAG128222		68411
B 420	3	T	Y	1	D	TPM-504	P	Y	Y	M	SN04	1G1AB08C3DY262608		89473
B 421	6	Q	M	3	F	YVC-189	P	N	NA	NA	NA	JM1NA351XM1221420		NA
B 422	6	Q	M	1	D	SBW-055	F	NA	NA	NA	NA	1G3HN54C2KW348470		NA
B 423	3	B416	M	1	F	PMA-698	P	N	NA	NA	NA	JHMEE2754MS003383		NA
B 424	3	.	M	1	D	XDN-211	P	Y	Y	M	134	1FABP3191GT147350		57544
B 425	3	S079	M	1	D	.	P	N	NA	NA	NA	.		NA
B 426	3	T	M	1	D	ZPJ-808	P	Y	Y	W	131	1B3BS44K1JN276747		77057
B 427	3	.	M	1	D	VHF-354	P	N	NA	NA	NA	1FABP64W6HH100306		NA
B 428	3	.	M	1	F	ZHZ-034	P	Y	Y	M	111	JHMAN5523GC000420		103274
B 429	6	Q	O	1	D	RTH-131	P	N	NA	NA	NA	2G4WB14T1K1462889		NA
B 430	3	T	M	2	D	183-090	F	NA	NA	NA	NA	1FTDF15Y4MNA52700		NA
B 431	6	Q	O	1	D	PVZ-471	P	Y	Y	NA	YEL11	1G3HN54C7KH300726		65643
B 432	3	B416	M	1	F	078-AME	P	N	NA	NA	NA	JT2AE94A5M3439124		NA

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
B 433	6	Q	M	1	D	WLP-729	P	Y	Y	NA	YEL13	1G4CW54C6K1617084		17027
B 434	6	Q	M	1	F	YVE-118	P	N	NA	NA	NA	JM1BG2264M0206204		NA
B 435	6	Q	M	1	F	894-AAH	P	Y	Y	NA	BLU15	JB3CU14XXKU025841		35500
B 436	3	B416	M	1	D	YWH-584	P	Y	Y	.	145	4P3CS34TXME109053	No	14984
B 437	3	.	M	1	D	RMW-619	P	N	NA	NA	NA	1FABP4036FG169788		NA
B 438	3	S079	M	1	F	847-ACG	P	Y	Y	S	104	JT2EL31G0H0069950		45900
B 439	6	Q	M	1	D	TPP-462	P	N	NA	NA	NA	1G3CX54C8K1329939		NA
B 440	3	T	M	1	F	VPS-062	F	NA	NA	NA	NA	JN1HB02S3CV468445	No	NA
B 441	3	S146	M	1	D	NKW-779	P	Y	Y	M	101	1G1AB08C5EA125860		45852
B 442	3	T	M	1	D	WYA-251	F	NA	NA	NA	NA	J81RG5192H8458841		NA
B 443	6	Q	M	1	D	YXG-219	P	N	NA	NA	NA	1G4HR54C0KH463458		NA
B 444	3	.	M	1	F	TPT-481	F	NA	NA	NA	NA	1HGAD7423FA060632		NA
B 445	3	S108	M	2	F	339-997	P	Y	Y	S	108	JT4YR29V5G5007140		157594
B 446	3	.	M	1	F	WVC-649	F	NA	NA	NA	NA	CM43N6C170081		NA
B 447	3	.	M	1	D	XBA-668	P	Y	Y	S	140	1G4AM69A7CH145805		92324
B 448	3	B398	M	1	F	WRZ-880	P	N	NA	NA	NA	JT2EL31D9K0349959		NA
B 449	3	T	M	1	F	XZC-415	F	NA	NA	NA	NA	KMHLD31J3HU021953		NA
B 450	6	Q	.	1	D	RTK-269	P	Y	N5	NA	NA	1P3BP44D5KN555699		NA
B 451	3	S233	M	1	D	REV-549	P	Y	Y	W	SN01	1P3BP36K4HF153374		75331
B 452	3	B430	M	2	D	XXB-029	P	Y	Y	W	123	1GMCU06D2LT200405	No	45317
B 453	6	Q	O	1	D	REM-835	F	NA	NA	NA	NA	1G4HP54C5MH469698		NA
B 454	6	Q	O	1	D	WVH-349	P	Y	Y	NA	YEL12	2G4WD14W3K1400883		45190
B 455	3	.	M	1	D	XXD-170	F	NA	NA	NA	NA	1G2JB2700F7567426		NA
B 456	3	B440	M	1	F	TXB-267	F	NA	NA	NA	NA	JT2RA63C7F6250542		NA
B 457	6	Q	M	1	D	YPZ-339	P	N	NA	NA	NA	1FACP52U2LA242346		NA
B 458	3	B398	M	1	F	XZH-653	F	NA	NA	NA	NA	4T1SV21E0KU049447		NA
B 459	3	.	M	1	F	XDF-576	P	N	NA	NA	NA	1HGAD5435EA055864		NA
B 460	3	S246	M	1	D	NJM-372	P	Y	Y	M	SN02	1FABP46F7D4168830		66683
B 461	6	Q	M	1	D	VHK-972	F	NA	NA	NA	NA	1FACP50U9MA194624		NA
B 462	6	Q	M	1	D	64677	F	NA	NA	NA	NA	2FABP74F0KX230689		NA
B 463	3	.	M	1	D	ZHG-538	P	N	NA	NA	NA	1FABP52U4HG286736		NA
B 464	3	.	M	1	D	TPB-641	.	.	NA	NA	NA	1G1JC5113JJ176450		NA
B 465	3	.	M	1	D	TPY-713	F	NA	NA	NA	NA	1G3BN37Y5FY397447		NA
B 466	3	B398	M	1	F	SRY-952	P	Y	Y	S	108	JT2AE72EXD2098772		114401
B 467	3	.	M	1	F	XTZ-609	P	Y	Y	M	SN03	1HGBA743XGA063308		72248
B 468	3	.	M	1	F	YVW-272	P	Y	Y	S	113	JT2EL31D5H0075958		141052
B 469	3	B110	M	1	D	YJP-153	P	N	NA	NA	NA	JG1MR6155JKJ02494	No	NA
B 470	3	B110	M	1	D	PCB-138	P	N	NA	NA	NA	1P3BP21C4DG136010		NA
B 471	3	B110	M	1	D	VEX-828	F	NA	NA	NA	NA	1G1LV11W5JY205140		NA
B 472	3	B110	M	1	D	ZHB-621	P	Y	Y	S	135	1P3BM18C6ED304919		42090
B 473	3	B117	M	1	D	XSM-185	P	N	NA	NA	NA	1FABP55U8HA180708		NA
B 474	3	B117	M	1	D	XYK-789	P	N	NA	NA	NA	1FABP22X4GK125291		NA
B 475	3	B117	M	1	D	RTK-159	P	N	NA	NA	NA	1G1AB08C7EY142408		NA

Table 4-2 (Continued)

Sample Number	Logger Candidate	Selection Method	Driver Age	Vehicle Type	Vehicle Origin	License Number	Vehicle Screen	Driver Agrees	Logger Installed	Distance Sensor	Logger Number	VIN	VIN Confirmed by Decoder	Final Odometer
B 476	3	B407	O	1	D	RKP-643	F	NA	NA	NA	NA	9K94T231057		NA
B 478	3	B440	M	1	F	AKA-0073	P	N	NA	NA	NA	JT2AE95C1K3212820		NA
B 479	6	Q	M	1	D	ZFZ-128	F	NA	NA	NA	NA	1B3BC5635KD448505		NA
B 480	6	Q	O	2	D	108029-M	P	Y	N5	NA	NA	2B4FK45K4KR249381		NA
B 481	6	Q	M	2	D	289288-M	P	N	NA	NA	NA	2P4FH45J0KR252752		NA
B 482	3	B407	O	1	D	56936	P	Y	Y	W	SN07	1C3CJ51E3HG185086		23084
B 483	6	Q	M	1	D	VHB-116	P	N	NA	NA	NA	1FACP53UXMG138796		NA
B 484	3	B440	M	1	F	NYL-603	P	N	NA	NA	NA	1HGCA5638JA093906		NA
B 343A	6	Q	M	1	D	YSV-862	P	N	NA	NA	NA	1LNCM83WXMY684364		NA
B 354A	6	Q	M	1	D	YSJ-611	P	N	NA	NA	NA	1G1LT54T7LY262991		NA

N1 VIN not acceptable
N2 No communication with logger
N3 Unable to pick up speed pulses
N5 Error codes
N6 Digital dash
N7 Unacceptable engine family
N8 Unacceptable model year

Baltimore City station. Each vehicle was solicited specifically as a candidate for a 3- or 6-parameter datalogger. This is indicated in the Logger Candidate column in Table 4-2.

The method used to select the vehicle from all of the vehicles passing through the I/M lane is given in Column 3. Selection of 3-parameter dataloggers was based on a randomly chosen time of day that they passed their I/M inspection. This is indicated in the table by a "T" in Column 3. Some of the vehicles selected by randomly selected time were not instrumented. In an attempt to keep the vehicles instrumented in this study unbiased, vehicles for the 3-parameter datalogger that were not instrumented were replaced by vehicles with similar vehicle and driver characteristics. These vehicles are shown in Table 4-2 by a sample number in Column 3 that shows the original sample number they replaced. For example, sample S011 was successfully instrumented, and it was a replacement for sample S009, which was solicited earlier but not instrumented.

6-parameter datalogger candidates were not selected randomly and were not selected according to time but according to a quota system developed to attempt to meet a distribution of vehicle manufacturers in the study. The selection method for these vehicles is designated in Column 3 by a "Q".

For the purposes of data analysis, the solicitor estimated the age of the driver in three categories: Young (<25), Middle (26-65), and Old (>65). The type of vehicle was placed in three general classes by the solicitor: 1 (sedan, luxury, station wagon), 2 (pick-up, utility, van), and 3 (sportscar). The origin of vehicle manufacture was determined and categorized as either F (foreign) or D (domestic). The next column gives the license number of the vehicle being solicited. In those cases where the license was an out-of-state license, the state is given in parentheses at the end of the license number.

Before a vehicle was considered to be an actual participant in the project, three stages had to be passed: the vehicle had to pass a set of screening questions asked

of the driver, the driver had to agree to participate, and the datalogger had to be successfully installed on the vehicle.

During solicitation of the vehicle's driver, several questions were asked to determine if the vehicle was appropriate for the study. These questions determined if the vehicle was in acceptable condition for the study, if the driver of the vehicle was the owner of the vehicle, if the vehicle was driven in normal everyday use, if it was anticipated that the car would be used for any long trips or would have major mechanical work done during the next week, and if the car was running normally. An undesired answer to any of these questions caused the vehicle to fail the screening stage. In neither Spokane nor Baltimore did any vehicle fail the vehicle screen because it was in unacceptable condition.

In the second stage, the driver was asked if he or she was interested in participating in the study. At this point, the driver was told that a monetary incentive was being offered. A "no" answer meant that the vehicle would not be instrumented.

The third stage involved actual installation of the datalogger. In most cases, the dataloggers could be installed; however, in a few cases mechanical or electronic problems prevented it from being instrumented. Table 4-2 shows the results of each of these three stages in the vehicle solicitation and installation process.

The type of distance sensor used for the 3-parameter dataloggers is given in the Distance Sensor column. S (adaptor on the speedometer cable), W (Scotch-Loked to the OEM speed sensor wire), and M (magnets attached to a drive shaft) were the three types of speed sensors used. In Table 4-2 "NA" means that the response is not applicable. A period indicates a missing value.

Each of the dataloggers was given an identifying code to help ensure that data from the correct datalogger would be matched with the other information in the

data packet. This is given in the Logger Number column in Table 4-2. The next column gives the vehicle identification number (VIN) for most of the vehicles solicited in this study. The VINs were checked against the 1989 Radian VIN decoder for 1972-1989 vehicles and were checked against VIN decoding literature for 1990-1992 vehicles. For those vehicles for which a correctly decoded VIN could not be elucidated, Table 4-2 indicates a "no" in the next-to-last column. All other VINs were decoded successfully. The last column gives the odometer reading of the vehicle when the dataloggers were removed from vehicles.

The target number of instrumentations for Spokane and Baltimore was 99 3-parameter vehicles and 45 6-parameter vehicles for each city. The 3-parameter dataloggers were generally left on the vehicles for eight days and the 6-parameter dataloggers were typically left on the vehicles for seven days to get approximately a full week's set of data subject to the daily availability of dataloggers ready for installation. Fifty-five 3-parameter dataloggers and 20 6-parameter dataloggers were available. These numbers proved adequate to meet the project's needs.

In the following two subsections, the details of the 3-parameter and 6-parameter instrumentation activities are discussed.

4.3.2 3-Parameter Instrumentation

The 3-parameter dataloggers were designed and fabricated so that they could be put on any vehicle that passed through the I/M station. This allowed the selection of vehicles to be instrumented to be as random as possible. The population of vehicles from which vehicles for 3-parameter dataloggers were solicited were all of those that passed through the I/M station and that had passed the inspection or been given a waiver. While in this report these vehicles are called randomly selected, the population from which they were selected probably does have biases. Only those vehicles that passed through the inspection station at the time that they were solicited were available

for instrumentation. Because drivers were offered a monetary incentive to participate, it is possible that less well-to-do drivers might participate disproportionately in this study.

Table 4-3 summarizes the solicitation and instrumentation success for the 3- and 6-parameter dataloggers in both cities. For example, in Spokane a total of 161 vehicles were solicited for the 3-parameter dataloggers. Of these, 144 passed the screening questions. Of those that passed the screening, 111 drivers were interested in participating. Of those interested in participating, the mechanics were able to install dataloggers successfully on 102 vehicles. Thus, 63 percent of the vehicles solicited for 3-parameter dataloggers in Spokane were successfully instrumented. In Baltimore the 3-parameter installation rate was only 36%. Because of this, twice the number of vehicles had to be solicited in Baltimore as in Spokane.

No vehicle was judged to be in unacceptable condition for this study, and very few drivers considered their vehicles to be running abnormally. Thus, most of the failures during the screening phase of the solicitation were due to the driver expecting to use the vehicle for a long trip, or to have major work done, or because the vehicle was not their everyday car. Because Washington is a community property state, when the vehicle was being driven by the husband or wife, the driver was usually the owner of record for the vehicle. In a few instances, vehicles were being driven by a son or daughter. Fleet vehicles were eligible for the study; however, usually these vehicles were driven by an employee, not the owner of the vehicle.

In Spokane, most of the drivers whose vehicles passed the screening questions were interested in participating in the study; in Baltimore only half of the screening passes were interested in participating. However, there were some possible biases in those who refused to participate. Most noticeable were elderly people

Table 4-3

Summary of Field Activity Rates

City	Datalogger Type	Vehicles Solicited	Screen Passes	Driver Participations	Successful Instrumentations
Spokane	3-Parameter	161	144	111	102
Spokane	6-Parameter	85	78	57	42
Baltimore	3-Parameter	318	230	115	113
Baltimore	6-Parameter	163	119	48	37

who had late-model luxury cars. These people tended to not be interested in participating.

The mechanics were not able to instrument 11 of the 226 eligible cars with 3-parameter dataloggers. Initially in Spokane, the presence of a distributorless ignition system (DIS) prevented the mechanics from performing an installation because such a system had not been encountered in the Austin and Spokane pilot studies. However, in the second half of the Spokane effort, a method for instrumenting these types of vehicles was found and the vehicles were successfully instrumented.

Table 4-4 identifies the vehicles that had 3-parameter dataloggers installed. The description of each vehicle was obtained by decoding the VINs. The year, make, and model of these decoded VINs were checked against the recorded data and the photograph in the data packets.

The VINs of the vehicles that were not instrumented with 3-parameter dataloggers were obtained via the vehicle license number. The VINs for these vehicles were also decoded and are shown in Table 4-5.

4.3.3 6-Parameter Instrumentation

Since the 6-parameter dataloggers were designed to work on certain models of 1989, 1990, and 1991 vehicles, only those model-year vehicles could be instrumented. For these instrumentations, the solicitor approached every eligible vehicle, if possible. Participation in the study was determined by the same three-stage procedure used to select the vehicles for 3-parameter dataloggers. In addition, 6-parameter dataloggers could be placed only on certain vehicles because not every late model vehicle for each manufacturer could be instrumented. Thus, a check of the vehicle identification number and other vehicle checks (for example, drive train configuration) had to be made. Finally, the manufacturer-specific datalogger for the vehicle solicited

Table 4-4
Vehicles Instrumented with 3-Parameter Dataloggers

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine		Fuel Induction	Emission Control Systems	Country	Comments
S 002	1GCGK24M8GJ162254		1986	GM	CHEVROLET	Conventional Cab GMT400 4x4	5.7 L	V8	4 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	TRK 3/4 ton RAT : 8001 - 9000 lbs
S 004	KMHLA31JBHU121264		1987	HYUNDAI	HYUNDAI	Excel	1.5 L	L4	FI	AIR/EVP/TWC/EGR/CLL	KOREA	CAR
S 005	WAUFC58AXLA061766		1990	AUDI	AUDI	Quattro	2.1 L	L5 TURBO	FI	EVP/TWC/CLL	GERMANY	CAR 200 Turbo 4 Dr. Sedan
S 008	1FAPP36X7JK162901		1988	FORD	FORD	Tempo 4 Dr. Sedan GL	2.3 L	L4	CFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
S 011	1G3NT69U9GM372803		1986	GM	OLDSMOBILE	Calais Supreme	2.5 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door 4 Window Notchback
S 015	HL41G6B367586		1978	CHRYSLER	PLYMOUTH	Volare	318 CI	V8	2 bbl	AIR/EVP/CAT/EGR/	U.S.A.	CAR 4 Dr. Sedan
S 018	GCFBAD246990	No	1980	FORD	FORD	Fiesta	.		.	.	.	. .
S 024	JF2KA83A2JD727208		1988	SUBARU	SUBARU	Justy 4WD	1.2 L	L3	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	MPV Justy
S 025	JT4RN50R6J0353266		1988	TOYOTA	TOYOTA	Land Cruiser	2.3 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK TRK
S 027	39128622	No	1969	CADILLAC	CADILLAC	Coupe DeVille	.		.	.	.	CAR .
S 030	LB110-800914		1972	NISSAN	DATSUN	210	2.0 L	L4	2 bbl	AIR/EVP/EGR/	JAPAN	CAR Sedan
S 036	JT3FJ62G5J0087906		1988	TOYOTA	TOYOTA	LandCruiser	4.0 L	L6	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	MPV MPV
S 038	1G4AT27P2EK537437		1984	GM	BUICK	Skyhawk Limited	2.0 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback
S 041	JT2AE92W1J3141485		1988	TOYOTA	TOYOTA	Corolla	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4x4 Wagon
S 043	1B7FN14C7JS796743		1988	CHRYSLER	DODGE	Dodge Dakota 4X2	2.2 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	TRK Conventional Cab RAT : 04001-05000 GVWR & H
S 046	2FTEF14N6GCA49786		1986	FORD	FORD	F150 Light Truck 4X4	5.0 L	V8	EFI	AIR/EVP/TWC/EGR/CLL	CANADA	TRK Light Truck Reg Cab RAT : 6001 - 7000
S 048	AA0BE8S328524		1978	CHRYSLER	PLYMOUTH	PW100 - Plymouth Trail Duster	318 CI	V8	2 bbl	EVP/CAT/EGR/	U.S.A.	TRK Sport Utility RAT : 6000# to 10000#
S 050	1MEBP89C9EG646134		1984	FORD	MERCURY	Marquis 4 Dr. Sedan LTS, Brougham	3.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
S 054	1B7HW14T0GS016645		1986	CHRYSLER	DODGE	Dodge Ram Pick-up 4X4	5.2 L	V8	2 bbl	AIR/EVP/CAT/EGR/	U.S.A.	TRK Conventional Cab RAT : 06001-07000 GVWR & H
S 055	1J089AA196188		1980	GM	CHEVROLET	Chevette Scooter	1.6 L	L4	2 bbl	AIR/EVP/CAT/EGR/	U.S.A.	CAR Sedan 2 Door Hatchback
S 061	JM1BF2227G0145368		1986	MAZDA	MAZDA	323	1.6 L	L4	FI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
S 066	1FABP3934EG169705		1984	FORD	FORD	LTD Brougham HT 4 Dr Sedan	3.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
S 067	1C3BH58E1GN168729		1986	CHRYSLER	CHRYSLER	Le Baron, GTS	2.2 L	L4 TURBO	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Hatchback
S 069	JM1BF2327J0116975		1988	MAZDA	MAZDA	323	1.6 L	L4	FI	EVP/TWC/CLL	JAPAN	CAR 3 Dr. Hatchback
S 072	2G2AK37H5E2268581		1984	GM	PONTIAC	Grand Prix LE	5.0 L	V8	4 bbl	AIR/EVP/TWC/EGR/CLL	CANADA	CAR Coupe 2 Door Notchback Special
S 073	JF2AN55B4GD439011		1986	SUBARU	SUBARU	Turbo	1.8 L	H4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	MPV Station Wagon
S 076	1FABP22X2GK155745		1986	FORD	FORD	Laser 4 Dr Sedan	2.3 L	L4	CFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
S 078	1C3BA54E0EG237812		1984	CHRYSLER	CHRYSLER	Laser	2.2 L	L4 TURBO	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr. Hatchback
S 079	1B3BZ18C5GD231063		1986	CHRYSLER	DODGE	OMNI	2.2 L	L4	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Hatchback
S 088	JT2AE92E6J3034861		1988	TOYOTA	TOYOTA	Corolla	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
S 090	1GNDL15Z6LB143279		1990	GM	CHEVROLET	Astro 4x4	4.3 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	MPV 1/2 ton RAT : 5001 - 6000 lbs
S 094	1G2WK14W3JF252210		1988	GM	PONTIAC	Grand Prix LE	2.8 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe/Sedan
S 096	1MEBP75X7GK641646		1986	FORD	MERCURY	Topaz 4 Dr. Sedan GS 4 WDR	2.3 L	L4	CFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
S 100	1G1AW19R0G6112873		1986	GM	CHEVROLET	Celebrity	2.5 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door 6 window Notchback
S 103	1G1LV14W9JE673479		1988	GM	CHEVROLET	Beretta	2.8 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe/Sedan
S 105	1FABP0521CW107600		1982	FORD	FORD	Escort 3 Dr. Sedan Hatchback	1.6 L	L4	2 bbl	AIR/EVP/CAT/EGR/	U.S.A.	CAR
S 108	JN6ND16Y0GW003899		1986	NISSAN	NISSAN	Truck	2.4 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK Pathfinder
S 110	JB3BA26KXGU135565		1986	CHRYSLER	DODGE/MITS	Colt	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR Station Wagon (import)
S 112	1YVGD31BXL5201264		1990	MAZDA	MAZDA	MX6	2.2 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr Coupe
S 114	KMHLF21J9HU104162		1987	HYUNDAI	HYUNDAI	Excel	1.5 L	L4	FI	AIR/EVP/TWC/EGR/CLL	KOREA	CAR
S 117	JT2AE94A4L3346545		1990	TOYOTA	TOYOTA	Corolla	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR
S 118	1G8CT18B1E0141922		1984	GM	CHEVROLET	Small Conventional Cab 4x4	2.8 L	V6	2 bbl	AIR/EVP/CAT/EGR/	U.S.A.	MPV 1/2 ton RAT : 4001 - 5000 lbs
S 120	JT2SV22E0L3407469		1990	TOYOTA	TOYOTA	Camry	2.0 L	L4	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
S 122	JHMSM5423BC116394		1981	HONDA	HONDA	Accord	1.7 L	L4	2 bbl	EVP/CAT/EGR/	JAPAN	CAR 4dr Sedan
S 126	1Y1SK5467LZ153033		1990	GM	CHEVROLET	Geo Prizm	1.6 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
S 128	1NXAE82G3JZ543668		1988	TOYOTA	TOYOTA	Corolla	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 3 Dr. Liftback
S 130	1FABP0757EW169481		1984	FORD	FORD	Escort 2 Dr. Sedan Hatchback GT	1.6 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
S 132	JHMAF5332ES007287		1984	HONDA	HONDA	Civic CRX	1.5 L	L4	2 bbl	AIR/EVP/CAT/TWC/EGR/CLL	JAPAN	CAR 2 Dr Hatchback/Coupe
S 134	1HGCA554XJA105600		1988	HONDA	HONDA	Accord	2.0 L	L4	2 bbl	EVP/TWC/CLL	U.S.A.	CAR 4dr Sedan (man)
S 135	JB7FM55E2JP049855		1988	CHRYSLER	DODGE/MITS	Dodge Ram Pick-up 4X4	2.5 L	L4	TBI	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK Club Cab RAT : 04001-05000 GVWR & H
S 137	1G2PG9793GP263091		1986	GM	PONTIAC	Fiero GT Coupe	2.8 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback Sport
S 138	3M69FAR476562		1980	GM	OLDSMOBILE	Cutlass Supreme Brougham	4.3 L	V8	2 bbl	AIR/EVP/CAT/EGR/	U.S.A.	CAR Sedan 4 Door Notchback
S 143	JM1BF2321J0174161		1988	MAZDA	MAZDA	323	1.6 L	L4	FI	EVP/TWC/CLL	JAPAN	CAR 3 Dr. Hatchback
S 144	1FABP28A4DF128103		1983	FORD	FORD	Mustang II 3Dr. Hatchback	2.3 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
S 146	1FABP4634EH101344		1984	FORD	FORD	Thunderbird 2 Dr. Sedan	3.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
S 147	JM2UF1133J0354042		1988	MAZDA	MAZDA	B2200 Truck	2.2 L	L4	2 bbl	EVP/TWC/EGR/CLL	JAPAN	TRK Short Bed
S 152	1G3CX69B6G1323859		1986	GM	OLDSMOBILE	Ninety-Eight Regency	3.8 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door 4 Window Notchback
S 154	SMG-2023538		1980	HONDA	HONDA	Accord	1.8 L	L4	3 bbl	EVP/	JAPAN	CAR 3 Door LX
S 156	1ZVPT20C1L5138646		1990	FORD	FORD/MAZDA	Probe GL 3Dr. Sedan	2.2 L	L4	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
S 158	1B3BA64E3EG128750		1984	CHRYSLER	DODGE	Daytona (U.S.)	2.2 L	L4 TURBO	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr. Hatchback
S 160	1FABP52UXJG185500		1988	FORD	FORD	Taurus GL 4 Dr. Wagon	3.0 L	V6	EFI	EVP/TWC/CLL	U.S.A.	CAR

Table 4-4 (Continued)

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine		Fuel Induction	Emission Control Systems	Country	Comments
S 163	1GCEK14L5EJ110666		1984	GM	CHEVROLET	Conventional Cab GMT400 4x4	5.7 L	V8	4 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	TRK 1/2 ton RAT : 6001 - 7000 lbs
S 165	1N4GB22B9LC742425		1990	NISSAN	NISSAN	Sentra	1.6 L	L4	2 bbl	.	U.S.A.	CAR 2dr Sedan
S 167	1GCBS14E3G2140458		1986	GM	CHEVROLET	Small Conventional Cab	2.5 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	TRK 1/2 ton RAT : 3001 - 4000 lbs
S 169	JF1AX9424JG316659		1988	SUBARU	SUBARU	XT-6	2.7 L	H6	FI	EVP/TWC/CLL	JAPAN	CAR XT Coupe
S 172	2B4FK41K2JR589231		1988	CHRYSLER	DODGE	Dodge Caravan	2.5 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	CANADA	MPV Wagon RAT : 04001-05000 GVWR & H
S 175	JN1PS26S4EW633444		1984	NISSAN	NISSAN	200SX	1.8 L	L4 TURBO	FI	EVP/TWC/EGR/CLL	JAPAN	CAR 2+2 (300ZX)
S 176	256690C110112	No	1970	GM	PONTIAC	Executive 400	.		.	.	.	CAR .
S 178	JF1AC43B1JC230491		1988	SUBARU	SUBARU	GL	1.8 L	H4	2 bbl	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
S 179	1GCBS14E5G2149162		1986	GM	CHEVROLET	Small Conventional Cab	2.5 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	TRK 1/2 ton RAT : 3001 - 4000 lbs
S 180	JM2UC2217C0554694		1982	MAZDA	MAZDA	B2000 Truck	2.2 L	L4	2 bbl	AIR/EVP/CAT/EGR/	JAPAN	TRK 4 Dr. Sedan
S 184	RA42-061277		1978	TOYOTA	TOYOTA	Celica	2.0 L	L4	2 bbl	AIR/EVP/EGR/	JAPAN	CAR 2 Dr. Coupe
S 187	1G8CT18R5G8134828		1986	GM	CHEVROLET	Small Conventional Cab 4x4	2.8 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	MPV 1/2 ton RAT : 4001 - 5000 lbs
S 189	1FAPP23J6JW186397		1988	FORD	FORD	Escort 2 Dr Sedan Hatchback GT	1.9 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
S 194	JM2UF2111G0523195		1986	MAZDA	MAZDA	B2000 Truck	2.2 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK Long Bed
S 196	U15SLFE3261		1978	FORD	FORD	Bronco 4X4	400 CI	V8	2 bbl	EVP/	U.S.A.	TRK Bronco RAT : < 6000
S 197	RN47-029466		1974	TOYOTA	TOYOTA	Hi-Lux	2.0 L	L4	2 bbl	EVP/EGR/	JAPAN	CAR 2 Dr. Pick-up
S 200	1X115A6114134		1980	GM	CHEVROLET	Citation	2.5 L	L4	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Sport
S 203	1FABP3497GW162154		1986	FORD	FORD	Escort 4 Dr. Station Wagon L	1.9 L	L4	2 bbl	AIR/EVP/TWC/EGR/	U.S.A.	CAR
S 204	5372057163		1977	VW	VW	Scirocco	1.6 L	L4	FI	EVP/EGR/	GERMANY	CAR
S 205	JM2UF1119G0634121		1986	MAZDA	MAZDA	B2000 Truck	2.2 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK Short Bed
S 207	JN1HT14S3DT103884		1983	NISSAN	DATSUN	Stanza	1.9 L	L4	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 2dr Hardtop
S 209	17A0987815		1980	VW	VW	Rabbit	1.6 L	L4	FI	EVP/CAT/EGR/	GERMANY	CAR
S 211	JM1BF2228G0153432		1986	MAZDA	MAZDA	323	1.6 L	L4	FI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
S 212	1M07VA7159960		1980	GM	CHEVROLET	Monza	2.5 L	L4	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Special Hatchback
S 214	1N6HD11YXJC317900		1988	NISSAN	NISSAN	Truck	3.0 L	V6	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	TRK Regular Bed
S 218	SMK-2089776		1980	HONDA	HONDA	Accord	1.8 L	L4	3 bbl	EVP/	JAPAN	CAR 4 Door
S 219	1W27M8K407920		1978	GM	CHEVROLET	Malibu	3.3 L	V6	2 bbl	EVP/CAT/EGR/	U.S.A.	CAR Coupe 2 Door Notchback
S 221	1G1AD35P5EJ104025		1984	GM	CHEVROLET	Cavalier CS	2.0 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Station Wagon 4 Door
S 222	JM2UF1136K0765114		1989	MAZDA	MAZDA	B2200 Truck	2.2 L	L4	2 bbl	EVP/TWC/EGR/CLL	JAPAN	TRK Short Bed
S 224	1FABP64T8JH140673		1988	FORD	FORD	Thunderbird Turbo Cpe 2 Dr. Sedan	2.3 L	L4 TURBO	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
S 226	1FTBR10C9JUB99316		1988	FORD	FORD	Ranger Super Cab	2.0 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	TRK Light Truck Ranger RAT : 3001 - 4000
S 227	1FABP40A4JF228320		1988	FORD	FORD	Mustang LX 2 Dr. Sedan	2.3 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR
S 229	JM2UC1218E0824500		1984	MAZDA	MAZDA	B2000 Truck	2.2 L	L4	2 bbl	EVP/TWC/EGR/CLL	JAPAN	TRK Short Bed
S 233	1P3BS48KXJN143963		1988	CHRYSLER	PLYMOUTH	Sundance	2.5 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Hatchback
S 235	2G2AF51R0H9223691		1987	GM	PONTIAC	Pontiac 6000	2.5 L	L4	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
S 238	1C3CJ41E6JG327477		1988	CHRYSLER	CHRYSLER	Le Baron	2.2 L	L4 TURBO	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr. Sedan/Coupe
S 239	1G1JF77W1GJ208794		1986	GM	CHEVROLET	Cavalier Z24	2.8 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Plain Back Hatchback
S 240	JT2ST65L5G7024536		1986	TOYOTA	TOYOTA	Celica	2.0 L	L4	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 3 Dr. Liftback
S 241	1FMDU15Y1ELA53608		1984	FORD	FORD	Bronco 4X4	4.9 L	I6	4 bbl	AIR/EVP/CAT/EGR/	U.S.A.	VAN Bronco RAT : 5001 - 6000
S 244	1FABP55U8JG122178		1988	FORD	FORD	Taurus L 4 Dr Wagon	3.0 L	V6	EFI	EVP/TWC/CLL	U.S.A.	CAR
S 246	1FABP52D3JG173298		1988	FORD	FORD	Taurus GL 4 Dr. Wagon	2.5 L	L4	CFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 002	1FTCR10A1MUC46371		1991	FORD	FORD	Ranger Super Cab	2.3 L	I4	EFI	EVP/TWC/EGR/CLL	U.S.A.	TRK Light Truck Ranger RAT : 4001 - 5000
B 007	JHMBB7232GC026142		1986	HONDA	HONDA	Prelude SI	2.0 L	L4	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 2 Door
B 010	YV1AX885XJ1793960		1988	VOLVO	VOLVO	240 Sedan & Wagon	2.3 L	L4	FI	EVP/TWC/CLL	SWEDEN	CAR 5 doors
B 016	1G1FP21S3KL104669		1989	GM	CHEVROLET	Camaro Sport	2.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Hatchback/Liftback
B 017	YS3AL75L6M7006092		1991	SAAB	SAAB	900 Turbo Series	2.0 L	L4 TURBO	FI	EVP/TWC/CLL	SWEDEN	CAR Convertible
B 019	1G1FP21S1JL193186		1988	GM	CHEVROLET	Camaro Sport	2.8 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Hatchback
B 037	2P4FH413XJR662190		1988	CHRYSLER	PLYMOUTH	Plymouth Voyager	3.0 L	V6	EFI	AIR/EVP/TWC/EGR/CLL	CANADA	MPV Wagon RAT : 04001-05000 GVWR & H
B 039	1P3BK46D2KC469869		1989	CHRYSLER	PLYMOUTH	Reliant, Custom, SE, LE	2.2 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
B 042	1G6AD6983D9266654		1983	GM	CADILLAC	De Ville	4.1 L	V8	DFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door Notchback
B 048	1N6SD11S8MC323930		1991	NISSAN	NISSAN	Truck	2.4 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	TRK Regular Bed
B 050	1GCEG25HXC7125742		1982	GM	CHEVROLET	Van	5.0 L	V8	4 bbl	EVP/CAT/EGR/	U.S.A.	TRK 3/4 ton RAT : 6001 - 7000 lbs
B 052	1HGCB7661MA049561		1991	HONDA	HONDA	Accord EX 4 Dr. Sedan	2.2 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4dr Sedan (auto)
B 058	1G2AB2705E7332521		1984	GM	PONTIAC	Sunbird 2000	1.8 L	L4	TBI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback
B 059	1G1JF11W2K7180967		1989	GM	CHEVROLET	Cavalier Z24	2.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe Sedan
B 062	1FAPP14J2MW269094		1991	FORD	FORD	Escort LX 4 Dr. Hatchback	1.9 L	L4	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 066	1YVGD31B5M5138706		1991	MAZDA	MAZDA	M05	2.2 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr Coupe
B 072	1FTCR10A1KUA84004		1989	FORD	FORD	Ranger Super Cab	2.3 L	I4	EFI	EVP/TWC/EGR/CLL	U.S.A.	TRK Light Truck Ranger RAT : 4001 - 5000
B 079	1FTBR10T6GUB61390		1986	FORD	FORD	Ranger Super Cab	2.9 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	TRK Light Truck Ranger RAT : 3001 - 4000
B 081	1G1JC1113KJ171405		1989	GM	CHEVROLET	Cavalier	2.0 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe Sedan
B 084	1G2AB2707E7250564		1984	GM	PONTIAC	Sunbird 2000	1.8 L	L4	TBI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback

Table 4-4 (Continued)

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine		Fuel Induction	Emission Control Systems	Country	Comments
B 086	1FAPP36X9KK201566		1989	FORD	FORD	Tempo 4 Dr. Sedan GL	2.3 L	L4	CFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 088	1GCDC14Z8KZ211565		1989	GM	CHEVROLET	Conventional Cab GMT400	4.3 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	TRK 1/2 ton RAT : 5001 - 6000 lbs
B 098	1GTBS14R2G2533452		1986	GM	GMC	Small Conventional Cab	2.8 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	TRK 1/2 ton RAT : 3001 - 4000 lbs
B 104	1G3AJ1137HD381642		1987	GM	OLDSMOBILE	Cutlass Ciera LS	3.8 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe/Sedan
B 105	JT4RN50R7G0173173		1986	TOYOTA	TOYOTA	Pickup	2.3 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK TRK
B 110	1H24KA440930B		1980	CHRYSLER	PLYMOUTH	Champ	1.6 L	L4	2 bbl	AIR/EVP/CAT/EGR/CLL	U.S.A.	CAR 2 Dr. Hatchback
B 117	1G1JC8118H7116530		1987	GM	CHEVROLET	Cavalier	2.0 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Station Wagon
B 123	TE72-509680	No	1980	TOYOTA	TOYOTA	Corolla	1.6 L	L4	2 bbl	AIR/EVP/CAT/EGR/	JAPAN	CAR 2 Dr./4 Dr. Wagon
B 124	1B3BP48D5KN589752		1989	CHRYSLER	DODGE	Shadow	2.2 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Hatchback
B 130	1FABP44E2KF117098		1989	FORD	FORD	Mustang LX 2 Dr Sedan Convertible	5.0 L	V8	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 139	1G4AL1937F6463396		1985	GM	BUICK	Century Limited	3.8 L	V6	MFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door 6 Window Notchback
B 143	JT2RA44C6B0001018		1981	TOYOTA	TOYOTA	Celica	2.4 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 2 Dr. Coupe
B 150	1B3YA44K6JG448546		1988	CHRYSLER	DODGE	Daytona (U.S.)	2.5 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr. Hatchback
B 153	1GNCT18Z3K0152538		1989	GM	CHEVROLET	Small Conventional Cab 4x4	4.3 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	MPV 1/2 ton RAT : 4001 - 5000 lbs
B 156	1GCFC24H1KE115678		1989	GM	CHEVROLET	Conventional Cab GMT400	5.0 L	V8	FI	EVP/TWC/EGR/CLL	U.S.A.	TRK 3/4 ton RAT : 7001 - 8000 lbs
B 163	JHMCA5386JC052224		1988	HONDA	HONDA	Accord	2.0 L	L4	EFI	EVP/TWC/CLL	JAPAN	CAR 2dr Hatchback (man)
B 164	1B3BD31D6FG241191		1985	CHRYSLER	DODGE	Aries SE	2.2 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr. Sedan/Coupe
B 169	1G4XB69R0FW454358		1985	GM	BUICK	Skylark Custom	2.5 L	L4	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door 4 Window Notchback
B 178	JH4DA3458KS013350		1989	HONDA	ACURA	Integra 3dr	1.8 L	L4	EFI	EVP/TWC/CLL	JAPAN	CAR Integra 3dr Hatchback 4speed
B 184	1G4AH51R1HT438622		1987	GM	BUICK	Century Custom	2.5 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 190	JT2EL34B2M0027569		1991	TOYOTA	TOYOTA	Tercel	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR
B 191	1GCDC14H3ME100424		1991	GM	CHEVROLET	Conventional Cab GMT400	5.0 L	V8	FI	EVP/TWC/EGR/CLL	U.S.A.	TRK 1/2 ton RAT : 5001 - 6000 lbs
B 193	1GCDC14Z6KE135013		1989	GM	CHEVROLET	Conventional Cab GMT400	4.3 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	TRK 1/2 ton RAT : 5001 - 6000 lbs
B 195	JHMBA7431GC066566		1986	HONDA	HONDA	Accord	2.0 L	L4	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Door Sedan
B 206	2MEBM75F1KX665883		1989	FORD	MERCURY	Grand Marquis 4Dr. Sedan LS	5.0 L	V8	2 bbl	AIR/EVP/TWC/EGR/CLL	CANADA	CAR
B 207	JG1MR2152HK746455		1987	GM	SUZUKI	Sprint	1.0 L	L3	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 2 Door Hatchback
B 208	JM1FC3312G0121078		1986	MAZDA	MAZDA	RX7	1.3 L	Rotary	FI	AIR/EVP/TWC/CLL	JAPAN	CAR Coupe
B 210	JF1AC42B2KC210379		1989	SUBARU	SUBARU	DL	1.8 L	H4	2 bbl	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
B 217	1FABP1323DT120604		1983	FORD	FORD	Escort 4 Dr. Sedan Hatchback	1.6 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 233	JN1GB21SXKU537381		1989	NISSAN	NISSAN	Sentra	1.6 L	L4	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4dr Sedan
B 236	1W19J9B567918		1979	GM	CHEVROLET	Malibu	4.4 L	V8	2 bbl	EVP/CAT/EGR/	U.S.A.	CAR Sedan 4 Door Notchback
B 241	1MEBM55UXKA633641		1989	FORD	MERCURY	Sable 4Dr. Stn Wgn GS	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 243	YV1AX8852H1723847		1987	VOLVO	VOLVO	240 Sedan & Wagon	2.3 L	L4	FI	EVP/TWC/CLL	SWEDEN	CAR 5 doors
B 247	2B4FK5131JR676116		1988	CHRYSLER	DODGE	Dodge Caravan	3.0 L	V6	EFI	AIR/EVP/TWC/EGR/CLL	CANADA	MPV Wagon RAT : 04001-05000 GVWR & H
B 255	1C3BC59KXHF330954		1987	CHRYSLER	CHRYSLER	Town and Country	2.5 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR Station Wagon (Import)
B 256	2FABP38S0HB102197		1987	FORD	FORD	Tempo Sport 4Dr. Sedan GLS	2.3 L	L4	CFI	EVP/TWC/EGR/CLL	CANADA	CAR
B 263	JHMBA3144HC019202		1987	HONDA	HONDA	Prelude SI	2.0 L	L4	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 2dr Sedan (man.)
B 265	1FABP30U2GA193321		1986	FORD	FORD	Taurus 4 Dr. Wagon	3.0 L	V6	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 268	1G1AW35K5CR225618		1982	GM	CHEVROLET	Malibu	3.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Station Wagon 4 Door
B 269	1B7HD14T7HS461522		1987	CHRYSLER	DODGE	Dodge Ram Pick-up 4X2	5.2 L	V8	2 bbl	AIR/EVP/CAT/EGR/	U.S.A.	TRK Conventional Cab RAT : 06001-07000 GVWR & H
B 273	1FTCR11T1JUE26260		1988	FORD	FORD	Ranger Super Cab	2.9 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	TRK Light Truck Ranger RAT : 4001 - 5000
B 275	JT2AL31G7E0225492		1984	TOYOTA	TOYOTA	Tercel	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 3 Dr. Liftback
B 280	YS3AG43S3D1020742		1983	SAAB	SAAB	900 Base Series	2.0 L	L4	FI	AIR/EVP/TWC/EGR/	SWEDEN	CAR 4 Dr Sedan
B 286	CRN1498264964		1979	GM	CHEVROLET	Luv 4 x 4	1.6 L	L4	2 bbl	AIR/EVP/CAT/EGR/	U.S.A.	TRK 1/2 ton
B 287	1Z37J9B412061		1979	GM	CHEVROLET	Monte Carlo	4.4 L	V8	2 bbl	EVP/CAT/EGR/	U.S.A.	CAR Coupe 2 Door Hardtop Pillar
B 293	VF3DA2128KS506151		1989	PEUGEOT	PEUGEOT	405	1.9 L	L4	FI	EVP/TWC/CLL	FRANCE	CAR
B 297	1MEBP9237GH654018		1986	FORD	MERCURY	Cougar 2 Dr. Sedan LS XR7	3.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 301	JHMST5434DS016244		1983	HONDA	HONDA	Civic 1500 Sedan	1.5 L	L4	2 bbl	AIR/EVP/CAT/EGR/	JAPAN	CAR 4dr Sedan
B 314	1G3CX69B9G4332506		1986	GM	OLDSMOBILE	Ninety-Eight Regency	3.8 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door 4 Window Notchback
B 315	1FTEX15H2GKA94158		1986	FORD	FORD	F150	5.8 L	V8	4 bbl	EVP/	U.S.A.	TRK Light Truck Super Ca RAT : 6001 - 7000
B 317	8G87H169118		1978	FORD	FORD	Thunderbird HT 2Dr.	351 CI	V8	2 bbl	AIR/EVP/CAT/EGR/	U.S.A.	CAR
B 319	1FABP259XHW116408		1987	FORD	FORD	Escort 4 Dr. Sedan Hatchback GL	1.9 L	L4	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 325	JT4RN50R7H0325017		1987	TOYOTA	TOYOTA	Land Cruiser	2.3 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK TRK
B 329	1G1GZ11G2HP118178		1987	GM	CHEVROLET	Monte Carlo S	5.0 L	V8	4 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe/Sedan
B 337	JT2MX62EXB0014430		1981	TOYOTA	TOYOTA	Cressida	2.8 L	L6	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
B 338	1G6AD478XC9150406		1982	GM	CADILLAC	De Ville	4.1 L	V8	DFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback Special
B 344	1Y1SK5167LZ072182		1990	GM	CHEVROLET	Geo Prizm	1.6 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 350	1P3BB26P3GX509455		1986	CHRYSLER	PLYMOUTH	Grand Fury, Salon	5.2 L	V8	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
B 351	1G4AJ47A8EH477206		1984	GM	BUICK	Regal	3.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback Special
B 361	JT2AE92W6J307G220		1988	TOYOTA	TOYOTA	Corolla	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4x4 Wagon
B 365	JT2AE83E4G3279918		1986	TOYOTA	TOYOTA	Corolla	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan

Table 4-4 (Continued)

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine		Fuel Induction	Emission Control Systems	Country	Comments
B 367	1G2JB6903G7538623		1986	GM	PONTIAC	Sunbird	1.8 L	L4	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door 4 Window Notchback
B 368	KMHLF31J3JU420717		1988	HYUNDAI	HYUNDAI	Excel	1.5 L	L4	FI	AIR/EVP/TWC/EGR/CLL	KOREA	CAR
B 369	JT2AE72SXD2040392		1983	TOYOTA	TOYOTA	Corolla	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR Hardtop
B 371	1N6ND06S0EC332168		1984	NISSAN	NISSAN	Truck	2.4 L	L4	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	TRK King Cab
B 375	2G1AW35X3G1114186		1986	GM	CHEVROLET	Celebrity	2.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	CANADA	CAR Station Wagon 4 Door 2 Seat
B 376	JN1HB11S5CU006220		1982	NISSAN	DATSUN	Sentra	1.5 L	L4	2 bbl	EVP/CAT/EGR/	JAPAN	CAR 4dr Sedan
B 381	1G3HY3735G1874913		1986	GM	OLDSMOBILE	Delta 88 Royale Brougham	3.8 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback Special
B 386	JT2AE82E1G3308647		1986	TOYOTA	TOYOTA	Corolla	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
B 389	JT2TE72W2C5109018		1982	TOYOTA	TOYOTA	Corolla	1.8 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Wagon
B 395	JN1PB12S4FU631495		1985	NISSAN	NISSAN	Sentra	1.6 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 2dr Sedan
B 398	JT2SV21W5H0026106		1987	TOYOTA	TOYOTA	Camry	2.0 L	L4	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 4x4 Wagon
B 406	1G2NE27L1FC746917		1985	GM	PONTIAC	Grand Am	3.0 L	V6	MFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback
B 410	JM2UF1135J0369027		1988	MAZDA	MAZDA	B2200 Truck	2.2 L	L4	2 bbl	EVP/TWC/EGR/CLL	JAPAN	TRK Short Bed
B 413	4J47AAG110524		1980	GM	BUICK	Regal	3.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback Special
B 419	4J47WAG128222		1980	GM	BUICK	Regal	4.9 L	V8	4 bbl	AIR/EVP/CAT/EGR/	U.S.A.	CAR Coupe 2 Door Notchback Special
B 420	1G1AB08C3DY262608		1983	GM	CHEVROLET	Chevette	1.6 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 2 Door Hatchback
B 424	1FABP3191GT147350		1986	FORD	FORD	Escort 2 Dr. Sedan Hatchback L	1.9 L	L4	2 bbl	AIR/EVP/TWC/EGR/	U.S.A.	CAR
B 426	1B3BS44K1JN276747		1988	CHRYSLER	DODGE	Shadow	2.5 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr. Hatchback
B 428	JHMAN5523GC000420		1986	HONDA	HONDA	Civic Wagon	1.5 L	L4	2 bbl	EVP/TWC/EGR/CLL	JAPAN	CAR Station Wagon
B 436	4P3CS34TXME109053	No	1991	CHRYSLER	PLYMOUTH	Laser	.	.	.	.	.	CAR
B 438	JT2EL31G0H0069950		1987	TOYOTA	TOYOTA	Tercel	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 3 Dr. Liftback
B 441	1G1AB08C5EA125860		1984	GM	CHEVROLET	Chevette CS	1.6 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 2 Door Hatchback
B 445	JT4YR29V5G5007140		1986	TOYOTA	TOYOTA	Cargo Van	2.2 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK TRK
B 447	1G4AM69A7CH145805		1982	GM	BUICK	Regal Limited	3.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door Notchback
B 451	1P3BP36K4HF153374		1987	CHRYSLER	PLYMOUTH	Reliant, Custom, SE, LE	2.5 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
B 452	1GMCU06D2LT200405	No	1990	GM	PONTIAC	Transport	3.1 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	MPV All Purpose Vehicle
B 460	1FABP46F7D4168830		1983	FORD	FORD	Thunderbird 2 Dr. Sedan	5.0 L	V8	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 466	JT2AE72EXD2098772		1983	TOYOTA	TOYOTA	Corolla	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
B 467	1HGBA743XGA063308		1986	HONDA	HONDA	Accord	2.0 L	L4	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 468	JT2EL31D5H0075958		1987	TOYOTA	TOYOTA	Tercel	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 2 Dr. Coupe All Trac
B 472	1P3BM18C6ED304919		1984	CHRYSLER	PLYMOUTH	Horizon	2.2 L	L4	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Hatchback
B 482	1C3CJ51E3HG185086		1987	CHRYSLER	CHRYSLER	Le Baron	2.2 L	L4 TURBO	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr. Sedan/Coupe

Table 4-5

Vehicles Solicited But Not Instrumented with 3-Parameter Dataloggers

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine	Fuel Induction	Emission Control Systems	Country	Comments
S 001	E14BHAH3213		1978	FORD	FORD	E150 Cargo Van	2.3 L L4 TURBO	2 bbl	AIR/EVP/CAT/EGR/	U.S.A.	TRK Econoline Van RAT : < 6000
S 009	1G2WK14W0JF285519		1988	GM	PONTIAC	Grand Prix LE	2.8 L V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe/Sedan
S 010	1G1AW19W4G6199697		1986	GM	CHEVROLET	Celebrity	2.8 L V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door 6 window Notchback
S 017	1G3NT27U4GM376852		1986	GM	OLDSMOBILE	Calais Supreme	2.5 L L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback
S 020	.		.	.	.	.	.	.	.	.	.
S 021	1G1AW27XXE6802201		1984	GM	CHEVROLET	Celebrity	2.8 L V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback
S 022	1HGCA6280JA000240		1988	HONDA	HONDA	Accord	2.0 L L4	2 bbl	EVP/TWC/CLL	U.S.A.	CAR 2dr Sedan (auto)
S 026	A6A057A339724		1976	AMERICAN	AMERICAN	Hornet	258 CI L6	1 bbl	AIR/EVP/CAT/EGR/	U.S.A.	CAR 4 Dr. Sedan
S 029	WBA-4007548		1978	HONDA	HONDA	CVCC Wagon	1.5 L L4	3 bbl	EVP/	JAPAN	CAR 5 Door
S 031	.		.	.	.	.	.	.	.	.	.
S 032	KL2TN5462LB317977		1990	GM	PONTIAC	LeMans	1.6 L L4	FI	EVP/TWC/EGR/CLL	KOREA	CAR 4 Door Sedan
S 034	2G2AF81R4J9232840		1988	GM	PONTIAC	Pontiac 6000	2.5 L L4	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Station Wagon
S 035	1G4HR54C9JH426908		1988	GM	BUICK	LeSabre Limited	3.8 L V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
S 039	2G3AJ51R5J9306520		1988	GM	OLDSMOBILE	Cutlass Ciera	2.5 L L4	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
S 059	8W82L268781		1978	FORD	FORD	Granada 2 Dr. Sedan	250 CI L6	1 bbl	AIR/EVP/CAT/EGR/	U.S.A.	CAR
S 060	.		.	.	.	.	.	.	.	.	.
S 064	2FABP43F7GX134162		1986	FORD	FORD	LTD Crown Victoria 4 Dr. Sedan	5.0 L V8	2 bbl	AIR/EVP/TWC/EGR/CLL	CANADA	CAR
S 075	1G1AZ37G9ER174613		1984	GM	CHEVROLET	Monte Carlo S	5.0 L V8	4 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback Special
S 083	WAUFB0856EA072906		1984	AUDI	AUDI	4000 Coupe or Quattro 4 WD	2.1 L L5	FI	EVP/TWC/CLL	GERMANY	CAR 4 Dr. Custom
S 085	JF2AM53B7CE437554		1982	SUBARU	SUBARU	GL	1.8 L H4	2 bbl	AIR/EVP/TWC/EGR/	JAPAN	MPV Station Wagon
S 086	1FTCR15X1LPA46236		1990	FORD	FORD	Ranger Regular Cab	4.0 L V6	EFI	.	U.S.A.	TRK Light Truck Ranger RAT : 4001 - 5000
S 087	1GNCT18Z2L8118030		1990	GM	CHEVROLET	Small Conventional Cab 4x4	4.3 L V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	MPV 1/2 ton RAT : 4001 - 5000 lbs
S 091	2G1WN54TXL1156917		1990	GM	CHEVROLET	Lumina Eurosport	3.1 L V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
S 099	1G1AX08X3CT128925		1982	GM	CHEVROLET	Citation	2.8 L V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 2 Door Hatchback
S 102	1FAPP9597LW140311		1990	FORD	FORD	Escort 4 Dr. Sedan Hatchback LX	1.9 L L4	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR
S 104	JE3CU36X4KU069206		1989	CHRYSLER	EAGLE	Summit DL	1.6 L L4	MPI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR Station Wagon (Import)
S 108	RA32034992	No	.	.	.	.	.	.	.	.	.
S 115	JA3CU26X3LU017846		1990	MITSUBISHI	MITSUBISHI	Mirage	1.5 L L4	MPI	.	JAPAN	CAR
S 116	JHMCB7652LC072385		1990	HONDA	HONDA	Accord	2.0 L L4	FI	.	JAPAN	CAR 4dr Sedan (auto)
S 121	AL10073510	No	1980	TOYOTA	TOYOTA	.	.	.	.		CAR Sedan
S 136	1FABP42E9JF199672		1988	FORD	FORD	Mustang GT 2 Dr. Sedan Hatchback	5.0 L V8	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
S 139	JM2UC2213E0816360		1984	MAZDA	MAZDA	B2000 Truck	2.2 L L4	2 bbl	EVP/TWC/EGR/CLL	JAPAN	TRK 4 Dr. Sedan
S 140	JN6ND06S6GW105226		1986	NISSAN	NISSAN	Truck	2.4 L L4	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK Pathfinder
S 141	JA7FL24W0LP020527		1990	MITSUBISHI	MITSUBISHI	Truck 4 x 2	2.4 L L4	MPI	.	JAPAN	TRK
S 142	2HGED634XLH529405		1990	HONDA	HONDA	Civic 1500 HB	1.5 L L4	MFI	EVP/TWC/CLL	CANADA	CAR 2dr Hatchback (man)
S 151	1FABP4637EH151073		1984	FORD	FORD	Thunderbird 2 Dr. Sedan	3.8 L V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
S 155	1ZVPT20C5L5206320		1990	FORD	FORD/MAZDA	Probe GL 3Dr. Sedan	2.2 L L4	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
S 159	1G4AL19E4ED440542		1984	GM	BUICK	Century Limited	3.0 L V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door Notchback
S 166	F15YKB54D13		1978	FORD	FORD	F150 Light Truck	4.9 L I6	4 bbl	AIR/EVP/CAT/EGR/	U.S.A.	TRK Light Truck Reg Cab RAT : < 6000
S 168	JG1MS2460LK743586		1990	GM	SUZUKI	Geo Metro	1.6 L L4	FI	EVP/TWC/EGR/CLL	JAPAN	CAR 2 Door Hatchback/Liftback
S 171	1B4FK40K6JX292532		1988	CHRYSLER	DODGE	Dodge Caravan	2.5 L L4	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	MPV
S 173	JN1HZ14S2GX141618		1986	NISSAN	NISSAN	300ZX	2.9 L V6	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 2dr Coupe
S 174	6K92L160868		1976	FORD	FORD	Maverick Sedan 4 Dr.	250 CI L6	1 bbl	AIR/EVP/CAT/EGR/	U.S.A.	CAR
S 182	.		.	.	.	.	.	.	.	.	.
S 185	JHMAD5334EC087076		1984	HONDA	HONDA	Accord	1.8 L L4	2 bbl	AIR/EVP/CAT/TWC/EGR/CLL	JAPAN	CAR 2 Dr Hatchback/Coupe
S 186	JT2AE82E3G3336773		1986	TOYOTA	TOYOTA	Corolla	1.5 L L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
S 190	SJD-3038E98		1978	HONDA	HONDA	Accord	1.6 L L4	3 bbl	EVP/	JAPAN	CAR 3 Door
S 191	1FTBR10C5JUB67141		1988	FORD	FORD	Ranger Super Cab	2.0 L L4	FI	EVP/TWC/EGR/CLL	U.S.A.	TRK Light Truck Ranger RAT : 3001 - 4000
S 193	1N6ND11S4JC361129		1988	NISSAN	NISSAN	Truck	2.4 L L4	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	TRK Regular Bed
S 195	JT4RN50R3G0127582		1986	TOYOTA	TOYOTA	Land Cruiser	2.3 L L4	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK TRK
S 208	JF2AN53B3JE427176		1988	SUBARU	SUBARU	GL	1.8 L H4	FI	EVP/TWC/EGR/CLL	JAPAN	MPV Station Wagon
S 213	JM2UF111XG0653535		1986	MAZDA	MAZDA	B2000 Truck	2.2 L L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK Short Bed
S 223	1Y1SK1943GZ168599		1986	GM	CHEVROLET	Nova	1.6 L L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door 6 window Notchback
S 225	2P4FH4538LR660001		1990	CHRYSLER	PLYMOUTH	Plymouth Voyager	3.0 L V6	EFI	AIR/EVP/TWC/EGR/CLL	CANADA	MPV Wagon RAT : 04001-05000 GVWR & H
S 228	JT4VN63C0J0020668		1988	TOYOTA	TOYOTA	Truck 4x4 Short Bed Sh. WB	3.0 L V6	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK TRK
S 232	JP3BA24K7FU109165		1985	CHRYSLER	PLYM/MITS	Colt, E, DL, Prem	1.5 L L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 3 Dr. Hatchback (Import)
S 234	1G1AZ3798ER106983		1984	GM	CHEVROLET	Monte Carlo S	3.8 L V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback Special
S 237	JT2SV21E3L3419214		1990	TOYOTA	TOYOTA	Camry	2.0 L L4	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
S 245	1B3BV41B9CG146685		1982	CHRYSLER	DODGE	400	2.2 L L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr. Sedan/Coupe
S 247	1G3AN69Y1EX334733		1984	GM	OLDSMOBILE	Delta 88 Royale	5.0 L V8	4 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door Notchback

Table 4-5 (Continued)

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine		Fuel Induction	Emission Control Systems	Country	Comments
B 001	1FTDF15Y4HNA67137		1987	FORD	FORD	F150 Light Truck	4.9 L	I6	EFI	AIR/EVP/TWC/EGR/CLL	USA	TRK Light Truck Reg Cab RAT : 5001 - 6000
B 012	1FABP57U4JA223282		1988	FORD	FORD	Taurus GL 4 Dr Station Wagon	3.0 L	V6	EFI	EVP/TWC/CLL	USA	CAR
B 015	1FAPP9194KT137977		1989	FORD	FORD	Escort 2 Dr. Sedan Hatchback	1.9 L	L4	2 bbl	EVP/TWC/EGR/CLL	USA	CAR
B 018	1G3HN54C6N1812733		1991	GM	OLDSMOBILE	Delta 88 Royale	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 020	1G4BR81Y3KA404971		1989	GM	BUICK	LeSabre Estate Wagon	5.0 L	V8	4 bbl	EVP/TWC/EGR/CLL	USA	CAR 4 Door Station Wagon
B 021	1G6CD13B2M4277240		1991	GM	CADILLAC	De Ville	4.9 L	V8	FI	AIR/EVP/TWC/EGR/CLL	USA	CAR 2 Door Coupe Sedan
B 022	1G3CW53L4M4318426		1991	GM	OLDSMOBILE	98 Regency Brougham	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 023	1B7FD04H6GS067280		1986	CHRYSLER	DODGE	Dodge Ram Pick-up 4X2	3.7 L	V6	1 bbl	AIR/EVP/TWC/EGR/CLL	USA	TRK Conventional Cab RAT : 04001-05000 GVWR & H
B 024	.		.	.	.	.	.	.	.	.	.	.
B 027	2B6HB23TXHK266154		1987	CHRYSLER	DODGE	Dodge Ram Van/Wagon	5.2 L	V8	2 bbl	AIR/EVP/CAT/EGR/	CANADA	INC Van RAT : 06001-07000 GVWR & H
B 029	1FTEF15N6JNA59850		1988	FORD	FORD	F150 Light Truck	5.0 L	V8	EFI	AIR/EVP/TWC/EGR/CLL	USA	TRK Light Truck Reg Cab RAT : 6001 - 7000
B 031	1G3AJ51W6KG324243		1989	GM	OLDSMOBILE	Cutlass Ciera	2.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 032	2MECM74F5MX661232		1991	FORD	MERCURY	Grand Marquis 4Dr. Sedan GS	5.0 L	V8	2 bbl	AIR/EVP/TWC/EGR/CLL	CANADA	CAR
B 033	1GCCT14B5E2173384		1984	GM	CHEVROLET	Small Conventional Cab 4x4	2.8 L	V6	2 bbl	AIR/EVP/CAT/EGR/	USA	TRK 1/2 ton RAT : 4001 - 5000 lbs
B 034	3B3BK46D3KT993747		1989	CHRYSLER	DODGE	Aries Custom LE	2.2 L	L4	FI	EVP/TWC/EGR/CLL	MEXICO	CAR 4 Dr. Sedan
B 035	2MEBM75F6KX675910		1989	FORD	MERCURY	Grand Marquis 4Dr. Sedan LS	5.0 L	V8	2 bbl	AIR/EVP/TWC/EGR/CLL	CANADA	CAR
B 036	1GNCT18Z5M8146406		1991	GM	CHEVROLET	Small Conventional Cab 4x4	4.3 L	V6	FI	AIR/EVP/TWC/EGR/CLL	USA	MPV 1/2 ton RAT : 4001 - 5000 lbs
B 038	1FABP52U8KA158932		1989	FORD	FORD	Taurus GL 4 Dr. Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 041	2P4FH51G4GR751156		1986	CHRYSLER	PLYMOUTH	Plymouth Voyager	2.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	CANADA	MPV Wagon RAT : 04001-05000 GVWR & H
B 049	.		.	.	.	.	.	.	.	.	.	.
B 051	1FABP44E1KF114998		1989	FORD	FORD	Mustang LX 2 Dr Sedan Convertible	5.0 L	V8	EFI	AIR/EVP/TWC/EGR/CLL	USA	CAR
B 054	1GNCT18R6K0155353		1989	GM	CHEVROLET	Small Conventional Cab 4x4	2.8 L	V6	FI	AIR/EVP/TWC/EGR/CLL	USA	MPV 1/2 ton RAT : 4001 - 5000 lbs
B 057	INTERCHANGEABLE		.	.	.	.	.	.	.	.	.	.
B 061	1FMCU14T6GUB88128		1986	FORD	FORD	Bronco II 4X4	2.9 L	V6	EFI	EVP/TWC/EGR/CLL	USA	VAN Bronco RAT : 4001 - 5000
B 063	1FTCR14A6GPA92256		1986	FORD	FORD	Ranger Regular Cab	2.3 L	I4	EFI	EVP/TWC/EGR/CLL	USA	TRK Light Truck Ranger RAT : 4001 - 5000
B 064	2GCCC14D5C1177157		1982	GM	CHEVROLET	Conventional Cab GMT400	4.1 L	L6	2 bbl	AIR/EVP/CAT/EGR/	CANADA	TRK 1/2 ton RAT : 4001 - 5000 lbs
B 067	1G3EV13L3MU306160		1991	GM	OLDSMOBILE	Toronado Trofeo	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Coupe Sedan
B 068	1G2FS23EXML205941		1991	GM	PONTIAC	Firebird	5.0 L	V8	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Hatchback/Liftback
B 069	.		.	.	.	.	.	.	.	.	.	.
B 070	JN1MS34P8MW003819		1991	NISSAN	NISSAN	200SX 2 Dr. Sedan	1.6 L	L4	FI	EVP/TWC/EGR/CLL	JAPAN	CAR 2dr Coupe
B 071	1FAPP1283MW223855		1991	FORD	FORD	Escort GT 2 Dr. Sedan Hatchback	1.8 L	L4	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 075	.		.	.	.	.	.	.	.	.	.	.
B 077	1G1AE27P1E7260581		1984	GM	CHEVROLET	Cavalier Type 10	2.0 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	USA	CAR Coupe 2 Door Notchback
B 078	1G1JC1111K7158004		1989	GM	CHEVROLET	Cavalier	2.0 L	L4	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Coupe Sedan
B 083	1B3BA64E2EG275318		1984	CHRYSLER	DODGE	Daytona (U.S.)	2.2 L	L4 TURBO	2 bbl	EVP/TWC/EGR/CLL	USA	CAR 2 Dr. Hatchback
B 085	1FABP29U1GG278824		1986	FORD	FORD	Taurus 4 Dr. Sedan	3.0 L	V6	EFI	AIR/EVP/TWC/EGR/CLL	USA	CAR
B 093	1G1JC5116K7194911		1989	GM	CHEVROLET	Cavalier	2.0 L	L4	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 095	1FTBR10S3EUB42008		1984	FORD	FORD	Ranger Super Cab	2.8 L	V6	2 bbl	EVP/TWC/EGR/CLL	USA	TRK Light Truck Ranger RAT : 3001 - 4000
B 096	.		.	.	.	.	.	.	.	.	.	.
B 097	2G1WL54T4M1118073		1991	GM	CHEVROLET	Lumina	3.1 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
B 100	7E35F526110		1977	FORD	MERCURY	Monark 2Dr. Sedan	302 CI	V8	2 bbl	AIR/EVP/CAT/EGR/	USA	CAR
B 102	1N4GB21S5KC782419		1989	NISSAN	NISSAN	Sentra	1.6 L	L4	FI	AIR/EVP/TWC/EGR/CLL	USA	CAR 4dr Sedan
B 103	CE239B669962	No	1971	AMERICAN	JEEP	.	.	.	.	.	USA	.
B 111	INTERCHANGEABLE		.	.	.	.	.	.	.	.	.	.
B 114	1G3AM19E4EG316495		1984	GM	OLDSMOBILE	Cutlass Ciera Brougham	3.0 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	USA	CAR Sedan 4 Door Notchback
B 115	1G1AZ3791DB110316		1983	GM	CHEVROLET	Monte Carlo S	3.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	USA	CAR Coupe 2 Door Notchback Special
B 116	1G4AL19X3GT414164		1986	GM	BUICK	Century Limited	2.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	USA	CAR Sedan 4 Door 6 window Notchback
B 120	2B4GK25KXMR130052		1991	CHRYSLER	DODGE	Dodge Caravan	2.5 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	CANADA	MPV Wagon RAT : 05001-06000 GVWR & H
B 121	YV1AX684XH1244342		1987	VOLVO	VOLVO	240 Sedan & Wagon	2.3 L	L4	FI	EVP/TWC/CLL	SWEDEN	CAR 4 doors
B 122	JT2AL22G2B2222699		1981	TOYOTA	TOYOTA	Tercel	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 3 Dr. Liftback
B 125	1FAPP36X0MK158001		1991	FORD	FORD	Tempo 4 Dr. Sedan GL	2.3 L	L4	CFI	EVP/TWC/EGR/CLL	USA	CAR
B 126	.		.	.	.	.	.	.	.	.	.	.
B 127	1G1JC54G6MJ194851		1991	GM	CHEVROLET	Cavalier	2.2 L	L4	TBI	AIR/EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 128	1FMCU14T5KUA42666		1989	FORD	FORD	Bronco II 4X4	2.9 L	V6	EFI	EVP/TWC/EGR/CLL	USA	VAN Bronco RAT : 4001 - 5000
B 129	JT4RN67PXH5048277		1987	TOYOTA	TOYOTA	Truck 4x4 SB Extra Cab LWB	2.3 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK TRK
B 131	F25HEZ04095		1978	FORD	FORD	F250 Light Truck	5.8 L	V8	4 bbl	AIR/EVP/CAT/EGR/	USA	TRK Light Truck Reg Cab RAT : 6001-8500
B 132	1G1GZ37G2GR110555		1986	GM	CHEVROLET	Monte Carlo S	5.0 L	V8	4 bbl	AIR/EVP/TWC/EGR/CLL	USA	CAR Coupe 2 Door Notchback Special
B 133	1G1AZ3799DB142009		1983	GM	CHEVROLET	Monte Carlo S	3.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	USA	CAR Coupe 2 Door Notchback Special
B 134	1G3AK47Y7EM450276		1984	GM	OLDSMOBILE	Cutlass Calais	5.0 L	V8	4 bbl	AIR/EVP/TWC/EGR/CLL	USA	CAR Coupe 2 Door Notchback Special
B 135	1G1TB68C9FA154310		1985	GM	CHEVROLET	Chevette CS	1.6 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	USA	CAR Sedan 4 Door 6 Window Plain Back Hatchback
B 137	.		.	.	.	.	.	.	.	.	.	.
B 138	CLN14A8241066		1980	GM	CHEVROLET	Luv	1.8 L	L4	2 bbl	AIR/EVP/CAT/EGR/	USA	TRK 1/2 ton
B 141	1B3BZ48C6GD222454		1986	CHRYSLER	DODGE	Charger	2.2 L	L4	2 bbl	EVP/TWC/EGR/CLL	USA	CAR 4 Dr. Hatchback
B 146	JT2ST65C5H7106008		1987	TOYOTA	TOYOTA	Celica	2.0 L	L4	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 2 Dr. Coupe
B 147	1G6DW51Y0J9713286		1988	GM	CADILLAC	Brougham	5.0 L	V8	FI	AIR/EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan

Table 4-5 (Continued)

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine		Fuel Induction	Emission Control Systems	Country	Comments
B 148	1FABP40A1HF150461		1987	FORD	FORD	Mustang LX 2 Dr. Sedan	2.3 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 149	JHMSM5429BC042513		1981	HONDA	HONDA	Accord	1.7 L	L4	2 bbl	EVP/CAT/EGR/	JAPAN	CAR 4dr Sedan
B 151	J9F17NH084652		1979	JEEP	JEEP	Cherokee, MPV, 2 Dr Wagon/Wt	304 CI	V8	2 bbl	AIR/EVP/CAT/EGR/	U.S.A.	TRK TRK RAT : 6025
B 152	1HGCA6281KA019512		1989	HONDA	HONDA	Accord	2.0 L	L4	EFI	EVP/TWC/CLL	U.S.A.	CAR 2dr Sedan (auto)
B 155	1FABP28M2F1553800	No	1985	FORD	FORD	Mustang II 3Dr. Hatchback	5.0 L	V8	CFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 158	1G3AJ51W8KG342307		1989	GM	OLDSMOBILE	Cutlass Ciera	2.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 160	2B4GK2536MR172629		1991	CHRYSLER	DODGE	Dodge Caravan	3.0 L	V6	EFI	AIR/EVP/TWC/EGR/CLL	CANADA	MPV Wagon RAT : 05001-06000 GVWR & H
B 161	1GTDK14K6KE527575		1989	GM	GMC	Conventional Cab GMT400 4x4	5.7 L	V8	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	TRK 1/2 ton RAT : 5001 - 6000 lbs
B 162	1MEPM6040MH619227		1991	FORD	MERCURY	Cougar 2 Dr. Sedan LS	3.8 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 166	1P3BP36DXHF290238		1987	CHRYSLER	PLYMOUTH	Reliant, Custom, SE, LE	2.2 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
B 168	1C3BF66P5FX553570		1985	CHRYSLER	CHRYSLER	Fifth Avenue	5.2 L	V8	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
B 170	WVWEA016XJW311553		1988	VW	VW	Jetta	1.8 L	L4	FI	EVP/TWC/CLL	GERMANY	CAR 4dr Basic
B 171	1FMDU34X1MUC95408		1991	FORD	FORD	Explorer XL	4.0 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	VAN 4x4 Wheel Drive
B 172	JT2RN81R5K5006631		1989	TOYOTA	TOYOTA	4x4 Truck Short Bed	2.3 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK
B 174	CCU148B158579		1978	GM	CHEVROLET	Conventional Cab	305 CI	V8	2 bbl	EVP/CAT/EGR/	U.S.A.	TRK 1/2 ton
B 175	1HGED3659JA026883		1988	HONDA	HONDA	Civic 1500 Sedan	1.5 L	L4	2 bbl	EVP/TWC/CLL	U.S.A.	CAR 4dr Sedan (auto)
B 176	1P3BM44C3ED293272		1984	CHRYSLER	PLYMOUTH	Turismo	2.2 L	L4	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr. Hatchback
B 177	YV1FX8848H2186523		1987	VOLVO	VOLVO	740 Sedan & Wagon	2.3 L	L4	FI	EVP/TWC/CLL	SWEDEN	CAR 4 doors
B 179	1G1BN51E6KA131084		1989	GM	CHEVROLET	Caprice Classic	5.0 L	V8	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 180	1G3WS14W8KD345586		1989	GM	OLDSMOBILE	Cutlass Supreme SL	2.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe Sedan
B 181	1Y1SK5149JZ025821		1988	GM	CHEVROLET	Nova	1.6 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 182	.		.	.	.	.	.	.	.	.	.	.
B 183	1G2NE14U6KC713016		1989	GM	PONTIAC	Grand Am LE	2.5 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe Sedan
B 185	1GCCW80H7ER108666		1984	GM	CHEVROLET	El Camino & Caballero	5.0 L	V8	4 bbl	EVP/CAT/EGR/	U.S.A.	TRK 1/2 ton El Camino Ca RAT : 4001 - 5000 lbs
B 186	1G1JC1117H7159408		1987	GM	CHEVROLET	Cavalier	2.0 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe/Sedan
B 200	1G4JS5116KJ409647		1989	GM	BUICK	Skyhawk	2.0 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 202	JM1BD2310E0760014		1984	MAZDA	MAZDA	GLC Station Wagon	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 3 Dr. Hatchback
B 203	1G3AM19EXDD420084		1983	GM	OLDSMOBILE	Cutlass Ciera Brougham	3.0 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door Notchback
B 204	1G4NM27H7FM478057		1985	GM	BUICK	Somerset Regal Limited	5.0 L	V8	4 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback
B 205	1G3NT54L4JM259390		1988	GM	OLDSMOBILE	Cutlass Calais SL	3.0 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 209	.		.	.	.	.	.	.	.	.	.	.
B 215	6D47S8E661372		1978	GM	CADILLAC	De Ville	425 CI	V8	4 bbl	EVP/CAT/EGR/	U.S.A.	CAR Coupe 2 Door Hardtop
B 225	YV1FX8848G2051945		1986	VOLVO	VOLVO	740 Sedan & Wagon	2.3 L	L4	FI	EVP/TWC/CLL	SWEDEN	CAR 4 doors
B 228	JF1AC45B7HC202556		1987	SUBARU	SUBARU	GL 10 Turbo	1.8 L	H4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
B 229	1HGED3553JA033488		1988	HONDA	HONDA	Civic 1500 Sedan	1.5 L	L4	2 bbl	EVP/TWC/CLL	U.S.A.	CAR 4dr Sedan (man)
B 231	JT2AE86S9E0049002		1984	TOYOTA	TOYOTA	Corolla	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 2 Dr. Coupe
B 234	1G4EZ13L2M4404077		1991	GM	BUICK	Riviera Luxury	3.8 L	V6	FI	EVP/TWC/CLL	U.S.A.	CAR 2 Door Coupe Sedan
B 237	JM1FC3314J0610704		1988	MAZDA	MAZDA	RX7	1.3 L	ROT	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR Coupe
B 239	2FABP74F1KX108679		1989	FORD	FORD	LTD Crown Victoria LX 4 Dr. Sedan	5.0 L	V8	2 bbl	AIR/EVP/TWC/EGR/CLL	CANADA	CAR
B 240	JN1HS34P7KW012610		1989	NISSAN	NISSAN	200SX	2.9 L	V6	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 2dr Coupe
B 242	1G2FS87S9FN215032		1985	GM	PONTIAC	Firebird	2.8 L	V6	MFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Plain Back Special
B 244	KMHLF21J7HU186053		1987	HYUNDAI	HYUNDAI	Excel	1.5 L	L4	FI	AIR/EVP/TWC/EGR/CLL	KOREA	CAR
B 245	KMHLD11J6HU043837		1987	HYUNDAI	HYUNDAI	Excel	1.5 L	L4	FI	AIR/EVP/TWC/EGR/CLL	KOREA	CAR
B 246	1GNCT18Z0K0165229		1989	GM	CHEVROLET	Small Conventional Cab 4x4	4.3 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	MPV 1/2 ton RAT : 4001 - 5000 lbs
B 250	1FABP132XDT137948		1983	FORD	FORD	Escort 4 Dr. Sedan Hatchback	1.6 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 251	1LNBM81F7JY847577		1988	FORD	LINCOLN	Town Car 4 Dr. Sedan	5.0 L	V8	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 252	1HGED3546KA028309		1989	HONDA	HONDA	Civic 1500 Sedan	1.5 L	L4	2 bbl	EVP/TWC/CLL	U.S.A.	CAR 4dr Sedan (man)
B 253	JT4RN50R2H5105660		1987	TOYOTA	TOYOTA	Land Cruiser	2.3 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	TRK TRK
B 259	1G1AW19R9D6815769		1983	GM	CHEVROLET	Celebrity	2.5 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door Notchback
B 261	JT8UF11E3M0066028		1991	TOYOTA	LEXUS	Lexus Luxury Sedan	4.0 L	V8	FI	EVP/TWC/EGR/CLL	JAPAN	CAR 4dr Sedan
B 262	YV1GA694XJ0054177		1988	VOLVO	VOLVO	760 Sedan & Wagon	2.8 L	V6	FI	EVP/TWC/CLL	SWEDEN	CAR 4 doors
B 264	2G2AF27X1E1219504		1984	GM	PONTIAC	Fiero SE Coupe	2.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	CANADA	CAR Coupe 2 Door Notchback
B 267	0G87F159842		1980	FORD	FORD	Thunderbird HT 2Dr.	5.0 L	V8	2 bbl	AIR/EVP/EGR/	U.S.A.	CAR
B 271	JN1GB21S0KU532349		1989	NISSAN	NISSAN	Sentra	1.6 L	L4	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4dr Sedan
B 272	YV1AX4951C1381436		1982	VOLVO	VOLVO	240 (w/ 3 Pt Seat Belt)	2.1 L	L4	FI	EVP/TWC/	SWEDEN	CAR 5 doors
B 274	2T1AE94A7MC084133		1991	TOYOTA	TOYOTA	Corolla	1.6 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 2dr. Sedan
B 276	KMHLF31J8HU117832		1987	HYUNDAI	HYUNDAI	Excel	1.5 L	L4	FI	AIR/EVP/TWC/EGR/CLL	KOREA	CAR
B 277	1B3BK46K3KC422625		1989	CHRYSLER	DODGE	Aries Custom LE	2.5 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
B 278	JN1HU11S0GT124004		1986	NISSAN	NISSAN	Maxima	2.9 L	V6	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4dr Sedan
B 279	WBADK8301D9206190		1983	BMW	BMW	528e/533i	3.4 L	L6	FI	EVP/TWC/CLL	GERMANY	CAR 528e/533i Sedan
B 283	2XMJP557XJA020762		1988	AMERICAN	AMER/EAGLE	Eagle 30 (SX/4) Premier	3.0 L	V6	MPI	AIR/EVP/TWC/EGR/CLL	CANADA	CAR 4 Dr. Sedan
B 284	YV1FX8848K2314251		1989	VOLVO	VOLVO	740 Sedan & Wagon	2.3 L	L4	FI	EVP/TWC/CLL	SWEDEN	CAR 4 doors
B 285	JT2MX62E1B0022724		1981	TOYOTA	TOYOTA	Cressida	2.8 L	L6	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
B 292	1G3BY69Y9FY342666		1985	GM	OLDSMOBILE	Delta 88 Royale Brougham LS	5.0 L	V8	4 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door 4 Window Notchback
B 298	1G1LW14T8LY125235		1990	GM	CHEVROLET	Beretta	3.1 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe Sedan

Table 4-5 (Continued)

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine		Fuel Induction	Emission Control Systems	Country	Comments
B 300	CGU157U196422		1977	GM	CHEVROLET	Chevy Van Sport/Van Vandura	305 CI	V8	2 bbl	EVP/CAT/EGR/	U.S.A.	TRK 1/2 ton
B 303	1G1JC5111H7170086		1987	GM	CHEVROLET	Cavalier	2.0 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 304	1G2HZ54C9HW322790		1987	GM	PONTIAC	Bonneville LE	1.6 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 305	CCL449A162789		1979	GM	CHEVROLET	Conventional Cab	5.7 L	V8	4 bbl	AIR/EVP/CAT/EGR/	U.S.A.	TRK 1/2 ton w/ Hd Susp
B 306	1MEBP6545DW644243		1983	FORD	MERCURY	Lynx 5Dr. Hatchback Sedan	1.6 L	L4	2 bbl	AIR/EVP/CAT/EGR/	U.S.A.	CAR
B 308	1B3BD49D2FF306621		1985	CHRYSLER	DODGE	Aries Custom LE	2.2 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR Station Wagon (Import)
B 309	1FAPP2899JW209976		1988	FORD	FORD	Escort 4 Dr. Station Wagon LX, GL	1.9 L	L4	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 310	1C3BH58E4HN460772		1987	CHRYSLER	CHRYSLER	Le Baron, GTS	2.2 L	L4 TURBO	2 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Hatchback
B 311	1N6ND11Y2GC446136		1986	NISSAN	NISSAN	Truck	2.4 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	TRK Regular Bed
B 312	F10GEZ01518		1978	FORD	FORD	F100 Light Truck	5.8 L	V8	2 bbl	AIR/EVP/CAT/EGR/	U.S.A.	TRK Light Truck Reg Cab RAT : < 6000
B 313	1G4AJ69A6EH621456		1984	GM	BUICK	Regal	3.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door Notchback
B 318	1G2BL81Y5JA200424		1988	GM	PONTIAC	Safari Wagon	5.0 L	V8	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Station Wagon
B 321	YV1AX8855G1681639		1986	VOLVO	VOLVO	240 Sedan & Wagon	2.3 L	L4	FI	EVP/TWC/CLL	SWEDEN	CAR 5 doors
B 322	JN1PB12S4FU631495		1985	NISSAN	NISSAN	Sentra	1.6 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 2dr Sedan
B 335	JN1HB11S5CU006220		1982	NISSAN	DATSUN	210	1.5 L	L4	2 bbl	EVP/CAT/EGR/	JAPAN	CAR 4dr Sedan
B 343	TE51-696464		1975	TOYOTA	TOYOTA	Corolla	1.6 L	L4	2 bbl	AIR/EVP/EGR/	JAPAN	CAR 2 Dr. Sedan
B 345	6Y89A624642		1978	FORD	LINCOLN	Mark IV or V HT 2 Dr.	460 CI	V8	4 bbl	AIR/EVP/CAT/EGR/	U.S.A.	CAR
B 346	JT2MX63E8D0008546		1983	TOYOTA	TOYOTA	Cressida	2.8 L	L6	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
B 347	JM1GD2222J1532651		1988	MAZDA	MAZDA	626	2.2 L	L4	FI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
B 348	1N4PB21S1HC885474		1987	NISSAN	NISSAN	Sentra	1.6 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 4dr Sedan
B 349	INTERCHANGEABLE		.	.	.	.	.	.	.	.	.	.
B 352	1FMCU14T7JUB25370		1988	FORD	FORD	Bronco II 4X4	2.9 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	VAN Bronco RAT : 4001 - 5000
B 355	JT2EL32D3J0254164		1988	TOYOTA	TOYOTA	Tercel	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 2 Dr. Coupe All Trac
B 356	.		.	.	.	.	.	.	.	.	.	.
B 359	1HGCA5620JA059966		1988	HONDA	HONDA	Accord	2.0 L	L4	EFI	EVP/TWC/CLL	U.S.A.	CAR 4dr Sedan (auto)
B 360	1FABP3191GT119712		1986	FORD	FORD	Escort 2 Dr. Sedan Hatchback L	1.9 L	L4	2 bbl	AIR/EVP/TWC/EGR/	U.S.A.	CAR
B 362	.		.	.	.	.	.	.	.	.	.	.
B 364	.		.	.	.	.	.	.	.	.	.	.
B 366	.		.	.	.	.	.	.	.	.	.	.
B 373	1P3BP26C5DF123152		1983	CHRYSLER	PLYMOUTH	Reliant	2.2 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
B 377	1G3AJ19R5FG398797		1985	GM	OLDSMOBILE	Cutlass Ciera LS	2.5 L	L4	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 4 Door 6 Window Notchback
B 378	1FABP55U5KA178079		1989	FORD	FORD	Taurus L 4 Dr Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 379	JM1GC22A4H1100650		1987	MAZDA	MAZDA	626	2.0 L	L4	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
B 380	1B3BD36K4GF152556		1986	CHRYSLER	DODGE	Aries SE	2.5 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
B 382	WBADB7401E1194390	No	1984	BMW	BMW	528e/533i	2.7 L	L6	FI	EVP/TWC/CLL	GERMANY	CAR 528e/533i Sedan
B 383	1FABP5347JA150060		1988	FORD	FORD	Taurus LX 4 Dr. Wagon	3.8 L	V6	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 384	JT2MX63E2E0054388		1984	TOYOTA	TOYOTA	Cressida	3.0 L	L4	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
B 385	JN1MN06S1CM004618		1982	NISSAN	DATSUN	310	1.6 L	L4	2 bbl	EVP/CAT/EGR/	JAPAN	CAR 2dr HB Sedan
B 387	JN1PB11SXFU629946		1985	NISSAN	NISSAN	Sentra	1.6 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4dr Sedan
B 388	JT2RA64L0D0024499		1983	TOYOTA	TOYOTA	Supra	2.4 L	L4	2 bbl	EVP/TWC/EGR/CLL	JAPAN	CAR Liftback
B 402	1FABP534XJA143314		1988	FORD	FORD	Taurus LX 4 Dr. Wagon	3.8 L	V6	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 404	1B3CA44KXJG365292		1988	CHRYSLER	DODGE	Daytona (U.S.)	2.5 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr. Hatchback
B 407	1G1JC1110H7162618		1987	GM	CHEVROLET	Cavalier	2.0 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe/Sedan
B 409	D14AB7S218324		1977	CHRYSLER	DODGE	Dodge D100	225 CI	V6	2 bbl	EVP/CAT/EGR/	U.S.A.	TRK Conventional Cab RAT : 6000# or Less
B 411	JH4KA765XMC016078		1991	HONDA	ACURA	Legend	3.2 L	V6	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR Legend 4dr Sedan 4speed
B 416	YS3AK46D8L5004586		1990	SAAB	SAAB	900 "S" Series 2dr	2.0 L	L4	FI	EVP/TWC/CLL	SWEDEN	CAR 4 Dr Sedan
B 418	JN1FU21P4MT313582		1991	NISSAN	NISSAN	Maxima	2.9 L	V6	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4dr Sedan
B 423	JHMEE2754MS003383		1991	HONDA	HONDA	Civic Wagon	1.5 L	L4	2 bbl	EVP/TWC/CLL	JAPAN	CAR 4dr Wgn & Wagovan (man)
B 425	.		.	.	.	.	.	.	.	.	.	.
B 427	1FABP84W6HH100306		1987	FORD	FORD	Thunderbird Turbo Cpe 2 Dr. Sedan	2.3 L	L4 TURBO	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 430	1FTDF15Y4MNA52700		1991	FORD	FORD	F150 Light Truck	4.9 L	I6	EFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	TRK Light Truck Reg Cab RAT : 5001 - 6000
B 432	JT2AE94A5M3439124		1991	TOYOTA	TOYOTA	Corolla Deluxe	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4 Door Sedan
B 437	1FABP4036FG169788		1985	FORD	FORD	LTD 4 Dr. Wagon Squire	3.8 L	V6	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 440	JN1HB02S3CV468445	No	1982	NISSAN	DATSUN	210	1.5 L	L4	2 bbl	EVP/CAT/EGR/	JAPAN	CAR 2dr Sedan
B 442	J81RG5192H8458841		1987	GM	CHEVROLET	Spectrum Sedan	1.5 L	L4	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4 Door Sedan
B 444	1HGAD7423FA060632		1985	HONDA	HONDA	Accord	1.8 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 446	CM43N6C170081		1976	CHRYSLER	CHRYSLER	Chrysler Full Sz	400 CI	V8	4 bbl	AIR/EVP/CAT/EGR/	U.S.A.	CAR 4 Dr. Sedan HT
B 448	JT2EL31D9K0349959		1989	TOYOTA	TOYOTA	Tercel	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 2 Dr. Coupe All Trac
B 449	KMHLD31J3HU021953		1987	HYUNDAI	HYUNDAI	Excel	1.5 L	L4	FI	AIR/EVP/TWC/EGR/CLL	KOREA	CAR
B 455	1G2JB2700F7567426		1985	GM	PONTIAC	Sunbird	1.8 L	L4	TBI	EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback
B 456	JT2RA63C7F6250542		1985	TOYOTA	TOYOTA	Supra	2.4 L	L4	2 bbl	EVP/TWC/EGR/CLL	JAPAN	CAR 2 Dr. Coupe
B 458	4T1SV21E0KU049447		1989	TOYOTA	TOYOTA	Camry	2.0 L	L4	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
B 459	1HGAD5435EA055864		1984	HONDA	HONDA	Accord	1.8 L	L4	2 bbl	AIR/EVP/CAT/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 463	1FABP52U4HG286736		1987	FORD	FORD	Taurus GL 4 Dr. Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 464	1G1JC5113JJ176450		1988	GM	CHEVROLET	Cavalier	2.0 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan

Table 4-5 (Continued)

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine		Fuel Induction	Emission Control Systems	Country	Comments
B 465	1G3BN37Y5FY397447		1985	GM	OLDSMOBILE	Delta 88 Royale	5.0 L	V8	4 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Coupe 2 Door Notchback Special
B 469	JG1MR6155JKJ02494	No	1988	GM	SUZUKI	Sprint	1.6 L	L4	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4 Door Hatchback
B 470	1P3BP21C4DG136010		1983	CHRYSLER	PLYMOUTH	Reliant	2.2 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr. Sedan/Coupe
B 471	1G1LV11W5JY205140		1988	GM	CHEVROLET	Beretta	2.8 L	V6	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe/Sedan
B 473	1FABP55U8HA180708		1987	FORD	FORD	Taurus L 4 Dr Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 474	1FABP22X4GK125291		1986	FORD	FORD	Laser 4 Dr Sedan	2.3 L	L4	CFI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 475	1G1AB08C7EY142408		1984	GM	CHEVROLET	Chevette CS	1.6 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR Sedan 2 Door Hatchback
B 476	9K94T231057		1979	FORD	FORD	Fairmont Station Wagon	3.3 L	L6	1 bbl	AIR/EVP/CAT/EGR/	U.S.A.	CAR
B 478	JT2AE95C1K3212820		1989	TOYOTA	TOYOTA	Corolla	1.5 L	L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 2 Dr. Coupe
B 484	1HGCA5638JA093906		1988	HONDA	HONDA	Accord	2.0 L	L4	EFI	EVP/TWC/CLL	U.S.A.	CAR 4dr Sedan (auto)

had to be available and not in use by a vehicle in the field. At the beginning of the field work in each city, most manufacturer's late model-year vehicles could be solicited because all of the 6-parameter datalogger systems were available for instrumentation. However, after the first week, usually only about five 6-parameter datalogger systems were available daily. This restricted the choice of solicited vehicles that could be instrumented on a given day.

For most vehicles, the NGK wide-range oxygen sensor was installed on the exhaust system of the vehicle by welding a boss on the exhaust pipe between the catalytic converter and the muffler or resonator. The boss was positioned as close as possible to the catalytic converter end of the pipe. At the end of the test period, the affected portion of the exhaust system behind the catalytic converter was replaced with Walker exhaust system parts. The exhaust system work was performed by a local muffler shop. For Spokane vehicles with sample numbers S003, S006, S007, S014, S019, and S028, the wide-range oxygen sensor was placed one foot behind the muffler outlet in a four-foot long tailpipe welded to the muffler.

Table 4-3 also summarizes the solicitation and installation activities for the 6-parameter dataloggers. A total of 85 vehicles in Spokane and 163 vehicles in Baltimore were solicited for 6-parameter installations. Of these, 79 instrumentations were performed. Just as for the 3-parameter systems, the installation rate for Spokane (49%) was higher than for Baltimore (23%). Reasons for the inability to instrument 26 vehicles with 6-parameter systems were: incompatibility of the 6-parameter dataloggers with the vehicle, vehicle diagnostic systems showing error codes indicating some sort of vehicle problem, and malfunctions of 6-parameter datalogger systems accompanied by a lack of an available replacement system.

Tables 4-6 and 4-7 show the decoded VINs for the 6-parameter instrumented and noninstrumented vehicles, respectively.

Table 4-6
Vehicles Instrumented with 6-Parameter Dataloggers

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine		Fuel Induction	Emission Control Systems	Country	Comments
S 003	JN1HJ01P8LT366371		1990	NISSAN	NISSAN	Maxima	2.9 L	V6	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4dr Sedan
S 006	1G2AF54T9L6235376		1990	GM	PONTIAC	Pontiac 6000 LE	3.1 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
S 007	2G1WL54RXL1169676		1990	GM	CHEVROLET	Lumina	2.5 L	L4	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
S 014	3G4AL54N3LS605881		1990	GM	BUICK	Century Limited	3.3 L	V6	FI	EVP/TWC/CLL	MEXICO	CAR 4 Door Sedan
S 019	JM1BG2265L0111262		1990	MAZDA	MAZDA	Protege	1.6 L	L4	EFI	.	JAPAN	CAR 4 Dr. Sedan
S 028	1G2HX54C9L1240876		1990	GM	PONTIAC	Bonneville LE	3.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
S 040	1G3AM54N2L6363462		1990	GM	OLDSMOBILE	Cutlass Ciera Brougham	3.3 L	V6	FI	EVP/TWC/CLL	U.S.A.	CAR 4 Door Sedan
S 042	2FAPP37X8LB105148		1990	FORD	FORD	Tempo 4 Dr. Sedan LX	2.3 L	L4	CFI	EVP/TWC/EGR/CLL	CANADA	CAR
S 045	1YVGD22B9L5241604		1990	MAZDA	MAZDA	626	2.2 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
S 047	1B3XA4636LF914626		1990	CHRYSLER	DODGE	Spirit	3.0 L	V6	TBI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
S 051	JM1GD222XL1822669		1990	MAZDA	MAZDA	626	2.2 L	L4	FI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
S 053	1FACP52U5LG167445		1990	FORD	FORD	Taurus GL 4 Dr. Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
S 058	1FACP50UXLG149557		1990	FORD	FORD	Taurus L 4 Dr. Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
S 063	JT2SV21E2L0336391		1990	TOYOTA	TOYOTA	Camry	2.0 L	L4	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
S 070	JA3CR46V8LZ036160		1990	MITSUBISHI	MITSUBISHI	Galant	2.0 L	L4	MPI	.	JAPAN	CAR
S 082	1MECM50U6LG649782		1990	FORD	MERCURY	Sable 4Dr. Sedan GS	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
S 089	1B4FK44R0LX295520		1990	CHRYSLER	DODGE	Dodge Caravan	3.3 L	V6	EFI	.	U.S.A.	MPV Extended Wagon RAT : 04001-05000 GVWR & H
S 092	1P3XA46K8LF815124		1990	CHRYSLER	PLYMOUTH	Acclaim	2.5 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
S 093	2G1WN54T4L9218037		1990	GM	CHEVROLET	Lumina Eurosport	3.1 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
S 097	2B4FK4530LR632793		1990	CHRYSLER	DODGE	Dodge Caravan	3.0 L	V6	EFI	AIR/EVP/TWC/EGR/CLL	CANADA	MPV Wagon RAT : 04001-05000 GVWR & H
S 098	1G4CW54C8L1624667		1990	GM	BUICK	Electra Park Avenue	3.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
S 107	1B3XA4639LF838812		1990	CHRYSLER	DODGE	Spirit	3.0 L	V6	TBI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
S 108	JT2SV24E2L3411553		1990	TOYOTA	TOYOTA	Camry	2.0 L	L4	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
S 119	1N4GB22B6LC764253		1990	NISSAN	NISSAN	Sentra	1.6 L	L4	FI	.	U.S.A.	CAR 2dr Sedan
S 125	1LNLM9848LY702663		1990	FORD	LINCOLN	Continetal Givenchy 4 Dr. Sedan	3.8 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
S 127	1G3AJ54N1L6343342		1990	GM	OLDSMOBILE	Cutlass Ciera	3.3 L	V6	FI	EVP/TWC/CLL	U.S.A.	CAR 4 Door Sedan
S 129	1YVGD22B6L5224054		1990	MAZDA	MAZDA	626	2.2 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
S 131	1MECM5344LG630501		1990	FORD	MERCURY	Sable 4Dr. Sedan LS	3.8 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
S 133	1G2NE54D1LC373895		1990	GM	PONTIAC	Grand Am LE	2.3 L	L4	FI	EVP/TWC/CLL	U.S.A.	CAR 4 Door Sedan
S 148	2G1WL54T8L1197259		1990	GM	CHEVROLET	Lumina	3.1 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
S 150	1FACP52UXLG233424		1990	FORD	FORD	Taurus GL 4 Dr. Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
S 164	1G3HY54C9LH309730		1990	GM	OLDSMOBILE	Delta 88 Royale Brougham	3.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
S 177	1G1LW14T8LE150508		1990	GM	CHEVROLET	Beretta	3.1 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe Sedan
S 181	3G4AH54N7LS609966		1990	GM	BUICK	Century Custom	3.3 L	V6	FI	EVP/TWC/CLL	MEXICO	CAR 4 Door Sedan
S 201	1G3HY54C9L1816555		1990	GM	OLDSMOBILE	Delta 88 Royale Brougham	3.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
S 206	2FAPP36X2LB167744		1990	FORD	FORD	Tempo 4 Dr. Sedan GL	2.3 L	L4	CFI	EVP/TWC/EGR/CLL	CANADA	CAR
S 210	JM1BG2261L0142055		1990	MAZDA	MAZDA	Protege	1.6 L	L4	EFI	.	JAPAN	CAR 4 Dr. Sedan
S 215	1N4GB22BXLC764143		1990	NISSAN	NISSAN	Sentra	1.6 L	L4	FI	.	U.S.A.	CAR 2dr Sedan
S 217	1G2WJ54T3LF263419		1990	GM	PONTIAC	Grand Prix	3.1 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
S 220	1MEPM36X2LK631896		1990	FORD	MERCURY	Topaz 4 Dr. Sedan GS 4 WDR	2.3 L	L4	CFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
S 236	1G1LV14T1LE144679		1990	GM	CHEVROLET	Beretta	3.1 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe Sedan
S 243	2G1WN54T9L9201394		1990	GM	CHEVROLET	Lumina Eurosport	3.1 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
B 005	3B3XA4633MT034156		1991	CHRYSLER	DODGE	Spirit	3.0 L	V6	TBI	EVP/TWC/EGR/CLL	MEXICO	CAR 4 Dr. Sedan
B 008	1G1LT64W8KY218187		1989	GM	CHEVROLET	Corsica	2.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Hatchback/Liftback
B 011	1B3XG24K5KG180041		1989	CHRYSLER	DODGE	Daytona (U.S.)	2.5 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr. Hatchback
B 044	1G2HZ54C2KW215880		1989	GM	PONTIAC	Bonneville SE	3.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 053	1G3NT14DXKM255041		1989	GM	OLDSMOBILE	Cutlass Calais SL	2.3 L	L4	FI	EVP/TWC/CLL	U.S.A.	CAR 2 Door Coupe Sedan
B 055	JM1GD2224L1810193		1990	MAZDA	MAZDA	626	2.2 L	L4	FI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
B 065	1FAPP6046KH126726		1989	FORD	FORD	Thunderbird Std. 2 Dr. Sedan	3.8 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 074	1MEPM6042LH679380		1990	FORD	MERCURY	Cougar 2 Dr. Sedan LS	3.8 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 076	1FACP57U7MA175592		1991	FORD	FORD	Taurus GL 4 Dr Station Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 099	1G3HY14C3KW311671		1989	GM	OLDSMOBILE	Delta 88 Royale Brougham	3.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe Sedan
B 101	1G3CW54C8K4300538		1989	GM	OLDSMOBILE	98 Regency Brougham	3.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 113	1N4GB2253KC735159		1989	NISSAN	NISSAN	Sentra	1.6 L	L4	FI	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR 2dr Sedan
B 119	1G1JF14T4M7133492		1991	GM	CHEVROLET	Cavalier Z24	3.1 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe Sedan
B 140	1MEPM36X2KK620959		1989	FORD	MERCURY	Topaz 4 Dr. Sedan GS 4 WDR	2.3 L	L4	CFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 144	JE3CU36X6KU035123		1989	CHRYSLER	EAGLE	Summit DL	1.6 L	L4	MPI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR Station Wagon (Import)
B 145	1G3NT14D2KM235737		1989	GM	OLDSMOBILE	Cutlass Calais SL	2.3 L	L4	FI	EVP/TWC/CLL	U.S.A.	CAR 2 Door Coupe Sedan
B 159	1G2HX54CXKW259695		1989	GM	PONTIAC	Bonneville LE	3.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 165	2B4GK55R7MR201092		1991	CHRYSLER	DODGE	Dodge Caravan LE	3.3 L	V6	EFI	AIR/EVP/TWC/EGR/CLL	CANADA	MPV Wagon RAT : 05001-06000 GVWR & H
B 167	1YVGD22B0M5125967		1991	MAZDA	MAZDA	626	2.2 L	L4	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan

Table 4-6 (Continued)

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine		Fuel Induction	Emission Control Systems	Country	Comments
B 196	2G1WN14T9L9302959		1990	GM	CHEVROLET	Lumina	3.1 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 2 Door Coupe Sedan
B 236	1B3XG24K4KG153848		1989	CHRYSLER	DODGE	Daytona (U.S.)	2.5 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Dr. Hatchback
B 281	2FAPP35X1MB126332		1991	FORD	FORD	Tempo L 4 Dr. Sedan	2.3 L	L4	CFI	EVP/TWC/EGR/CLL	CANADA	CAR
B 282	1FABP55UXKA153310		1989	FORD	FORD	Taurus L 4 Dr Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 291	1FAPP36XXKK176728		1989	FORD	FORD	Tempo 4 Dr. Sedan GL	2.3 L	L4	CFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 302	1G1LT54T2LY160319		1990	GM	CHEVROLET	Corsica	3.1 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 324	1LNBM81F0KY736595		1989	FORD	LINCOLN	Town Car 4 Dr. Sedan	5.0 L	V8	2 bbl	AIR/EVP/TWC/EGR/CLL	U.S.A.	CAR
B 354	1FAPP36X0KK176575		1989	FORD	FORD	Tempo 4 Dr. Sedan GL	2.3 L	L4	CFI	EVP/TWC/EGR/CLL	U.S.A.	CAR
B 358	1G1AW51W8K6151308		1989	GM	CHEVROLET	Celebrity	2.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 363	1G1JF14T2M7136097		1991	GM	CHEVROLET	Cavalier Z24	3.1 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 2 Door Coupe Sedan
B 370	JN1HJ01P7KT248360		1989	NISSAN	NISSAN	Maxima	2.0 L	V6	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4dr Sedan
B 390	1P3BA46K1KF430173		1989	CHRYSLER	PLYMOUTH	Acclaim	2.5 L	L4	1 bbl	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Dr. Sedan
B 392	2G4WB54T1M1805808		1991	GM	BUICK	Regal Custom	3.1 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
B 414	1G4HR54C3KH422726		1989	GM	BUICK	LeSabre Limited	3.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 431	1G3HN54C7KH300726		1989	GM	OLDSMOBILE	Delta 88 Royale	3.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 433	1G4CW54C6K1517084		1989	GM	BUICK	Electra Park Avenue	3.8 L	V6	FI	EVP/TWC/EGR/CLL	U.S.A.	CAR 4 Door Sedan
B 435	JB3CU14XKKU025841		1989	CHRYSLER	DODGE/MITS	Colt	1.6 L	L4	MPI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 3 Dr. Hatchback (Import)
B 454	2G4WD14W3K1400883		1989	GM	BUICK	Regal Limited	2.8 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 2 Door Coupe Sedan

Table 4-7

Vehicles Solicited But Not Instrumented with 6-Parameter Dataloggers

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine	Fuel Induction	Emission Control Systems	Country	Comments
S 012	1P3XA5635LF774787		1990	CHRYSLER	PLYMOUTH	Acclaim LE	3 0 L V6	TBI	EVP/TWC/EGR/CLL	U S A	CAR 4 Dr Sedan
S 013	1G4NV54U0LM079776		1990	GM	BUICK	Skylark	2 5 L L4	FI	EVP/TWC/EGR/CLL	U S A	CAR 4 Door Sedan
S 016	JM1GD2226L1812401		1990	MAZDA	MAZDA	626	2 2 L L4	FI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr Sedan
S 023	JM1GD2227L1806476		1990	MAZDA	MAZDA	626	2 2 L L4	FI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr Sedan
S 033	1C3XJ41K1LG431532		1990	CHRYSLER	CHRYSLER	Le Baron	2 5 L L4	1 bbl	EVP/TWC/EGR/CLL	U S A	CAR 2 Dr Sedan/Coupe
S 037	1C3XC66R9LD898601		1990	CHRYSLER	CHRYSLER	New Yorker Landau	2 2 L L4 TURBO	FI	AIR/EVP/TWC/EGR/CLL	U S A	CAR 4 Dr Sedan
S 044	1FAPP93J0LW139667		1990	FORD	FORD	Escort 2 Dr. Sedan Hatchback GT	1 9 L L4	EFI	EVP/TWC/EGR/CLL	U S A	CAR
S 049											
S 052	1G1LT54G6LE180304		1990	GM	CHEVROLET	Corsica	2 2 L L4	TBI	AIR/EVP/TWC/EGR/CLL	U S A	CAR 4 Door Sedan
S 056	JA3CR46V2LZ041788		1990	MITSUBISHI	MITSUBISHI	Galant	2 0 L L4	MPI		JAPAN	CAR
S 057	1B3XC5639LD718780		1990	CHRYSLER	DODGE	Dynasty LE (U.S.)	3 0 L V6	TBI	EVP/TWC/EGR/CLL	U S A	CAR 4 Dr Sedan
S 062	1G1LT54G8LY249993		1990	GM	CHEVROLET	Corsica	2 2 L L4	TBI	AIR/EVP/TWC/EGR/CLL	U S A	CAR 4 Door Sedan
S 065	JT2AE92E6J3034861		1988	TOYOTA	TOYOTA	Corolla	1 5 L L4	2 bbl	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr Sedan
S 068	JT3VN39WXL0023696		1990	TOYOTA	TOYOTA	Van 4x4	3 0 L V6	EFI	AIR/EVP/TWC/EGR/CLL	JAPAN	MPV MPV
S 071	1C3XC66R5LD858645		1990	CHRYSLER	CHRYSLER	New Yorker Landau	2 2 L L4 TURBO	FI	AIR/EVP/TWC/EGR/CLL	U S A	CAR 4 Dr Sedan
S 074	1LNCM92EXLY703010		1990	FORD	LINCOLN	Mark VII Bass 2 Dr Coupe	5 0 L V8	EFI	AIR/EVP/TWC/EGR/CLL	U S A	CAR
S 077	2FACP73F4LX149931		1990	FORD	FORD	LTD Crown Victoria 4 Dr. Sedan	5 0 L V8	2 bbl	AIR/EVP/TWC/EGR/CLL	CANADA	CAR
S 080	1P4FH44R0LX303404		1990	CHRYSLER	PLYMOUTH	Plymouth Voyager	3 3 L V6	EFI		U S A	MPV Extended Wagon RAT 04001-05000 GVWR & H
S 081	1FTCR14X1LPA46236	No	1990	FORD	FORD	Taurus					CAR
S 084	1B3XP48K1LN166561		1990	CHRYSLER	DODGE	Shadow	2 5 L L4	1 bbl	EVP/TWC/EGR/CLL	U S A	CAR 4 Dr Hatchback
S 095	1G3WS54T9LD395198		1990	GM	OLDSMOBILE	Cutlass Supreme SL	3 1 L V6	FI	EVP/TWC/EGR/CLL	U S A	CAR 4 Door Sedan
S 101	1FAPP959XLW190029		1990	FORD	FORD	Escort 4 Dr Sedan Hatchback LX	1 9 L L4	2 bbl	EVP/TWC/EGR/CLL	U S A	CAR
S 111	1G3WS54TXLD375651		1990	GM	OLDSMOBILE	Cutlass Supreme SL	3 1 L V6	FI	EVP/TWC/EGR/CLL	U S A	CAR 4 Door Sedan
S 113											
S 123	1G3WH54T8LD351674		1990	GM	OLDSMOBILE	Cutlass Supreme	3 1 L V6	FI	EVP/TWC/EGR/CLL	U S A	CAR 4 Door Sedan
S 124	JHMCB7662LC076249		1990	HONDA	HONDA	Accord	2 0 L L4	FI		JAPAN	CAR 4dr Sedan (auto)
S 145	1FAC052U1LG214289	No	1990	FORD	FORD	Taurus GL 4 Dr. Wagon	3 0 L V6	EFI	EVP/TWC/EGR/CLL	U S A	CAR
S 149	3G4AH54NXLS613221		1990	GM	BUICK	Century Custom	3 3 L V6	FI	EVP/TWC/CLL	MEXICO	CAR 4 Door Sedan
S 153	JT2VV22W8L0101238		1990	TOYOTA	TOYOTA	Camry	2 5 L V6	EFI		JAPAN	CAR 4x4 Wagon
S 157	2G1WN54T2L1150707		1990	GM	CHEVROLET	Lumina Eurosport	3 1 L V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
S 161	1G3AJ54N5L6319366		1990	GM	OLDSMOBILE	Cutlass Ciera	3 3 L V6	FI	EVP/TWC/CLL	U S A	CAR 4 Door Sedan
S 162	1G3WR54TXL0373223	No	1990	GM	OLDSMOBILE	Cutlass Supreme Inter.	3 1 L V6	FI	EVP/TWC/EGR/CLL	U S A	CAR 4 Door Sedan
S 170											
S 183	1G1LT54G2LE134260		1990	GM	CHEVROLET	Corsica	2 2 L L4	TBI	AIR/EVP/TWC/EGR/CLL	U S A	CAR 4 Door Sedan
S 188	1FACP52U7LG149271		1990	FORD	FORD	Taurus GL 4 Dr. Wagon	3 0 L V6	EFI	EVP/TWC/EGR/CLL	U S A	CAR
S 192	1G3NL54U3LM758872		1990	GM	OLDSMOBILE	Cutlass Calais	2 5 L L4	FI	EVP/TWC/EGR/CLL	U S A	CAR 4 Door Sedan
S 198	1FACP5345LG123282		1990	FORD	FORD	Taurus LX 4 Dr. Wagon	3 8 L V6	EFI	EVP/TWC/EGR/CLL	U S A	CAR
S 199	1G1FP23T7LL133597		1990	GM	CHEVROLET	Camaro Sport	3 1 L V6	FI	EVP/TWC/EGR/CLL	U S A	CAR 2 Door Hatchback/Liftback
S 202	1MEPM6047L8619434		1990	FORD	MERCURY	Cougar 2 Dr. Sedan LS	3 8 L V6	EFI	EVP/TWC/EGR/CLL	U S A	CAR
S 216	1MECM50U7LG630755		1990	FORD	MERCURY	Sable 4Dr. Sedan GS	3 0 L V6	EFI	EVP/TWC/EGR/CLL	U S A	CAR
S 230	1G1LT54G1LY208139		1990	GM	CHEVROLET	Corsica	2 2 L L4	TBI	AIR/EVP/TWC/EGR/CLL	U S A	CAR 4 Door Sedan
S 231	2G1WL54R7L9128388		1990	GM	CHEVROLET	Lumina	2 5 L L4	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
S 242	1FACP52U1LG262150		1990	FORD	FORD	Taurus GL 4 Dr. Wagon	3 0 L V6	EFI	EVP/TWC/EGR/CLL	U S A	CAR

Table 4-7 (Continued)

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine		Fuel Induction	Emission Control Systems	Country	Comments
B 003	.											
B 004	2G4WD14W7K1435099		1989	GM	BUICK	Regal Limited	2.8 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 2 Door Coupe Sedan
B 006	1B3BA76J4KF443588		1989	CHRYSLER	DODGE	Spirit LE, ES	2.5 L	L4 TURBO	1 bbl	EVP/TWC/EGR/CLL	USA	CAR 4 Dr. Sedan
B 009	1G2NE14D3KC752033		1989	GM	PONTIAC	Grand Am LE	2.3 L	L4	FI	EVP/TWC/CLL	USA	CAR 2 Door Coupe Sedan
B 013	1YVGD22B9M5123943		1991	MAZDA	MAZDA	626	2.2 L	L4	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Dr. Sedan
B 014	1FABP44A6KF128781		1989	FORD	FORD	Mustang LX 2 Dr Sedan Convertible	2.3 L	L4	1 bbl	EVP/TWC/EGR/CLL	USA	CAR
B 025	.											
B 026	2G1WN54T0L9311377		1990	GM	CHEVROLET	Lumina Eurosport	3.1 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
B 028	2B4FK25K7KR269211		1989	CHRYSLER	DODGE	Dodge Caravan	2.5 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	CANADA	MPV Wagon RAT : 04001-05000 GVWR & H
B 040	2FABP74F8KX183167		1989	FORD	FORD	LTD Crown Victoria LX 4 Dr. Sedan	5.0 L	V8	2 bbl	AIR/EVP/TWC/EGR/CLL	CANADA	CAR
B 043	1FACP57U3MA155663		1991	FORD	FORD	Taurus GL 4 Dr Station Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 045	JM1BG2262M0228959		1991	MAZDA	MAZDA	Protege 4 Dr. Sedan	1.6 L	L4	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
B 046	1FABP50U8KA177987		1989	FORD	FORD	Taurus L 4 Dr. Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 047	2G4WB14LXM1861528		1991	GM	BUICK	Regal Custom	3.8 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 2 Door Coupe Sedan
B 056	.											
B 060	1N4GB22S8KC733973		1989	NISSAN	NISSAN	Sentra	1.6 L	L4	FI	AIR/EVP/TWC/EGR/CLL	USA	CAR 2dr Sedan
B 073	1MEBM55U2KA601525		1989	FORD	MERCURY	Sable 4Dr Stn Wgn GS	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 080	1LNBM83FXKY727917		1989	FORD	LINCOLN	Town Car Carber 4 Dr. Sedan	5.0 L	V8	2 bbl	AIR/EVP/TWC/EGR/CLL	USA	CAR
B 082	1G1AW81W6K6214925		1989	GM	CHEVROLET	Celebrity	2.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Station Wagon
B 087	1G3HN54C6KW357480		1989	GM	OLDSMOBILE	Delta 88 Royale	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 089	1G2HX54C4L1219871		1990	GM	PONTIAC	Bonneville LE	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 090	1G3WH14TXMD308045		1991	GM	OLDSMOBILE	Cutlass Supreme	3.1 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Coupe Sedan
B 091	1G4HP54C1MH431160		1991	GM	BUICK	LeSabre Custom	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 092	1G3HN54C7MH335477		1991	GM	OLDSMOBILE	Delta 88 Royale	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 094	1N4GB21S8KC733988		1989	NISSAN	NISSAN	Sentra	1.6 L	L4	FI	AIR/EVP/TWC/EGR/CLL	USA	CAR 4dr Sedan
B 106	1G1LT53T4MY110010		1991	GM	CHEVROLET	Corsica	3.1 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 107	1G2WH54T9MF200743		1991	GM	PONTIAC	Grand Prix LE	3.1 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 108	1G4AL51N1KT476385		1989	GM	BUICK	Century Limited	3.3 L	V6	FI	EVP/TWC/CLL	USA	CAR 4 Door Sedan
B 109	1G2HX54C9KW206714		1989	GM	PONTIAC	Bonneville LE	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 112	1G4NC54N0KM038312		1989	GM	BUICK	Skylark Custom (4-DR)	3.3 L	V6	FI	EVP/TWC/CLL	USA	CAR 4 Door Sedan
B 118	1G1JC111KK3195751		1989	GM	CHEVROLET	Cavalier	2.0 L	L4	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Coupe Sedan
B 136	1LNCM81W8MY714826		1991	FORD	LINCOLN	Town Car 4 Dr. Sedan	4.6 L	V8	EFI	AIR/EVP/TWC/EGR/CLL	USA	CAR
B 142	1FABP52U2KA150753		1989	FORD	FORD	Taurus GL 4 Dr. Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 154	1G3WH54T6MD326808		1991	GM	OLDSMOBILE	Cutlass Supreme	3.1 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 157	1G3HN54C0MH308981		1991	GM	OLDSMOBILE	Delta 88 Royale	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 173	.											
B 187	1G4AL51N1KT466805		1989	GM	BUICK	Century Limited	3.3 L	V6	FI	EVP/TWC/CLL	USA	CAR 4 Door Sedan
B 188	1G3AJ51N6KG330762		1989	GM	OLDSMOBILE	Cutlass Ciera	3.3 L	V6	FI	EVP/TWC/CLL	USA	CAR 4 Door Sedan
B 189	JN1HJ01P0LT376777		1990	NISSAN	NISSAN	Maxima	2.9 L	V6	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4dr Sedan
B 192	1G1LV13T6MY139222		1991	GM	CHEVROLET	Beretta	3.1 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Coupe Sedan
B 194	1G2NE54U6MC527177		1991	GM	PONTIAC	Grand Am LE	2.5 L	L4	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 197	1G1JF11WXK7174673		1989	GM	CHEVROLET	Cavalier Z24	2.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Coupe Sedan
B 198	1G4CW54C7K1839319		1989	GM	BUICK	Electra Park Avenue	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 199	1G2WJ54T1MF245132		1991	GM	PONTIAC	Grand Prix	3.1 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 201	1G3HY14C2KW368282		1989	GM	OLDSMOBILE	Delta 88 Royale Brougham	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Coupe Sedan
B 211	1MEPM60T2MH631632		1991	FORD	MERCURY	Cougar 2 Dr. Sedan LS	5.0 L	V8	EFI	AIR/EVP/TWC/EGR/CLL	USA	CAR
B 212	1B3XG24K7KG107124		1989	CHRYSLER	DODGE	Daytona (U.S.)	2.5 L	L4	1 bbl	EVP/TWC/EGR/CLL	USA	CAR 2 Dr. Hatchback
B 213	1G3AJ51N2KG325381		1989	GM	OLDSMOBILE	Cutlass Ciera	3.3 L	V6	FI	EVP/TWC/CLL	USA	CAR 4 Door Sedan
B 214	1P4GH54R0MX579766		1991	CHRYSLER	PLYMOUTH	Plymouth Voyager	3.3 L	V6	EFI	EVP/TWC/EGR/CLL	USA	MPV Extended Wagon RAT 05001-06000 GVWR & H
B 216	3G4AH54NXMS603113		1991	GM	BUICK	Century Custom	3.3 L	V6	FI	EVP/TWC/CLL	MEXICO	CAR 4 Door Sedan
B 218	1G2JC14K0M7585174		1991	GM	PONTIAC	Sunbird	2.0 L	L4	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Coupe Sedan
B 219	2G4WD54LXM1855715		1991	GM	BUICK	Regal Limited	3.8 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
B 220	1B3XA4630MF564988		1991	CHRYSLER	DODGE	Spirit	3.0 L	V6	TBI	EVP/TWC/EGR/CLL	USA	CAR 4 Dr. Sedan
B 221	1G4HR54C8MH401146		1991	GM	BUICK	LeSabre Limited	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 222	1G1JC111XKJ215111		1989	GM	CHEVROLET	Cavalier	2.0 L	L4	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Coupe Sedan
B 223	1G4AH51N7KG406800		1989	GM	BUICK	Century Custom	3.3 L	V6	FI	EVP/TWC/CLL	USA	CAR 4 Door Sedan
B 224	1G2FS23T0ML212481		1991	GM	PONTIAC	Firebird	3.1 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Hatchback/Liftback
B 226	2G1WL54T1M9113477		1991	GM	CHEVROLET	Lumina	3.1 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
B 227	.											
B 230	1G3AJ51W7KG320122		1989	GM	OLDSMOBILE	Cutlass Ciera	2.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 232	1G3NF54N4KM270366		1989	GM	OLDSMOBILE	Cutlass Calais S	3.3 L	V6	FI	EVP/TWC/CLL	USA	CAR 4 Door Sedan
B 235	1G4NV54N1MM259987		1991	GM	BUICK	Skylark	3.3 L	V6	FI	EVP/TWC/CLL	USA	CAR 4 Door Sedan
B 248	1FACP50U4LA153137		1990	FORD	FORD	Taurus L 4 Dr. Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 249	1FABP54Y4KA190602		1989	FORD	FORD	Taurus SHO	3.8 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 254	1MEPM6040KH624702		1989	FORD	MERCURY	Cougar 2 Dr. Sedan LS	3.8 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR

Table 4-7 (Continued)

Sample Number	VIN	VIN Confirmed by Decoder	Model Year	Manufacturer	Make	Model	Engine		Fuel Induction	Emission Control Systems	Country	Comments
B 257												
B 258	JN1HJ01P4LT430681		1990	NISSAN	NISSAN	Maxima	2.9 L	V6	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4dr Sedan
B 260	1LNLM9645KY673685		1989	FORD	LINCOLN	Continental Givenchy 4 Dr. Sedan	3.8 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 268	2G4WD54L4M1844158		1991	GM	BUICK	Regal Limited	3.8 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
B 270	1G4HR54C3MH445510		1991	GM	BUICK	LeSabre Limited	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 288	1FAPP6045KH163835		1989	FORD	FORD	Thunderbird Std 2 Dr. Sedan	3.8 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 289	JN1HJ01P6KT240078		1989	NISSAN	NISSAN	Maxima	2.9 L	V6	FI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 4dr Sedan
B 290	1G4HP54C1MH424337		1991	GM	BUICK	LeSabre Custom	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 294	1MEPM6041KH604264		1989	FORD	MERCURY	Cougar 2 Dr. Sedan LS	3.8 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 295	1G3AJ51N9KG340220		1989	GM	OLDSMOBILE	Cutlass Ciera	3.3 L	V6	FI	EVP/TWC/CLL	USA	CAR 4 Door Sedan
B 298	1LNBM81F0KY640370		1989	FORD	LINCOLN	Town Car 4 Dr. Sedan	5.0 L	V8	2 bbl	AIR/EVP/TWC/EGR/CLL	USA	CAR
B 299	1FAPP36X6KK153561		1989	FORD	FORD	Tempo 4 Dr. Sedan GL	2.3 L	L4	CFI	EVP/TWC/EGR/CLL	USA	CAR
B 307	1G1LV14W6KY180794		1989	GM	CHEVROLET	Beretta	2.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Coupe Sedan
B 316	1G3AJ51N7KG332410		1989	GM	OLDSMOBILE	Cutlass Ciera	3.3 L	V6	FI	EVP/TWC/CLL	USA	CAR 4 Door Sedan
B 320	1MEBM55U9KA632819		1989	FORD	MERCURY	Sable 4Dr. Stn Wgn GS	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 323	1FABP55U1KA106599		1989	FORD	FORD	Taurus L 4 Dr Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 326	1C3XY56R3LD910804		1990	CHRYSLER	CHRYSLER	Imperial	2.2 L	L4 TURBO	FI	AIR/EVP/TWC/EGR/CLL	USA	CAR 4 Dr. Sedan
B 327	1P3XA5630MF541808		1991	CHRYSLER	PLYMOUTH	Acclaim LE	3.0 L	V6	TBI	EVP/TWC/EGR/CLL	USA	CAR 4 Dr. Sedan
B 328	2MEPM36X5K8608556		1989	FORD	MERCURY	Topaz 4 Dr. Sedan GS 4 WDR	2.3 L	L4	CFI	EVP/TWC/EGR/CLL	CANADA	CAR
B 330	1FABP52U4KA146986		1989	FORD	FORD	Taurus GL 4 Dr. Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 331	1G3HN54C2KW334147		1989	GM	OLDSMOBILE	Delta 88 Royale	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 332	2G3AJ54N8M2333118		1991	GM	OLDSMOBILE	Cutlass Ciera	3.3 L	V6	FI	EVP/TWC/CLL	CANADA	CAR 4 Door Sedan
B 333	1FABP50D1KG155127		1989	FORD	FORD	Taurus L 4 Dr. Wagon	2.5 L	L4	CFI	AIR/EVP/TWC/EGR/CLL	USA	CAR
B 334	2G4WB54T2M1415297		1991	GM	BUICK	Regal Custom	3.1 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
B 336	1G4AH54N4M6415191		1991	GM	BUICK	Century Custom	3.3 L	V6	FI	EVP/TWC/CLL	USA	CAR 4 Door Sedan
B 339	1YVGD22B9M5105315		1991	MAZDA	MAZDA	626	2.2 L	L4	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Dr. Sedan
B 340	1FABP5346KA149225		1989	FORD	FORD	Taurus LX 4 Dr. Wagon	3.8 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 341	1B3XP28D2MN554504		1991	CHRYSLER	DODGE	Shadow	2.2 L	L4	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Dr. Hatchback
B 342	1YVGD22B6M5125617		1991	MAZDA	MAZDA	626	2.2 L	L4	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Dr. Sedan
B 357	2B4FK25K6KR225698		1989	CHRYSLER	DODGE	Dodge Caravan	2.5 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	CANADA	MPV Wagon RAT 04001-05000 GVWR & H
B 372	1C3BC6637KD543222		1989	CHRYSLER	CHRYSLER	New Yorker Landau	3.0 L	V6	TBI	EVP/TWC/EGR/CLL	USA	CAR 4 Dr. Sedan
B 374	1G4AH51N6KT421352		1989	GM	BUICK	Century Custom	3.3 L	V6	FI	EVP/TWC/CLL	USA	CAR 4 Door Sedan
B 391	1G2HX54CXKW263004		1989	GM	PONTIAC	Bonneville LE	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 393	1G4HR54C1MH474455		1991	GM	BUICK	LeSabre Limited	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 394	1G3HN54C2KW324623		1989	GM	OLDSMOBILE	Delta 88 Royale	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 396	2G1WL54T3L9124656		1990	GM	CHEVROLET	Lumina	3.1 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 4 Door Sedan
B 397	1G1JF11W0K7173824		1989	GM	CHEVROLET	Cavalier Z24	2.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Coupe Sedan
B 399	1N4GB22S1KC768337		1989	NISSAN	NISSAN	Sentra	1.6 L	L4	FI	AIR/EVP/TWC/EGR/CLL	USA	CAR 2dr Sedan
B 400	1G3HN54C0KH300390		1989	GM	OLDSMOBILE	Delta 88 Royale	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 401	1G4HP54C1KH536052		1989	GM	BUICK	LeSabre Custom	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 403	1G3AJ51W0KG317014		1989	GM	OLDSMOBILE	Cutlass Ciera	2.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 405	1G1AW81WXK6166023		1989	GM	CHEVROLET	Celebrity	2.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Station Wagon
B 408	1G1LW14W4KY160895		1989	GM	CHEVROLET	Beretta	2.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Door Coupe Sedan
B 412	JP3CU24X2KU050690		1989	CHRYSLER	PLYMMITSI	Colt, E, DL, Prem	1.6 L	L4	MPI	AIR/EVP/TWC/EGR/CLL	JAPAN	CAR 3 Dr. Hatchback (Import)
B 415	1G4AH51N2KT474159		1989	GM	BUICK	Century Custom	3.3 L	V6	FI	EVP/TWC/CLL	USA	CAR 4 Door Sedan
B 417	1G3CX54C7L4358932		1990	GM	OLDSMOBILE	Ninety-Eight Regency	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 421	JM1NA351XM1221420		1991	MAZDA	MAZDA	MX5 Miata	1.6 L	L4	FI	EVP/TWC/EGR/CLL	JAPAN	CAR Convertible
B 422	1G3HN54C2KW346470		1989	GM	OLDSMOBILE	Delta 88 Royale	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 429	2G4WB14T1K1462869		1989	GM	BUICK	Regal Custom	3.1 L	V6	FI	EVP/TWC/EGR/CLL	CANADA	CAR 2 Door Coupe Sedan
B 434	JM1BG2264M0206204		1991	MAZDA	MAZDA	Protege	1.8 L	L4	EFI	EVP/TWC/EGR/CLL	JAPAN	CAR 4 Dr. Sedan
B 439	1G3CX54C8K1329939		1989	GM	OLDSMOBILE	Ninety-Eight Regency	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 443	1G4HR54C0KH463458		1989	GM	BUICK	LeSabre Limited	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 450	1P3BP44D5KN555699		1989	CHRYSLER	PLYMOUTH	Sundance	2.2 L	L4	FI	EVP/TWC/EGR/CLL	USA	CAR 2 Dr. Hatchback
B 453	1G4HP54C5MH469696		1991	GM	BUICK	LeSabre Custom	3.8 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan
B 457	1FACP52U2LA242346		1990	FORD	FORD	Taurus GL 4 Dr. Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 461	1FACP50U9MA194624		1991	FORD	FORD	Taurus L 4 Dr. Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 462	2FABP74F0KX230689		1989	FORD	FORD	LTD Crown Victoria LX 4 Dr. Sedan	5.0 L	V8	2 bbl	AIR/EVP/TWC/EGR/CLL	CANADA	CAR
B 479	1B3BC5635KD446505		1989	CHRYSLER	DODGE	Dynasty LE (U.S.)	3.0 L	V6	TBI	EVP/TWC/EGR/CLL	USA	CAR 4 Dr. Sedan
B 480	2B4FK45K4KR249381		1989	CHRYSLER	DODGE	Dodge Caravan	2.5 L	L4	EFI	AIR/EVP/TWC/EGR/CLL	CANADA	MPV Wagon RAT : 04001-05000 GVWR & H
B 481	2P4FH45J0KR252752		1989	CHRYSLER	PLYMOUTH	Plymouth Voyager	2.5 L	L4 TURBO	FI	AIR/EVP/TWC/EGR/CLL	CANADA	MPV Wagon RAT : 04001-05000 GVWR & H
B 483	1FACP53UXMG138796		1991	FORD	FORD	Taurus LX 4 Dr. Wagon	3.0 L	V6	EFI	EVP/TWC/EGR/CLL	USA	CAR
B 343A	1LNCM83WXMY684364		1991	FORD	LINCOLN	Town Car Cartier 4 Dr. Sedan	4.6 L	V8	EFI	AIR/EVP/TWC/EGR/CLL	USA	CAR
B 354A	1G1LT54T7LY262991		1990	GM	CHEVROLET	Corsica	3.1 L	V6	FI	EVP/TWC/EGR/CLL	USA	CAR 4 Door Sedan

4.4 Factors Affecting the Data

In addition to the vehicle and driver factors already described that could affect the driving pattern data, weather conditions could also affect the way people drive. As part of this study, an effort was made to document pavement conditions during the days vehicles were driving with instrumentation on-board.

Table 4-8 summarizes the estimated driving conditions in Spokane and Baltimore. The table gives the solicitor's estimate of the pavement condition for each day of instrumentation. Because there were some days where the solicitor did not document pavement conditions, the National Climatic Data Center (NCDC) meteorological data collected at the Spokane Airport and downtown Baltimore are also shown. The Spokane Airport is on a plateau above the city of Spokane, which is in a valley; therefore, the meteorological data at the airport and the actual road conditions in the city do not necessarily agree. In addition, it is likely that drivers who had instrumented vehicles did not drive only in the city of Spokane, but may have driven to surrounding areas, including to Mt. Spokane, where snow was present during the study.

Data from the downtown Baltimore station is probably representative of conditions at the Baltimore City station, which is two miles north of downtown, but not necessarily of the Baltimore County station, which is 10 miles north-northeast of downtown Baltimore. In addition, it is likely that drivers who had instrumented vehicles did not drive only in the city of Baltimore, but may have driven to surrounding areas -- most notably to Washington, D.C.

Table 4-8 shows NCDC meteorological data for precipitation, snowfall, and snow depth in inches. The overall estimates of pavement condition given in Table 4-8 are based on the solicitor's observations and on the NCDC data.

Table 4-8
Road Condition Estimates

City	Date	Solicitor Observations		NCDC Meteorological Data			Overall Estimate of Pavement Condition
		Pavement Condition	Comments	Precipitation (in.)	Snowfall (in.)	Snow Depth (in.)	
Spokane	03Feb92	Dry	Sunny, 35	0	0	0	Dry
Spokane	04Feb92	Dry	Sunny, 40	0	0	0	Dry
Spokane	05Feb92	Dry	Foggy, 30	<0.005	<0.05	0	Dry
Spokane	06Feb92	Dry	Sunny, 30	0	0	0	Dry
Spokane	07Feb92	Dry	Sunny, 35	0.08	0	0	Dry
Spokane	08Feb92	Wet	Rainy, 35	0.17	1.4	0	Wet
Spokane	09Feb92	.	.	<0.005	0	<0.5	Dry
Spokane	10Feb92	Dry	Sunny, 30	0	0	0	Dry
Spokane	11Feb92	Dry	Sunny, 38	<0.005	0	0	Dry
Spokane	12Feb92	Wet	Cloudy, 35, streets damp	<0.005	0	0	Dry
Spokane	13Feb92	Wet	Cloudy, 38, streets damp	0.03	0	0	Dry
Spokane	14Feb92	Wet	Rainy, 38	0	0	0	Dry
Spokane	15Feb92	Dry	Sunny, 40	0.02	0	0	Dry
Spokane	16Feb92	.	.	0	0	0	Dry
Spokane	17Feb92	.	.	0.09	<0.05	0	Dry
Spokane	18Feb92	Wet	Rainy, 34	0.66	<0.05	0	Wet
Spokane	19Feb92	Wet	Sunny, 36, streets damp	0.01	<0.05	0	Dry
Spokane	20Feb92	Wet	Rainy, 34	0.44	<0.05	0	Wet
Spokane	21Feb92	Wet	Cloudy, 38, streets damp	0.06	0	0	Dry
Spokane	22Feb92	.	.	<0.005	0	0	Dry
Spokane	23Feb92	.	.	0.11	0	0	Dry
Spokane	24Feb92	.	.	0.09	0	0	Dry
Spokane	25Feb92	.	.	<0.005	0	0	Dry
Spokane	26Feb92	.	.	0	0	0	Dry
Spokane	27Feb92	.	.	0	0	0	Dry
Spokane	28Feb92	.	.	<0.005	0	0	Dry
Spokane	29Feb92	.	.	<0.005	0	0	Dry
Spokane	01Mar92	.	.	0.10	0	0	Dry
Spokane	02Mar92	.	.	0.005	0	0	Dry

Table 4-8
(Continued)

City	Date	Solicitor Observations		NCDC Meteorological Data			Overall Estimate of Pavement Condition
		Pavement Condition	Comments	Precipitation (in.)	Snowfall (in.)	Snow Depth (in.)	
Baltimore	05Mar92	Dry	Cloudy	0	0	0	Dry
Baltimore	06Mar92	Dry	Morning fog, drizzly afternoon	0.07	0	0	Dry
Baltimore	07Mar92	Wet	Rainy	0.85	0	0	Wet
Baltimore	08Mar92	.	.	0	0	0	Dry
Baltimore	09Mar92	Dry	Sunny	0	0	0	Dry
Baltimore	10Mar92	Dry	Sunny	0.09	0	0	Dry
Baltimore	11Mar92	Dry	Flurries, high winds	0	2.8	0	Dry
Baltimore	12Mar92	Dry	Sunny, cold	0	0	0	Dry
Baltimore	13Mar92	Dry	Sunny, windy	0	0	0	Dry
Baltimore	14Mar92	Dry	Sunny	0	0	0	Dry
Baltimore	15Mar92	.	.	0	0	0	Dry
Baltimore	16Mar92	Dry	Sunny	0	0	0	Dry
Baltimore	17Mar92	Icy/Wet	Morning sleet, afternoon rain	0	0	0	Dry
Baltimore	18Mar92	Dry	Sunny	0.45	0	0	Wet
Baltimore	19Mar92	Icy/Wet	Rain/sleet	0.2	0	0	Wet
Baltimore	20Mar92	Dry	Sunny	0	0	0	Dry
Baltimore	21Mar92	Dry	Sunny	0	0	0	Dry
Baltimore	22Mar92	.	.	0.2	0	0	Wet
Baltimore	23Mar92	Dry	Sunny	0	0	0	Dry
Baltimore	24Mar92	Dry	Sunny	0	0	0	Dry
Baltimore	25Mar92	Dry	Sunny	0.03	0	0	Dry
Baltimore	26Mar92	Wet	Rainy	1.89	0	0	Wet
Baltimore	27Mar92	.	.	0.01	0	0	Dry
Baltimore	28Mar92	.	.	0	0	0	Dry
Baltimore	29Mar92	.	.	0	0	0	Dry
Baltimore	30Mar92	.	.	0	0	0	Dry
Baltimore	31Mar92	.	.	0	0	0	Dry
Baltimore	01Apr92	.	.	0.06	0	0	Dry
Baltimore	02Apr92	.	.	0	0	0	Dry

5.0 DATA QUALITY CHECKING AND ARCHIVING

The next step after collecting field data is checking the data quality and archiving it in a suitable format in preparation for data analysis. These activities include writing computer programs to highlight suspect data points for manual inspection, manual inspection of the data, editing the data, and writing computer programs to convert the raw and edited data into SAS data sets for analysis.

In this section, the data quality checking methodology is outlined and sample plots are used to describe the method. The rules developed during the data quality check are summarized and the results of the data quality check are presented.

5.1 Data Quality Checking Methodology

Checking of data quality was intended to be accomplished as soon as possible after the field data arrived for each vehicle. Because of the rate at which the data arrived in Austin and the large amount of work required to check it for each vehicle, data from the field for almost all the vehicles were examined many days after arrival. Nevertheless, validation and inspection of the data for the first few cars was used to detect systematic problems in the installation and removal of dataloggers and transducers in the field.

In general, the data from the field were checked using a multiple step methodology that combined highlighting suspect data points using SAS software programs with manual editing and examination of graphical output by engineering personnel. Figure 5-1 shows a flow diagram of the steps used to check the quality of the raw data and to load it into the final edited SAS data files. The following discussion presents the details of the activities outlined in Figure 5-1.

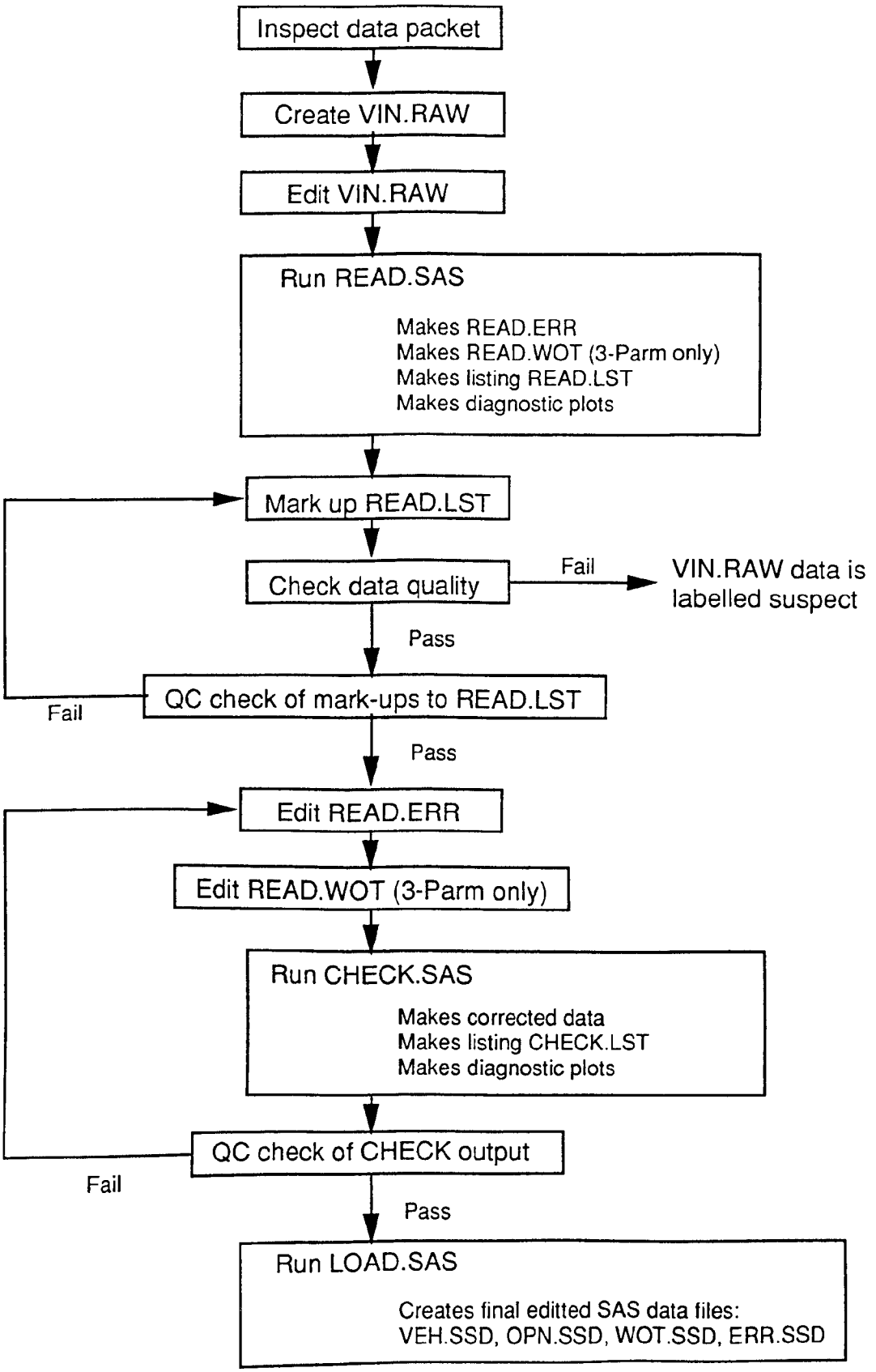


Figure 5-1. Data Quality Checking Methodology

The raw data for each vehicle were received in Austin from the field on 3½-inch floppy disks. The data had been compressed in the field using ARJ software. With the floppy disk was a photocopy of the data packet used in the field.

The first step in checking the data quality was to inspect the data packet. This inspection indicated whether the installation and removal of datalogging equipment on the vehicle had been successful and whether the data had been successfully downloaded from the datalogger. Any difficulties with the instrumentation of the vehicle were noted in the data packet.

The compressed data from the floppy disk was uncompressed, again using ARJ software and an ASCII file was created. The name of the file was made up of the last eight digits of the vehicle identification number. For the purposes of this discussion, VIN.RAW will indicate raw data files. This file was placed on the mainframe computer for data quality checking and conversion to SAS format. The raw data file was examined using an editor to determine if any obvious errors could be found. In a few instances, the beginning of the data file was corrected where spurious keystrokes were mistakenly inserted by data downloading personnel. The second-by-second numerical data were briefly reviewed and, in all but a few cases, were found to be clean.

The next major step in the data quality checking methodology was to run each of the VIN.RAW files through a SAS program called READ.SAS. READ.SAS was written to make several diagnostic checks of the raw data, to present the results of the driving patterns to engineering personnel in a way that would highlight suspect values, and to create files that could be used to correct the raw data files when personnel decided that individual logged values needed to be corrected. READ.SAS makes two files, a listing, and several diagnostic plots. The two files are READ.ERR and READ.WOT.

READ.ERR contained a listing of all of the values that READ.SAS considered suspect, based on criteria in the READ.SAS program. The logged values five seconds before and five seconds after suspect data points were also included in READ.ERR so that the editing personnel could use surrounding data information to judge the suspect data value. The suspect data values and their neighboring values are called a group. The criteria that READ.SAS used to flag suspect data values are given in Tables 5-1 and 5-2 for 3-parameter and 6-parameter data, respectively. The READ.ERR files contained the logged data values in duplicate columns. This permitted the second of the columns to be edited to the correct values, so that when the READ.ERR file was merged with the raw data file, the corrections would be applied to the raw data file without disturbing the original values in the raw data file. In this way, the corrected data could be analyzed; however, if an investigator wants to examine the edits made to the raw data to get the corrected data, he can examine READ.ERR, because it contains both the original suspect values and the values they were changed to.

READ.SAS also made a file called READ.WOT. These files were made for the 3-parameter data only, and the files contained all observations made when the datalogger was in the calibration mode. That is, whenever the installation and removal crew were driving the vehicle, the data logged under those circumstances were put in the READ.WOT file. During the calibration drive during installation and during the removal drive, wide-open throttles were performed. The READ.WOT files were later edited so they contained only the vehicle data obtained during wide-open throttle operation. These files would be useful for evaluating how the vehicle driver drove the vehicle, compared with a measure of the ultimate performance of the vehicle.

READ.SAS also created a listing file that contained a number of diagnostic aids. This included a listing of any parity errors that may have occurred in the data as logged on the datalogger, a comparison of the difference in time between the time stamp at the beginning of a trip and the time stamp at the end of a trip with the number of seconds of observations between the time stamps, a listing of the start and end of each

Table 5-1

Suspect Observation Flagging Parameters for 3-Parameter Data

$\lvert Accel \rvert > 4\ m/s^2$
$\lvert \Delta\ RPM \rvert > 1400$ rpm/s
$\lvert \Delta\ MAP \rvert > 60$ kPa/s
Speed > 40 m/s
RPM > 6000 rpm
RPM < 300 rpm
MAP < 10 kPa
MAP > 100 kPa
The first or last speed of a trip > 0 m/s.
Speed = 0 m/s and RPM = 0 rpm
MAP > 80 kPa and Speed = 0 m/s

Table 5-2

Suspect Observation Flagging Parameters for 6-Parameter Data

|Accel| > 8.95 mph/s (4 m/s^2)	
|Δ RPM| > 1400 rpm/s	
Speed > 89.5 mph (40 m/s)	
RPM > 6000 rpm	
RPM < 300 rpm	
For MAP systems:	MAP < 10 kPa MAP > 100 kPa |Δ MAP| > 60 kPa
For MAF systems:	MAF > 500
For LV8 systems:	LV8 > 255
Throttle position > 103%	
Throttle position < -3%	
Coolant Temperature > 150°C	
Coolant Temperature < -25°C	
|Δ Coolant Temperature| > 20°C/s	
ϕ > 1.5	
ϕ < 0.5 when Throttle Position > 15%	
The last speed of a trip > 1 mph.	

trip for all the trips, summary statistics on speed, RPM, manifold absolute pressure, acceleration, change in RPM, and change in manifold absolute pressure, a listing of all the suspect data values found in the file, and a listing of all the groups associated with each suspect data value. This group listing was similar to the READ.ERR file, but included additional diagnostic aids that identified the start and end of each trip and the suspect observation.

Finally, READ.SAS made diagnostic plots for the data file. A copy of the diagnostic plots for READ.SAS for one vehicle appear in Appendix A. This series of plots is for a vehicle with a 3-parameter datalogger. Figure A-1 is a plot of the number of groups, identified as having suspect data values, versus the date and time. The uncalibrated speed in meters per second for the vehicle during the installation calibration drive is given in Figure A-2. Note that the speed during the first half of the drive pins at 40.95 m/s because the speed transducer had not yet been calibrated. The second half of the calibration drive contains a wide-open throttle acceleration. Figure A-3 shows the removal drive, during which there is an additional wide-open throttle acceleration. Wide-open throttle accelerations can be determined by consulting the time recorded for the wide-open throttle acceleration in the data packet and by considering the manifold absolute pressure logged in the data file.

The number and time of occurrence of the trips are given in Figures A-4 and A-5, versus date and time and cumulative engine-on time, respectively. The date and time of trips during the entire instrumentation period of approximately a week can be seen in Figure A-6. Spaces between the vertical peaks usually indicate periods when the engine was not operating. Figure A-7 shows vehicle speed versus cumulative engine-on time. This plot does not show any engine-off time; therefore, horizontal lines at zero speed indicate idles. Engine RPM versus cumulative engine-on time is given in Figure A-8. Data values at engine starts and stops sometimes went to zero RPM. These can be seen in the figure as spikes pointing towards zero. In the data editing process, these values were removed from the beginning and end of trips.

The trend of manifold absolute pressure with cumulative engine-on time is shown in Figure A-9. Values around 20 kPa represent a throttle that is mostly closed, and values near 100 kPa represent operation with the throttle mostly open. Values that spike towards 0 kPa can occur at the beginning and end of trips. These are routinely edited out in the data quality checking process. Vehicle acceleration was computed by subtracting adjacent speed values and plotting in Figure A-10 versus cumulative engine-on time. An acceleration of zero represents driving at a constant speed or idling, whereas positive values mean an acceleration and negative values mean a deceleration. The rate of change of engine RPM is plotted in Figure A-11. The rate of change of manifold absolute pressure is plotted in Figure A-12. Figure A-13 shows the second derivative of speed, which is the jerk.

Three additional diagnostic plots were used to examine vehicle and engine operation between pairs of parameters. In Figure A-14, the acceleration plotted against the speed shows the regime of vehicle operation on the road. Because of the characteristics of transmissions, higher accelerations can be obtained at low speeds, when the transmission is in a low gear, whereas at high speeds more moderate accelerations are typical, because the transmission is in a high gear. This behavior produces a characteristic triangular shape in the acceleration vs. speed plots, which was seen throughout the data of all the vehicles. Figure A-15 shows a plot of engine RPM versus manifold absolute pressure. The region of high density data between 20 and 100 kPa and between 1000 and 3000 rpm was typical of most vehicles in the data sets. Turbocharged vehicles frequently had manifold absolute pressures that exceeded atmospheric pressure (100 kPa). These high pressures were correctly logged by the dataloggers. In Figure A-16, the ratio of speed to RPM was plotted against vehicle speed. The ratio of speed to RPM is proportional to the overall gear ratio of the vehicle at different speeds. In the example shown in the figure, the vehicle had a 5-speed manual transmission. This is characterized in the figure by data that lie on 5 horizontal lines. Close examination of the data indicates the speeds at which shifts were made as speed increased.

The same approach was used to validate and identify suspect data values in the 6-parameter data.

All of these diagnostic plots were used to determine if outliers in the data existed. The same plots were made using later programs in the data quality checking methodology and compared with these first plots to determine if the data edits improved the visual appearance of the data as plotted.

Following these diagnostic plots, additional plots were made of the logged data for each group of data values surrounding suspect data values. These plots enabled the data editor to visualize the region around suspect data values and to suggest the best way to handle suspect data values.

The outputs from READ.SAS were used by data file editors to consider the suspect value observations flagged by READ.SAS. If the editor thought a change was justified, he marked the second printed value in the listing READ.LST. The guidelines used to help the editor make these decisions are reviewed in Section 5.2. The data editor considered the diagnostic plots and the diagnostics given at the beginning of the READ.LST listing. The basic concept followed was that logged values that were reasonably possible for the vehicle to produce were left alone. If it was judged that the logged values were not possible, they were either changed to estimates of the correct values or changed to missing values.

If, in the judgment of the data quality checking team, the logged data exhibited characteristics that would bias the overall results of the study and that were not possible to check without fabricating a considerable amount of data, the entire file for that vehicle was considered suspect. These files were set aside and not considered further. Thus, all of the data presented and analyzed for this final report are the cleanest and most reliable data collected in the study. In the future, the suspect files will

be re-examined to determine if portions of the data can be recovered for inclusion in the data set.

After the initial markup of the READ.LST listing, a second data editor made a quality control check of the markups to the listing. If the second editor disagreed with some of the markups, a conference on the data file was held. Otherwise, the data file passed to the next step of editing.

In the next step, the marked up READ.LST listing was used by the file editor to make edits on the computer to the READ.ERR file. In addition, the file editor examined the READ.WOT files and the data packets and determined which portion of that file represented the best example of wide-open throttle accelerations for the calibration drive during installation and the calibration drive during removal of the datalogging equipment. Since wide-open throttle accelerations were performed only on vehicles equipped with 3-parameter dataloggers, this edit could only be performed for 3-parameter data. The identity of the wide-open throttle accelerations in the data was determined by the rate of increase of vehicle speed, an elevated manifold absolute pressure, and the time recorded in the data packet by the drivers performing the wide-open throttle acceleration. All other driving data obtained during the calibration drives were deleted from the READ.WOT files.

In the next step of the data quality control checking process, another program called CHECK.SAS was run. This program took the raw data in VIN.RAW and the edits made to READ.ERR and READ.WOT and produced a corrected data file, which includes all the edits. In addition, CHECK.SAS made all of the same diagnostic checks that were included in READ.SAS and produced a listing called CHECK.LST and all of the same diagnostic plots. The purpose of these diagnostic aids was to enable the data editing team to ensure that the edits to the data entered in READ.ERR were made correctly and were reasonable.

Accordingly, the data editing team took the outputs of CHECK.SAS and examined them by considering them by themselves and also by comparing them with the outputs of READ.SAS to see if improvements were made. If the examination determined that additional edits needed to be made, the READ.ERR file was re-edited and CHECK.SAS was run again until the data editing team was satisfied.

In the final stage of the data quality checking process, a program called LOAD.SAS created the final edited SAS data files in the required data archiving format, which is described in Section 5.3. The data for all vehicles were concatenated with each other and the units of the recorded values were made consistent for both 3-parameter and 6-parameter data.

5.2 Data Correction Guidelines

The criteria used to decide if an individual data value was reasonable or unreasonable were developed as the data quality checking procedures were taking place. This was done because before any data were collected, the types of data value errors and their characteristics were not known. The characteristics of the 3-parameter datalogger and the 6-parameter datalogger were different. In addition, some modifications to the 3-parameter datalogger software were made between the Spokane and Baltimore trips. These modifications changed and improved the characteristics of the data collected in Baltimore.

The sections that follow present, in some detail, the guidelines used to edit the data for the Spokane 3-parameter, the Baltimore 3-parameter, and the 6-parameter datalogging systems. It was found that many of the suspect data values occurred during engine startup and engine shutdown; therefore, the criteria used by the dataloggers to determine the beginning and end of data logging episodes is important to outline before discussing the data editing criteria. The criteria were described in Section 2.1.1.

5.2.1 Guidelines for Spokane 3-Parameter Data Editing

The following guidelines were used to edit the data obtained from the 3-parameter dataloggers used in Spokane and from the first 11 3-parameter vehicles (S002, S007, S010, S016, S017, S019, S037, S048, S050, S052, and S066) instrumented in Baltimore.

Speed

1. For driving episodes with nearly constant speed, constant RPM, and constant MAP, when a sudden drop in speed occurs for one second followed by a resumption of the previous speed or a speed close to it, the speed spike value was replaced by an interpolation of the points adjacent to it.

2. A characteristic speed spike was observed in the Spokane 3-parameter data and was linked to the datalogger software. This error is characterized by a speed about 2.7 times the actual speed for one observation and then by a speed about 0.61 times the actual speed for the next observation. When the spike produced an acceleration value in excess of 4 m/s^2, these incorrect values were replaced by corrected values calculated from the logged values divided by their corresponding correction factor. This error occurred once approximately every 20,000 seconds of driving.

3. For a non-zero speed value at the beginning or end of a trip adjacent to other non-zero speeds, the speed value was left unchanged.

4. For a non-zero speed value at the beginning or end of a trip adjacent to two or more zero speed values, the speed value was considered to be a startup or shutdown spike and was set to zero.

5. If the first speed value at the beginning of a trip was large (>5 m/s) and was followed by non-zero speeds that were much lower, the first speed value was considered to be a startup spike of unknown true value and was changed to a missing value.

6. If the end of a trip had two or more non-zero speed values preceded by zero speed values, all values were left alone.

7. A datalogger shutdown that resulted in one or more seconds of lost data could be identified by examining the vehicle and engine speeds at the suspected end of trip and corresponding beginning of the next trip. If the speed was non-zero and the RPM was idle rpm or greater, then this was probably a datalogger shutdown error. If the engine RPM dropped below idle (<500 rpm) and the MAP went to atmospheric pressure, then the vehicle may have stalled, and this could not be considered a datalogger error. But if the MAP was still low, the datalogger was probably shut off because of a low quality RPM signal.

RPM

1. If the RPM value was greater than 2500 rpm for the first observation at the beginning of a trip and then the RPM value dropped to normal idle (≤1000 rpm), the RPM value was considered to be a startup spike. It is unlikely that such high RPMs would be experienced for an engine for only one second at startup. This error was changed to a missing value because the real RPM was unknown.

2. A characteristic RPM spike was observed in the Spokane 3-parameter data and was linked to the datalogger software. This error was characterized by an RPM about 2.7 times the actual RPM for one observation and then by an RPM about 0.61 times the actual RPM for the next observation. When the spike produced an RPM charge greater than 1400 rpm/s, these incorrect values were replaced by corrected values calculated from the logged values, divided by their corresponding correction factor. This error occurred once approximately every 20,000 seconds of driving.

MAP

1. If there was a very low MAP (<5 kPa) during the first second of a trip followed by an MAP near atmospheric pressure, the first MAP data value was considered a datalogger startup spike and was changed to a missing value.

2. A MAP value was flagged if the absolute value of the change in MAP was greater than 60 kPa/s. Such a MAP change could occur

frequently during shifting while accelerating and general revving of the engine to avoid a stall. The MAP change should be accompanied by a similar pattern in RPM. If it was not, and the MAP change occurred for one second only, then it was considered a MAP spike. In this case, the MAP value was changed to a missing value.

5.2.2 Guidelines for Baltimore 3-Parameter Editing

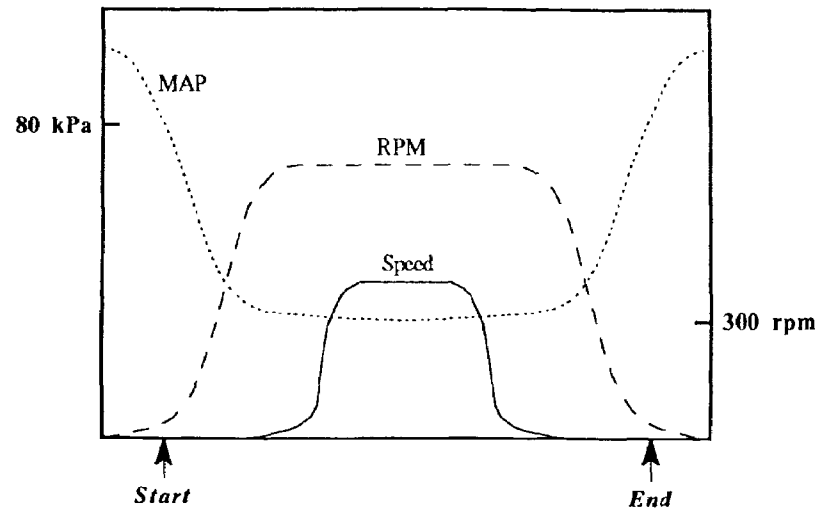
The following guidelines were used in addition to the guidelines used for the Spokane data for all Baltimore 3-parameter data except for data from the first 11 Baltimore 3-parameter vehicles.

1. If the RPM was less than 300 rpm for a few seconds at the beginning of a trip, these observations for all parameters were deleted from the file.

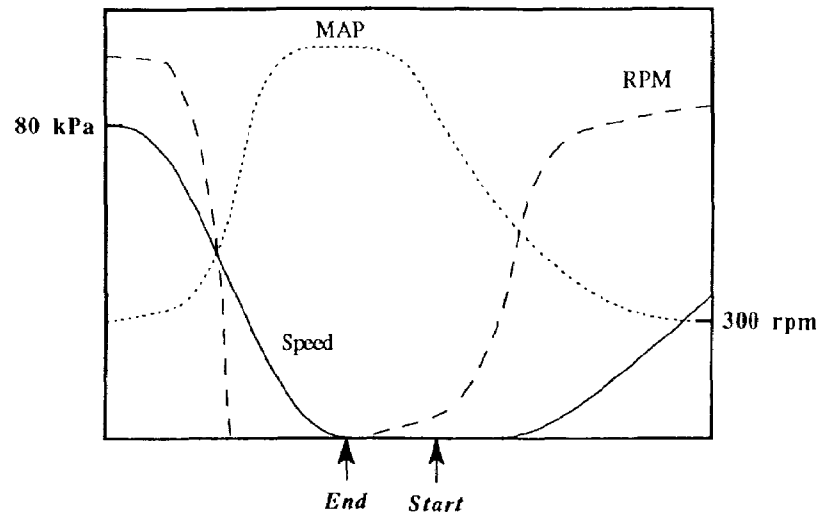
2. If at the end of a trip, RPM equaled 0 rpm and speed equaled 0 m/s and MAP was rising, the entire observation was deleted for all parameters. In this case, the vehicle had been shut off, but the MAP had not reached atmospheric pressure yet.

Logic used for the 3-parameter datalogger in Baltimore produced a slightly different kind of data for the beginning and end of trips than that produced by the 3-parameter datalogger in Spokane and the 6-parameter datalogger. This can be illustrated by considering a number of different shutdown and startup scenarios, all of which were observed in the Baltimore data.

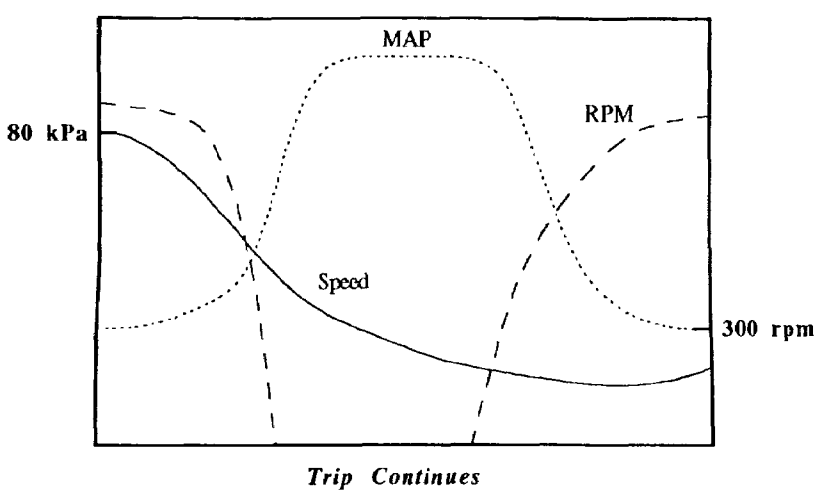
The most common beginning and end of a trip are shown in Figure 5-2a. For a normal trip, the datalogger turns on as soon as the manifold absolute pressure drops below 80 kPa. A short time after this occurs, the engine RPM increases from the cranking RPM up to idle RPM. When the driver begins moving the vehicle, speed increases above 0.1 m/s, and the vehicle is in motion. At the end of a trip, the driver



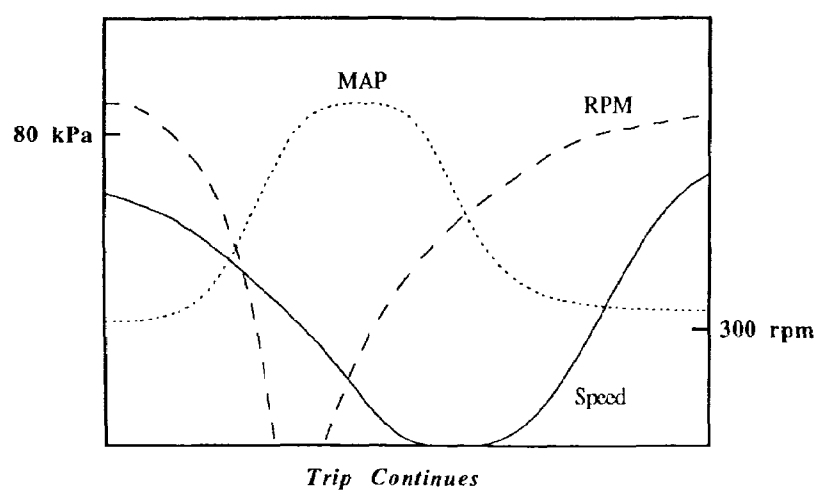
a) A normal trip



b) Coasting with engine off



c) Engine dies and is restarted with no stop of motion



d) Engine dies and is restarted, but motion stops only after a restart

Figure 5-2. Vehicle/Engine Operating Scenarios Relevant to Datalogger Operation

stops the vehicle and turns off the engine. During this period, vehicle speeds drops below 0.1 m/s, the RPM drops abruptly below 300 rpm; however, the MAP may still be below 80 kPa. Thus, the end of the datalogging period occurs when the MAP exceeds 80 kPa. Thus, it is clear under a normal circumstance that it is actually the MAP that is turning the datalogger on and off. One advantage of this logic is that it allows the data to be collected during cranking of the engine. Subsequent examination of the data can determine whether the engine was started on the first cranking attempt or whether it required several cranking attempts. If the MAP is connected improperly to the datalogger or the MAP sensor does not respond, trip beginning and end will be determined by the RPM signal exceeding 300 rpm. Finally, if the RPM signal is unreliable or not working, the actual motion of the vehicle can start the datalogger, as provided for by the logic in the datalogger program.

Figure 5-2b shows another type of driving behavior that was observed in the Baltimore data on several occasions. Some drivers either deliberately or accidentally experienced an engine shutdown while the vehicle was still in motion. Some time later, the engine was restarted and another trip began. Figure 5-2b shows that for the Baltimore 3-parameter datalogger, the end of the datalogging episode would occur when the speed of the vehicle became less than 0.1 m/s. The datalogger would start again when the cranking of the engine caused the MAP to drop below 80 kPa. For the 6-parameter datalogger and for the 3-parameter datalogger in Spokane, the end of the trip would be somewhat different, since it was controlled by the engine RPM dropping below 300. A shutdown of the datalogger at this point would result in a non-zero speed at the end of the trip. An editor examining such data would not be able to determine whether the vehicle had coasted after the datalogger shut down or whether the data values for the speed were not accurate at all. With the 3-parameter datalogger in Baltimore, the speed of the vehicle could be followed as it coasted down with the engine off to the end of the trip.

Another type of event that happened on a few occasions in Baltimore is shown in Figure 5-2c. In this instance, the engine died while the vehicle was in motion. However, the engine was restarted before the vehicle came to a complete stop. Because of this, the 3-parameter datalogger in Baltimore did not turn off at all. In the data checking process, this was viewed as a continuation of an existing trip. For the 6-parameter datalogger and the 3-parameter datalogger in Spokane, this same situation would have been recorded as the end of one trip and the beginning of another trip. However, both the speeds at the end of the trip and the beginning of the next trip would be non-zero. This would have been viewed with concern by the data checking team, since what happened between those two events was not logged and could not be known.

A more unusual scenario is shown in Figure 5-2d. In this instance, the engine died and the vehicle began slowing down, but the driver of the vehicle was able to restart the engine before the vehicle came to a stop. But the vehicle did come to a stop after the engine was restarted. Again in this instance, the Baltimore 3-parameter datalogger did not shut down during this event because at all times at least one of the three sensors was in the running state. If the 3-parameter Spokane datalogger or the 6-parameter datalogger had experienced this situation, it would have recorded the end of the one trip and the beginning of another trip when engine RPM passed through 300 rpm.

These examples show that the beginning and the end of a trip is not always a clear-cut event. But whatever the event may be, the logic used for the Baltimore 3-parameter datalogger was able to record the information throughout such events so that the investigator could determine what was happening to the automobile.

5.2.3 Guidelines for 6-Parameter Data Editing

The 6-parameter datalogger did not experience problems at the beginning of trips because of datalogger startup transients, because the 6-parameter datalogger did

not record any values for all six parameters during the first five seconds after engine startup. In addition, the equivalence ratio determined by the exhaust system oxygen sensor did not record any data on the datalogger for the first 60 seconds after engine startup. All of these data points are represented as missing values in the data files.

The following guidelines were used to edit the 6-parameter data:

1. If any one of the six parameters displayed a spike at the end of a trip, the spike value was replaced with a missing value.

2. If the end of trip speed was non-zero and it was preceded by larger non-zero speed values, the speed value was left alone.

3. If the end of trip speed value was non-zero and it was preceded by two or more zero speeds, the value was changed to zero.

4. If more than one of the six parameters displayed a spike at the end of a trip, the entire last observation of the trip was deleted. This type of spike value set was observed frequently, and it was presumably the result of datalogger shutdown transients at the end of trips.

5. If the value of the equivalence ratio for the last second of a trip had a spike value near 2.3, the entire last second of the trip was deleted, since this value for equivalence ratio indicated that the datalogger was in the process of shutting down and values for other parameters would not be reliable.

6. If RPM, MAP, and throttle position were all relatively constant and the equivalence ratio changed significantly ($\Delta\phi > 0.3/s$), the value of the equivalence ratio was replaced by an interpolation of adjacent values.

7. Spikes in equivalence ratio occurring during transients of the other five parameters were left alone, because it was not known what the response of equivalence ratio would be during transient behavior of the vehicle.

5.3 Data Archiving Format

Running the SAS program LOAD.SAS produced four SAS data set files that contain all of the driving pattern data. The four files are the vehicle file, the operation file, the wide-open throttle file, and the error file. These four files were analyzed to produce the desired results of this study.

The data archiving formats of these four files are given in Table 5-3. The files have the same formats for both 3-parameter and 6-parameter data. For data that do not exist because of the type of datalogger on which they were obtained, the values for observations will have missing values designated by a period in accordance with SAS protocol. For example, data observations collected on the 3-parameter datalogger will always have missing values for throttle closed position voltage, throttle open position voltage, MAF, LV8, throttle position, coolant temperature, and equivalence ratio.

The vehicle file (VEH.SSD) contains descriptions of the test vehicles that were instrumented. The file contains one observation for each vehicle. Thus, the vehicle file has 216 observations. The VIN in all four files is the parameter used to connect the four files for data analysis. The VIN in these files is the VIN as it was read from the vehicle in the field. Many of the field VINs have transcription errors. The correct VINs were determined after returning from the field, but the VINs in the data files were left uncorrected to avoid database problems. The corrected VINs are given elsewhere in this document. The model year, make, model, transmission type, and odometer reading have values determined by the on-site personnel when they inspected the vehicle. Load measurement type has a value of MAP, MAF, or LV8, depending on which type of load was used by the datalogging system. MAP was the load measurement type for all 3-parameter logged data. The 6-parameter datalogging system used any of the three load measurement types. The throttle closed position voltage and the throttle open position voltage were recorded in the data packets for 6-parameter datalogger

Table 5-3

Data Archiving Formats

VEHICLE FILE (VEH.SSD)

- Sample ID
- VIN
- Model Year
- Make
- Model
- Transmission Type
- Initial Odometer Reading
- Load Measurement Type (MAP, MAF, or LV8)
- Throttle Closed Position Voltage (mV)
- Throttle Open Position Voltage (mV)

OPERATION FILE (OPN.SSD)

- VIN
- Date (DDMMMYY)
- Local Time (HH:MM:SS)
- Speed (miles/hour)
- RPM (rpm)
- MAP (kPa)
- MAF (kg/hr)
- LV8 (8 bit MAF)
- Throttle Position (%)
- Coolant Temperature (°C)
- Equivalence Ratio

WIDE OPEN THROTTLE FILE (WOT.SSD)

- VIN
- Date (DDMMMYY)
- Local Time (HH:MM:SS)
- Speed (miles/hour)
- RPM (rpm)
- MAP (kPa)
- MAF (kg/hr)
- LV8 (8-bit MAF)
- Throttle Position (%)
- Coolant Temperature (°C)
- Equivalence Ratio

Table 5-3

(Continued)

ERROR FILE (ERR.SSD)

- VIN
- Local Time (DDMMMYY:HH:MM:SS)
- Error Flag
- Group
- Logged Speed (m/s)
- Logged RPM (rpm)
- Logged MAP (kPa)
- Logged MAF (kg/hr)
- Logged LV8 (8-bit MAF)
- Logged Throttle Position (%)
- Logged Coolant Temperature (°C)
- Logged Equivalence Ratio
- Corrected Speed (m/s)
- Corrected RPM (rpm)
- Corrected MAP (kPa)
- Corrected MAF (kg/hr)
- Corrected LV8 (8-bit MAF)
- Corrected Throttle Position (%)
- Corrected Coolant Temperature (°C)
- Corrected Equivalence Ratio
- Record Deletion Flag

installations for the purpose of converting the logged throttle position voltage to percent throttle position.

The operation file (OPN.SSD) is the largest file of the four files and contains 6,940,411 observations for the 216 vehicles. The parameters contained in this file are shown in Table 5-3. The parameter called LV8 is General Motors' measurement of MAF. It has values from 0 to 255 and is an 8-bit representation of relative mass airflow.

The data collected on the 3-parameter datalogger during the installation and removal drives by the study team were distinguished during data collection by a flag in the raw data. Thus, the data present in the operations file for 3-parameter dataloggers are only the data logged by the normal driver of the vehicle.

The 6-parameter dataloggers used a special procedure to avoid collecting driving data made by the crew during installation and removal of the dataloggers. For the GM datalogger, the operations data was erased just after the datalogger installation and calibration check had been completed and just before the vehicle was released to the owner for the one-week data collection period. At the end of the one-week period, the removal crew removed the datalogger without driving the vehicle. For the non-GM dataloggers, the installation drives were made with the memory modules disconnected. Just before release of the vehicle to the driver, the datalogger internal memory was erased of operations data and the empty memory modules were connected to the datalogger. At the end of the one-week period, the memory modules were disconnected without driving the vehicle.

The wide-open throttle file (WOT.SSD) contains the vehicle operation data obtained during wide-open throttle accelerations of 3-parameter-instrumented vehicles. For most of these vehicles, two wide-open throttles were recorded. The format of this file is exactly the same as the format of the operation file. There is no wide-open

throttle acceleration data for any of the 6-parameter instrumented vehicles, since the 6-parameter datalogging system was not able to distinguish between calibration driving and vehicle owner driving.

The error file (ERR.SSD) is not used directly in the analysis of the data. Instead, it is a documentation of the changes made to the raw data by the data quality checking team. It contains the VIN and the time of each suspect group, which was made up of each observation that was flagged and the surrounding observations. Each group contains all of the parameters as they were logged and all of the parameters as they were corrected during quality checking. When an entire parameter for a vehicle file was changed to a missing value (for example, if all the MAPs were changed to missing values), the corrected values are not part of the error file. Instead, this information is given in Section 5.4 for all of the vehicles.

5.4 Results of Data Quality Checking

For each of the 293 data files produced by each of the instrumented vehicles, the data quality checking methodology was used. At one point in that methodology, the quality of the data was judged to be good or suspect for each vehicle file. The results of this decision and the reason for labelling certain data files suspect are given in Table 5-4. In addition, for a number of data files which were judged to be good, some of the parameters were found to be unreliable and were therefore changed to missing values for the entire data file. This is also shown in the table. Overall, the table shows that of the 293 instrumented vehicles, 216 vehicles, or 74%, contained data judged to be entirely reasonable.

The data analysis for this study was performed on data from the 216 vehicles. In the future, the data for the suspect vehicle data files will be re-examined to determine if the data can be made good by judicious editing.

Table 5-4

Summary of Data Quality Checking

Sample Number	Logger Type	Changed to Missing Values in Database					Reason for Labelling Suspect
		RPM	MAP	Coolant Temp.	Throttle Position	Equiv. Ratio	
S002	3						Good speed data
S003	6		X				Good speed data
S004	3						Good speed data
S005	3	NA	NA	NA	NA	NA	No data in logger; RPM = 0 all the time.
S006	6						Good speed data
S007	6					X	Odd end of trips
S008	3						Good speed data
S011	3						Good speed data
S014	6		X				Good speed data
S015	3						Good speed data
S018	3						Good speed data
S019	6		X				Good speed data
S024	3						Good speed data
S025	3	NA	NA	NA	NA	NA	Uncalibrated datalogger
S027	3	X					Good speed data
S028	6		X				Good speed data
S030	3	NA	NA	NA	NA	NA	Datalogger shut off in mid-trip
S036	3						Good speed data
S038	3						Good speed data
S040	6		X				Good speed data
S041	3						Good speed data
S042	6	NA	NA	NA	NA	NA	Noise in speed at idle
S043	3	NA	NA	NA	NA	NA	Numerous speed spikes
S045	6		X				Good speed data
S046	3						Good speed data
S047	6						Good speed data
S048	3						Good speed data
S050	3						Good speed data
S051	6		X				Good speed data
S053	6						Good speed data
S054	3						Good speed data
S055	3						Good speed data
S058	6	NA	NA	NA	NA	NA	Noise in speed at idle
S061	3						Good speed data
S063	6		X				Good speed data
S066	3	NA	NA	NA	NA	NA	Logger shutoff during trip
S067	3						Good speed data
S069	3						Good speed data
S070	6						Good speed data
S072	3						Good speed data
S073	3						Good speed data
S076	3	NA	NA	NA	NA	NA	Numerous speed spikes. Engine misfiring
S078	3						Good speed data
S079	3	NA	NA	NA	NA	NA	Speed fluctuates in an uncorrectable manner
S082	6	NA	NA	NA	NA	NA	Noise in speed at idle
S088	3						Good speed data
S089	6						Good speed data
S090	3						Good speed data
S092	6						Good speed data
S093	6						Good speed data

Table 5-4
(Continued)

Sample Number	Logger Type	Changed to Missing Values in Database					Reason for Labelling Suspect
		RPM	MAP	Coolant Temp.	Throttle Position	Equiv. Ratio	
S094	3						Good speed data
S096	3	NA	NA	NA	NA	NA	Lost speed calibration
S097	6						Good speed data
S098	6		X				Good speed data
S100	3						Good speed data
S103	3						Good speed data
S105	3						Good speed data
S107	6						Good speed data
S108	3	NA	NA	NA	NA	NA	Memory turning off in mid-trip
S109	6		X				Good speed data
S110	3	NA	NA	NA	NA	NA	Speed fluctuation. Lost speed calibration
S112	3						Good speed data
S114	3						Good speed data
S117	3						Good speed data
S118	3						Good speed data
S119	6		X				Good speed data
S120	3						Good speed data
S122	3	NA	NA	NA	NA	NA	Shuts off in mid-trip. Speed sensitivity high
S125	6	NA	NA	NA	NA	NA	Noise in speed at idle
S126	3						Good speed data
S127	6		X				Turns off in mid-trip
S128	3						Good speed data
S129	6		X				Good speed data
S130	3	NA	NA	NA	NA	NA	Turns off in mid-trip. Holes in speed data
S131	6		X	X	X	X	Good speed data
S132	3	NA	NA	NA	NA	NA	Many speed problems
S133	6						Good speed data
S134	3		X				Good speed data
S135	3						Good speed data
S137	3						Good speed data
S138	3						Good speed data
S143	3						Good speed data
S144	3						Good speed data
S146	3	NA	NA	NA	NA	NA	Holes in speed data. Turns off in mid-trip
S147	3						Good speed data
S148	6						Good speed data
S150	6	NA	NA	NA	NA	NA	Noise in speed at idle
S152	3	NA	NA	NA	NA	NA	Logger turns off every five seconds
S154	3	NA	NA	NA	NA	NA	Noise in speed at idle
S156	3						Good speed data
S158	3						Good speed data
S160	3	NA	NA	NA	NA	NA	Noise in speed at idle
S163	3						Good speed data
S164	6		X				Good speed data
S165	3						Good speed data
S167	3						Good speed data
S169	3						Good speed data
S172	3						Good speed data
S175	3						Good speed data
S176	3						Good speed data

Table 5-4

(Continued)

Sample Number	Logger Type	Changed to Missing Values in Database					Reason for Labelling Suspect
		RPM	MAP	Coolant Temp.	Throttle Position	Equiv. Ratio	
S177	6						Good speed data
S178	3						Good speed data
S179	3						Good speed data
S180	3						Good speed data
S181	6		X				Good speed data
S184	3						Good speed data
S187	3						Good speed data
S189	3	NA	NA	NA	NA	NA	Logger shut off during 2 trips
S194	3						Good speed data
S196	3	NA	NA	NA	NA	NA	Logger shutdown from RPM drop below 300
S197	3						Good speed data
S200	3						Good speed data
S201	6		X				Good speed data
S203	3						Good speed data
S204	3	NA	NA	NA	NA	NA	Noise in speed at idle
S205	3						Good speed data
S206	6	NA	NA	NA	NA	NA	Noise in speed at idle
S207	3	NA	NA	NA	NA	NA	Logger turns off in mid-trip; Noise in speed.
S209	3						Good speed data
S210	6	NA	NA	NA	NA	NA	Speed sensor went bad at ~11000th sec.
S211	3						Good speed data
S212	3						Good speed data
S214	3						Good speed data
S215	6	NA	NA	NA	NA	NA	No disk
S217	6		X				Good speed data
S218	3						Good speed data
S219	3						Good speed data
S220	6	NA	NA	NA	NA	NA	Noise in speed at idle
S221	3						Good speed data
S222	3						Good speed data
S224	3						Good speed data
S226	3	NA	NA	NA	NA	NA	Numerous speed spikes
S227	3						Good speed data
S229	3						Good speed data
S233	3	NA	NA	NA	NA	NA	Noise in speed at idle
S235	3						Good speed data
S236	6						Good speed data
S238	3	NA	NA	NA	NA	NA	Noise in speed at idle
S239	3						Good speed data
S240	3	NA	NA	NA	NA	NA	Noise in speed input at all speeds
S241	3						Good speed data
S243	6						Good speed data
S244	3	NA	NA	NA	NA	NA	Noise in speed at idle
S246	3	NA	NA	NA	NA	NA	Noise in speed at idle
B002	3						Good speed data
B005	6						Good speed data
B007	3	NA	NA	NA	NA	NA	Noise in speed
B008	6						Good speed data
B010	3						Good speed data
B011	6						Good speed data

Table 5-4
(Continued)

Sample Number	Logger Type	Changed to Missing Values in Database					Reason for Labelling Suspect
		RPM	MAP	Coolant Temp.	Throttle Position	Equiv. Ratio	
B016	3						Good speed data
B017	3						Good speed data
B019	3						Good speed data
B037	3						Good speed data
B039	3						Good speed data
B042	3						Good speed data
B044	6		X				Good speed data
B048	3	NA	NA	NA	NA	NA	Logger shut off a lot
B050	3						Good speed data
B052	3						Good speed data
B053	6						Good speed data
B055	6		X				Good speed data
B058	3						Good speed data
B059	3						Good speed data
B062	3						Good speed data
B065	6	NA	NA	NA	NA	NA	Noise in speed at idle
B066	3						Good speed data
B072	3						Good speed data
B074	6						Good speed data
B076	6	NA	NA	NA	NA	NA	Noise in speed at idle
B079	3	NA	NA	NA	NA	NA	Noise in speed
B081	3						Good speed data
B084	3						Good speed data
B086	3						Good speed data
B088	3						Good speed data
B098	3		X				Good speed data
B099	6		X				Good speed data
B101	6		X				Logger shuts off
B104	3	NA	NA	NA	NA	NA	No data on disk
B105	3						Good speed data
B110	3	NA	NA	NA	NA	NA	No data on disk
B113	6		X				Good speed data
B117	3	NA	NA	NA	NA	NA	No data on disk
B119	6		X				Good speed data
B123	3						Good speed data
B124	3		X				Good speed data
B130	3						Good speed data
B139	3						Good speed data
B140	6						Good speed data
B143	3		X				Good speed data
B144	6						Good speed data
B145	6						Logger shuts off
B150	3						Good speed data
B153	3						Good speed data
B156	3						Good speed data
B159	6		X				Logger shuts off
B163	3		X				Good speed data
B164	3						Good speed data
B165	6						Good speed data
B167	6		X				Good speed data

Table 5-4

(Continued)

Sample Number	Logger Type	Changed to Missing Values in Database					Reason for Labelling Suspect
		RPM	MAP	Coolant Temp.	Throttle Position	Equiv. Ratio	
B169	3						Good speed data
B178	3	X					Good speed data
B184	3						Good speed data
B190	3	X					Good speed data
B191	3						Good speed data
B193	3						Good speed data
B195	3						Good speed data
B196	6						Logger shuts off
B206	3						Good speed data
B207	3	NA	NA	NA	NA	NA	Noise in speed
B208	3		X				Good speed data
B210	3						Good speed data
B217	3	NA	NA	NA	NA	NA	Noise in speed
B233	3	X					Good speed data
B236	3						Good speed data
B238	6	NA	NA	NA	NA	NA	No disk
B241	3	NA	NA	NA	NA	NA	Noise in speed
B243	3						Good speed data
B247	3						Good speed data
B255	3						Good speed data
B256	3	NA	NA	NA	NA	NA	0.8g accels unbelievable
B263	3	NA	NA	NA	NA	NA	Noisy speed. Excursions to 40.95m/s
B268	3		X				Good speed data
B269	3	NA	NA	NA	NA	NA	Abrupt high speed at trip starts.
B273	3						Good speed data
B275	3		X				Good speed data
B280	3	NA	NA	NA	NA	NA	Noisy speed
B281	6	NA	NA	NA	NA	NA	Noise in speed at idle
B282	6	NA	NA	NA	NA	NA	Noise in speed at idle
B286	3		X				Good speed data
B287	3						Good speed data
B291	6	NA	NA	NA	NA	NA	Noise in speed at idle
B293	3	NA	NA	NA	NA	NA	Speed Bad
B297	3						Good speed data
B301	3	NA	NA	NA	NA	NA	Spikes in speed
B302	6		X				Good speed data
B314	3						Good speed data
B315	3						Good speed data
B317	3						Good speed data
B319	3						Good speed data
B324	6	NA	NA	NA	NA	NA	Noise in speed at idle
B325	3	NA	NA	NA	NA	NA	Parity errors
B329	3						Good speed data
B337	3						Good speed data
B338	3		X				Good speed data
B344	3						Good speed data
B350	3						Spikes & noise in speed
B351	3						Good speed data
B354	6						Good speed data
B358	6						Good speed data

Table 5-4

(Continued)

Sample Number	Logger Type	Changed to Missing Values in Database					Reason for Labelling Suspect
		RPM	MAP	Coolant Temp.	Throttle Position	Equiv. Ratio	
B361	3	X					Good speed data
B363	6						Good speed data
B365	3		X				Good speed data
B367	3						Good speed data
B368	3	X					Good speed data
B369	3		X				Good speed data
B370	6		X				Good speed data
B371	3						Good speed data
B375	3						Good speed data
B376	3						Good speed data
B381	3	X					Good speed data
B386	3		X				Good speed data
B389	3						Good speed data
B390	6						No disk
B392	6						Good speed data
B395	3						Good speed data
B398	3						No speed calibration
B406	3						Good speed data
B410	3						Good speed data
B413	3						Good speed data
B414	6		X				Logger shuts off
B419	3						Good speed data
B420	3	X					Good speed data
B424	3	NA	NA	NA	NA	NA	Speed noise
B426	3	NA	NA	NA	NA	NA	Very jerky speed transducer
B428	3	NA	NA	NA	NA	NA	Speed spiking
B431	6		X				Logger shuts off
B433	6		X				Logger shuts off
B435	6						Good speed data
B436	3		X				Good speed data
B438	3						Good speed data
B441	3						Good speed data
B445	3	X					Good speed data
B447	3		X				Good speed data
B451	3						Good speed data
B452	3	NA	NA	NA	NA	NA	Noisy speed for a period of time
B454	6						Good speed data
B460	3						Good speed data
B466	3	NA	NA	NA	NA	NA	No speed reading
B467	3	X					Good speed data
B468	3						Good speed data
B472	3						Good speed data
B482	3	NA	NA	NA	NA	NA	Noisy speed at high speeds

6.0 DATA ANALYSIS

The immediate objective of this project is to collect driving pattern data to evaluate the representativeness of the current FTP driving cycle. If it is found that the current FTP cycle does not accurately represent today's driving, then a new test procedure may need to be developed. Although the development of a new driving cycle is not part of this work, it is useful to consider the methodology that might be used to evaluate or develop candidate driving cycles, because it will help guide analyses of the driving pattern data and make development or evaluation of candidate driving cycles more efficient.

There appear to be at least two ways to arrive at new driving cycles for a new Federal Test Procedure. The more conventional of the two methods is to select a driving pattern experienced by an actual car in the study that is believed to be representative of all of the driving done in the study. The second method is to use all of the driving data in the database to develop a procedure for simulating driving patterns. For both approaches, measures of the representativeness of the chosen cycle or cycles need to be determined.

Representativeness can be measured by calculating statistics on the driving cycle candidate and calculating the same statistics on all of the data in the database. If all of the statistics that can possibly be imagined agree exactly for both the driving cycle candidate and the database, the driving cycle is said to be representative of the driving. In practice, it is unlikely that a driving cycle of reasonable length will exactly match any and all possible statistics of the database driving behavior data. Instead, a more practical goal is to find driving cycle candidates that match the statistics of the database as closely as possible.

The driving behavior of vehicles is made up of two basic parts: soaks and trips. Both of these features need to be considered when evaluating the driving pattern

data. Soaks are important for both exhaust and evaporative emissions because of the thermal nature of today's vehicle propulsion systems. The length of the soak influences the exhaust emissions of the following trip. For evaporative emissions, the temperature level of the vehicle power plant during soaks and the length of the soak periods are important factors. When the soaks occur is not as important as the length of the soaks between the trips.

The detailed speed behavior within a trip is also an important characteristic of driving behavior. The reason for this is that the emissions behavior of today's vehicles depend not only on the fact that the engine is on, but on the loads and the duration of the loads that the engine experiences.

Because statistics will be used to determine whether a candidate driving cycle is a good representative of the driving behavior of today's vehicles, the first section contains the results of many analyses of the database for reference purposes. Analyses are performed for speed and acceleration measures, measures of trips, and vehicle/driver measures. This statistical analysis should be considered to be preliminary in nature because of the size of the database and the short time devoted to the task. A review of the results of the statistical analyses will lead any investigator to ask many more questions and to desire to conduct additional analyses of the database.

The same statistics are calculated for the FTP cycles for comparison with the statistics on the driving pattern database.

A review of biases which may be present in the data is reviewed in the next section. Because of the algorithms that were used to calculate speed in the datalogger and acceleration in the data analysis phase, certain biases may exist. This discussion provides an estimate of the magnitude of these biases. While attempts were made to select vehicles in a representative manner for the 3-parameter datalogger installations, it is necessary to perform statistical tests to determine if the sample taken was

representative of the population. Finally, if the driver of a vehicle knows that a datalogger is collecting data from his vehicle, it is possible that the driver may alter his behavior. This is examined in the data bias section by looking at driving behavior at the beginning of the week, in comparison with driving behavior at the end of the week.

The next section presents two options for advanced analysis and simulation of driving patterns. The two options are based on advanced statistical analysis and on signal processing approaches. For both options, the emphasis is on the selection or development of driving cycles representative of the driving patterns measured in this study. Neither of these approaches is implemented in this study, but they serve as ideas for the development of new driving cycles and test procedures.

Finally, in the last section, options for formulating driving cycles are presented. The EPA need not necessarily concentrate on developing a Federal Test Procedure that involves a single cast-in-iron driving cycle for the next generation of certification procedures. Several other options can be considered, and each has its advantages and disadvantages.

6.1 Statistical Analysis

The summary statistics for trips and soaks are presented in this section. To perform the routine statistical analysis of the driving patterns database, a series of definitions and description of variables are presented. In later sections, the results of speed and acceleration measures, trip measures, and driver and vehicle measures are presented. Finally, the same types of measures for the current Federal Test Procedure are calculated and compared with the statistics that were calculated on the driving pattern database.

Because many different statistics have been calculated, they are presented in different ways. Many of the statistics are described using distribution plots in the text.

In many cases, these are plotted on a log scale because of the large range the distributions span. As in any technical area, distribution plots made on linear or log scales require some understanding of how these results are to be interpreted. Care should be exercised when using these distribution plots to arrive at conclusions about trends in the data. Additional aids to the reader are provided by bar charts and tabular listings of the values used for the bar charts and log plots. These aids are in Appendix B. Finally, the averages of many of the parameters are provided in tables in the conventional format of mean, standard deviation, minimum value, and maximum value.

The values calculated from the driving patterns database were compared whenever possible with the results obtained in the 1979 General Motors driving survey, in which GM had NPD Research, Inc. (5) conduct a diary survey nationwide of about 2000 households. Drivers recorded the trip start and trip end data in a notebook for every trip that they made during a one-week period. About 73,000 trips were recorded for 3157 vehicles. The two studies, however, may yield slightly different results because the methods used to acquire the data were different. In this driving patterns study, electronic dataloggers were used, whereas in the General Motors survey written survey instruments were used to record information.

6.1.1 Definitions of Terms

Table 6-1 lists the definitions of the terms used in this analysis. The definition of trip needs some discussion, because its meaning must be known to allow interpretation of the results of the statistical analysis.

Trip has been defined in Table 6-1 to have the same meaning as the period during which the dataloggers turned on and off during data collection periods on the vehicles. In general, this beginning and end of trip was caused by the engine being turned on and off. However, in the normal use of a vehicle, the actual engine on and

Table 6-1 Definition of Terms

Idle: The mode when the engine is on and the vehicle has a speed of 0.00 mph.

Running: The mode when the engine is on and the vehicle speed is greater than 0.00 mph.

Trip: A trip starts every time the engine is turned on and ends when the engine is turned off.

Beginning of a Stop: Occurs when vehicle speed first drops below 4 mph after having been above 10 mph and speed has not already been below 4 mph since speed dropped below 10 mph.

End of a Stop: Occurs when vehicle speed first exceeds 4 mph if speed eventually goes above 10 mph without first dropping back below 4 mph.

Beginning of a Creep: Occurs when vehicle speed first exceeds 4 mph and remains below 10 mph and is followed by the end of a creep.

End of Creep: Occurs when vehicle speed drops below 4 mph after having been below 10 mph since the speed was above 4 mph.

Observation Phase (transition, stable): Transition phase extends from logger installation to the second 1:00 am after installation. The stable phase extends from the second 1:00 am after installation to the removal of the logger.

MPH (mph): Vehicle speed averaged over a one second period. Resolution is 0.02 mph for the 3-parameter datalogger. Resolution varies for the 6-parameter datalogger. For example, resolution is 1 mph for the GM datalogging system.

ACCEL (mph/s): Average vehicle acceleration from the previous second to this second.

POWER (mph^2/s): Average Specific Power from the previous second to this second.

$$= \quad \text{if speed}(t) \leq \text{speed}(t-1)$$
$$= \text{speed}^2(t) - \text{speed}^2(t-1), \quad \text{if speed}(t) > \text{speed}(t-1).$$

engine off events may not be those which were intended by the driver. That is, the engine may do something different than what the driver wants it to do.

The most common example of this is starting an engine after a long soak. The driver intends for the engine to start, to idle a short period, and for the vehicle to begin moving. However, because the engine is cold, it may not start on the first attempt. Therefore, there may be one or more periods when the engine starts and dies. This stall can be repeated several times. According to the trip definition, a stall is a trip; it is followed by a short soak.

To evaluate the effects on the statistical results of defining a trip in one way or another way, EPA requested that an attempt be made to find a way to identify very short duration trips which are adjacent to long duration trips. The concept here is that if the vehicle had started properly the first time, the intent of the driver would have been realized, and a fewer number of trips would have occurred. The problem in trying to identify these minor trips is that the datalogger has no way of knowing the intent of the driver. Perhaps he turned off the engine immediately after starting it to perform some other very short task. In addition, the vehicle emissions do not respond to the driver's intent.

An analysis of the 3-parameter data taken in Spokane was examined to determine if there was a way to separate the minor trips from the remainder of the trips, which will be called major trips. Two frequency distributions were created to look for this separation. In the first, the frequency of the trip duration versus the duration of soak after the trip was created. This frequency distribution showed an island of observations for short trips with short post-soaks. A natural valley in the data was observed for trip durations at about 18 seconds and at post-soak duration of about 18 seconds. These minor trips would include those in which a cold engine had stalled during a start, but then was started again a short time later. Approximately 7% of the Spokane trips were in this island. Another frequency distribution was made of trip

duration versus the soak time before the trip. In this distribution, a smaller number of trips were found to have short durations and short soaks preceding them. These short trips would not be expected to be caused by stalls at cold starts, because they had occurred after the engine had been running. A natural valley falls in the data for durations less than 6 seconds and presoak times less than 10 seconds. In this small island, only about 1.4% of the Spokane trips were found.

Because the presence of a large number of short duration trips can affect the statistics on the trips in the entire data set, it is desirable to calculate the trip measures and vehicle and driver measures, both with major and minor trips (that is, all of the trips) and with major trips alone (that is, leaving out the minor trips). For this analysis, the minor trips which have been left out of one analysis are those which have durations less than 18 seconds with a following soak of less than 18 seconds.

Table 6-2 lists the computed variables and their descriptions. These variables are used throughout this section to calculate statistics on the driving pattern data.

6.1.2 Discussion of Results

The goal of this section on data analysis is to evaluate the driving pattern data and summarize vehicle driving behavior in Spokane and Baltimore. The analysis was directed to consider three different aspects of vehicle driving: speed and acceleration measures, trip measures, and vehicle/driver measures. At EPA's request, summary statistics were developed for each of these categories. The statistics for all observations in the data set are presented in Table 6-3; these are discussed later at several places in this section. Speed and acceleration measures summarize the second-by-second driving behavior reflected by vehicle speed and acceleration. The trip measures describe patterns of time and distance spent on individual trips. The vehicle/driver measures describe differences in operating individual vehicles.

Table 6-2 Variable Descriptions

SITE: Denotes the I/M station where vehicle was solicited: Spokane, Baltimore-Rossville, or Baltimore-Exeter.

SAMPLE: Sample identification number unique to each solicited vehicle whether it was instrumented or not.

VIN: Vehicle identification number.

MAKE: Make of the vehicle.

MODEL: Model of the vehicle.

YEAR: Model year of the vehicle.

TPL: Throttle Closed Position Voltage (mV) for 6-parameter dataloggers.

TPH: Throttle Open Position Voltage (mV) for 6-parameter dataloggers.

TR: Transmission type: A for automatic, M for manual.

SP5: Speed classification with a width of 5 mph. For example, SP5 = 15 contains observations with: 10 < speed (mph) ≤15. For idle, SP5 = 0 contains only observations with speed (mph) = 0.

AC1: Acceleration classification with a width of 1 mph/s. For example, AC = -3 contains observations with: -4 < acceleration (mph/s) ≤ -3.

TRIPTIME (s): The duration of a trip from engine on to engine off.

T_IDLE (s): The time spent in the idle mode.
T_IDLE + T_RUN = TRIPTIME.

T_FIDLE (s): The time spent in idle after start and before the vehicle moves for a trip.

T_RUN (s): The time spent in a trip at non-zero speed.

AVG_MPH (mph): Average speed for a trip.

Table 6-2 continued

SOAKTIME (s): Soak time before a trip begins.

TRIPDIST (mile): The distance travelled during a trip.

A_STOPD (mile): Average distance between stops for a trip.

AV_R_MPH (mph): Average speed during the non-zero speed portion of a trip.

AVE_PKE (mph^2/s): Average specific power for the trip.

VEHMIDAY (minutes): Average vehicle operation time per day for a vehicle.

VEHDIDAY (miles): Average distance driven per day for a vehicle.

TRIPSDAY: Average number of trips driven per day for a vehicle.

NUMSTHR: Average number of stops per hour of use for a vehicle.

ACCGT3 (%): Percent of observations with accelerations ≥ 3 mph/s.

ACCGT4 (%): Percent of observations with accelerations ≥ 4 mph/s.

ACCGT5 (%): Percent of observations with accelerations ≥ 5 mph/s.

ACCGT6 (%): Percent of observations with accelerations ≥ 6 mph/s.

MPHGT0 (%): Percent of observations with speeds ≥ 0 mph.

MPHGT10 (%): Percent of observations with speeds ≥ 10 mph.

MPHGT20 (%): Percent of observations with speeds ≥ 20 mph.

MPHGT30 (%): Percent of observations with speeds ≥ 30 mph.

MPHGT40 (%): Percent of observations with speeds ≥ 40 mph.

MPHGT50 (%): Percent of observations with speeds ≥ 50 mph.

MPHGT60 (%): Percent of observations with speeds ≥ 60 mph.

Table 6-2 continued

MPHGT70 (%):	Percent of observations with speeds ≥ 70 mph.
MPHGT80 (%):	Percent of observations with speeds ≥ 80 mph.
PKEGT100 (%):	Percent of observations with specific power ≥ 100 mph^2/s
PKEGT120 (%):	Percent of observations with specific power ≥ 120 mph^2/s
PKEGT140 (%):	Percent of observations with specific power ≥ 140 mph^2/s
PKEGT160 (%):	Percent of observations with specific power ≥ 160 mph^2/s
PKEGT180 (%):	Percent of observations with specific power ≥ 180 mph^2/s
PKEGT200 (%):	Percent of observations with specific power ≥ 200 mph^2/s
PKEGT220 (%):	Percent of observations with specific power ≥ 220 mph^2/s
PKEGT240 (%):	Percent of observations with specific power ≥ 240 mph^2/s
PKEGT260 (%):	Percent of observations with specific power ≥ 260 mph^2/s
PKEGT280 (%):	Percent of observations with specific power ≥ 280 mph^2/s
PKEGT300 (%):	Percent of observations with specific power ≥ 300 mph^2/s

Table 6-3

Summary of Statistics for All Observations in the Driving Pattern Data Set

	Variable	Units	Number of Observations	Weighted by	Mean	Standard Deviation	Minimum	Maximum
A	MPH	(mph)	6927206	None	24.70	20.04	0.00	94.46
	ACCEL	(mph/s)	6915785	None	0.00	1.51	-33.20	33.34
	POWER	(mph^2/s)	2690251	None	48.83	48.29	0.00	2876.14
B	TRIPTIME	(s)	12073	None	575	650	1	14797
	T_IDLE	(s)	11532	None	112	173	0	3182
	T_FIDLE	(s)	12073	None	28	81	0	2085
	T_RUN	(s)	11532	None	515	573	0	14768
	AVE_MPH	(mph)	11405	None	18.18	10.78	0.00	71.36
	SOAKTIME	(s)	11857	None	11719	24075	2	416053
	TRIPDIST	(miles)	12073	None	3.94	7.50	0.00	255.00
	A_STOPD	(miles)	10300	None	0.88	2.24	0.00	127.48
	AV_R_MPH	(mph)	10817	None	23.11	10.33	0.02	71.63
	AVE_PKE	(mph^2/s)	10782	None	45.92	22.14	0.00	254.01
C	A_STOPD	(miles)	10300	Number of Stops	0.83	1.65	0.00	127.48
D	AVE_MPH	(mph)	11405	Trip Distance	30.71	13.18	0.00	71.36
	AV_R_MPH	(mph)	10817	Trip Distance	34.94	12.40	0.02	71.63
	AVE_POWER	(mph^2/s)	10782	Trip Distance	56.15	34.06	0.00	254.01
E	AVE_MPH	(mph)	11405	Trip Time	24.69	12.18	0.00	71.36
	AV_R_MPH	(mph)	10817	Trip Time	29.67	11.31	0.02	71.63
	AVE_POWER	(mph^2/s)	10782	Trip Time	51.38	26.68	0.00	254.01
F	VEHMIDAY	(min)	216	Number of Days	68.51	30.33	16.49	197.38
	VEHDIDAY	(miles)	216	Number of Days	28.15	18.02	4.78	123.23
	TRIPSDAY	(trips/day)	216	Number of Days	7.15	5.47	2.14	81.46
G	NUMSTHR	(stops/hr)	216	Number of Hours of Operation	36.3	11.6	13.1	221.7
H	ACCGT3	(% obs)	216	Number of Hours of Operation	3.26	1.90	0.67	16.01
	ACCGT4	(% obs)	216	Number of Hours of Operation	1.28	0.77	0.06	3.76
	ACCGT5	(% obs)	216	Number of Hours of Operation	0.53	0.47	0.00	3.59
	ACCGT6	(% obs)	216	Number of Hours of Operation	0.21	0.22	0.00	1.93
	MPHGTH0	(% obs)	216	Number of Hours of Operation	100.00	0.00	100.00	100.00
	MPHGTH10	(% obs)	216	Number of Hours of Operation	69.03	9.56	40.96	90.71
	MPHGTH20	(% obs)	216	Number of Hours of Operation	56.92	11.59	25.86	86.59
	MPHGTH30	(% obs)	216	Number of Hours of Operation	40.96	14.75	10.81	80.68
	MPHGTH40	(% obs)	216	Number of Hours of Operation	20.95	16.39	0.10	71.36
	MPHGTH50	(% obs)	216	Number of Hours of Operation	13.35	14.05	0.00	69.11
	MPHGTH60	(% obs)	216	Number of Hours of Operation	6.25	10.39	0.00	58.07
	MPHGTH70	(% obs)	216	Number of Hours of Operation	0.87	3.12	0.00	20.74
	MPHGTH80	(% obs)	216	Number of Hours of Operation	0.02	0.14	0.00	1.26
	POWERGT100	(% obs)	216	Number of Hours of Operation	14.08	12.73	0.81	83.97
	POWERGT120	(% obs)	216	Number of Hours of Operation	9.14	11.62	0.17	79.87
	POWERGT140	(% obs)	216	Number of Hours of Operation	5.85	10.03	0.04	72.88
	POWERGT160	(% obs)	216	Number of Hours of Operation	3.92	9.09	0.00	67.22
	POWERGT180	(% obs)	216	Number of Hours of Operation	2.82	8.38	0.00	61.32
	POWERGT200	(% obs)	216	Number of Hours of Operation	2.12	7.68	0.00	57.16
	POWERGT220	(% obs)	216	Number of Hours of Operation	1.46	5.81	0.00	43.11
	POWERGT240	(% obs)	216	Number of Hours of Operation	0.79	2.87	0.00	22.76
	POWERGT260	(% obs)	216	Number of Hours of Operation	0.48	1.71	0.00	13.39
	POWERGT280	(% obs)	216	Number of Hours of Operation	0.26	0.81	0.00	8.26
	POWERGT300	(% obs)	216	Number of Hours of Operation	0.17	0.58	0.00	5.75

6.1.2.1 Speed and Acceleration Measures

As part of this analysis, the second-by-second speed and acceleration behavior of 216 vehicles were evaluated to consider the range of behavior of the overall vehicle population. Table B-1 lists these vehicles. Descriptive statistics for speed and acceleration, as well as the time spent at any given speed or acceleration, are presented in this section.

Figure 6-1 shows a contour plot of speed versus acceleration for 216 vehicles instrumented in both Spokane and Baltimore. This contour plot was developed by using speed classes of 2 mph and acceleration classes of 0.5 mph/s. This figure represents 6.9 million observations. The shading of each cell in the contour plot represents the percent of all observations that satisfy the boundary limits of the cell. In general, the figure shows that a large percentage of vehicle operation time was spent at idle. Large peaks are seen around 35 mph and around 60 mph. A higher percentage of positive accelerations is seen between 0 and 25 mph. This can be attributed to similar acceleration behavior for drivers while they have dissimilar deceleration behavior. In addition, it shows that most of the vehicle operation is over mild acceleration conditions between -2 and +2 mph/s. However, accelerations as high as 6.0 mph/s were observed, and many accelerations above 3.3 mph/s, the FTP maximum acceleration, were common. Table B-2 shows the percent of vehicle operation time spent at any given speed and acceleration condition.

Figure 6-2 shows the distribution of speeds for the vehicles in the two cities. 19.5% of the vehicle operation time was spent while the vehicle speed was 0 mph. Consistent with the contour plot, about 11% of the vehicle operation time was spent between 30 and 35 mph; in addition, a smaller peak occurs between 55 and 60 mph. Thus, while drivers drove their vehicles at many speeds, 0, 35, and 60 mph stand out as being most common. Figure 6-3 shows the range of accelerations for the driving pattern data. The figure shows the occurrence of a high percentage of 0 and near 0

Figure 6-1. Speed/Acceleration Contours for All Observations

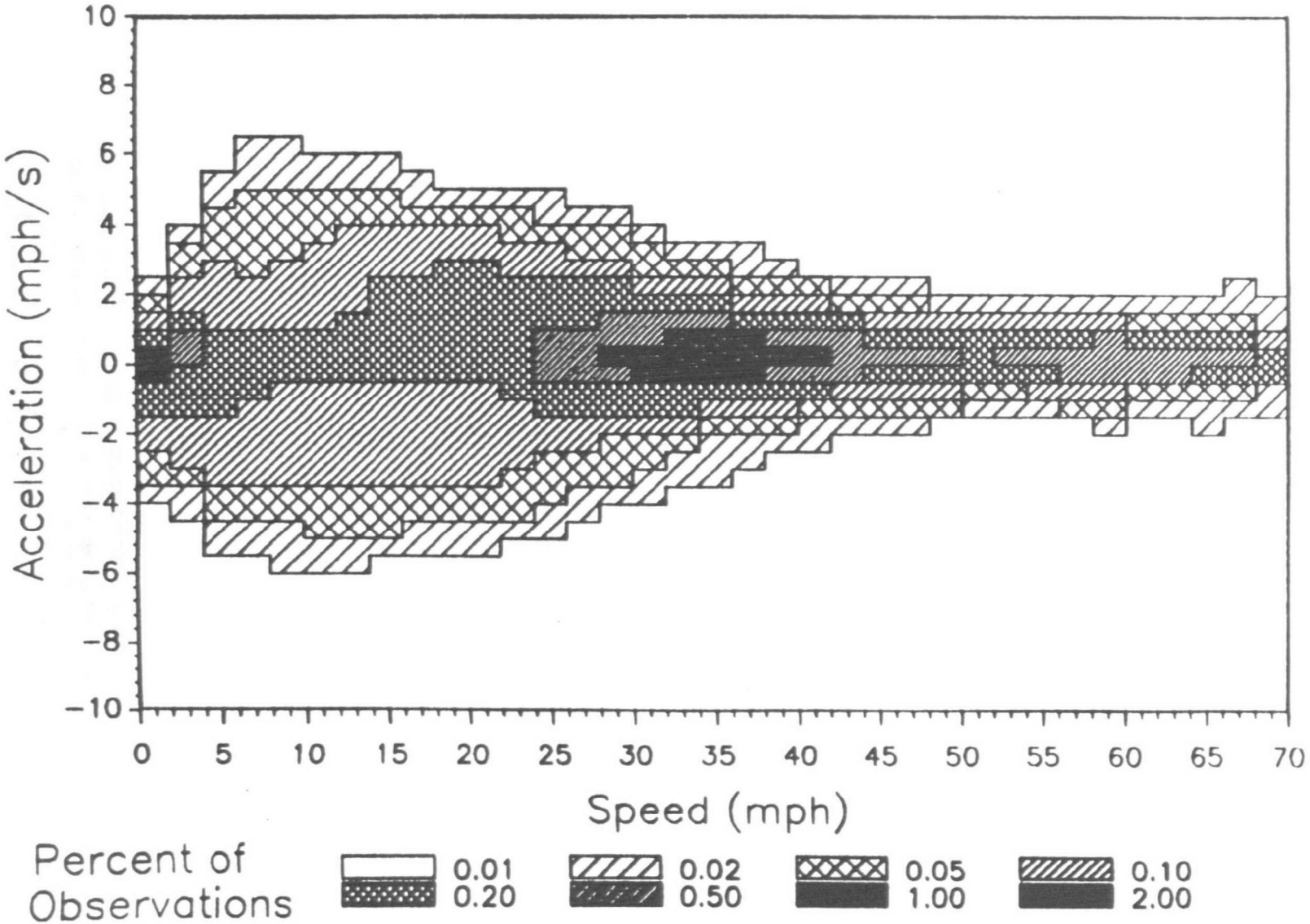


Figure 6-2. Speed Distribution for All Observations

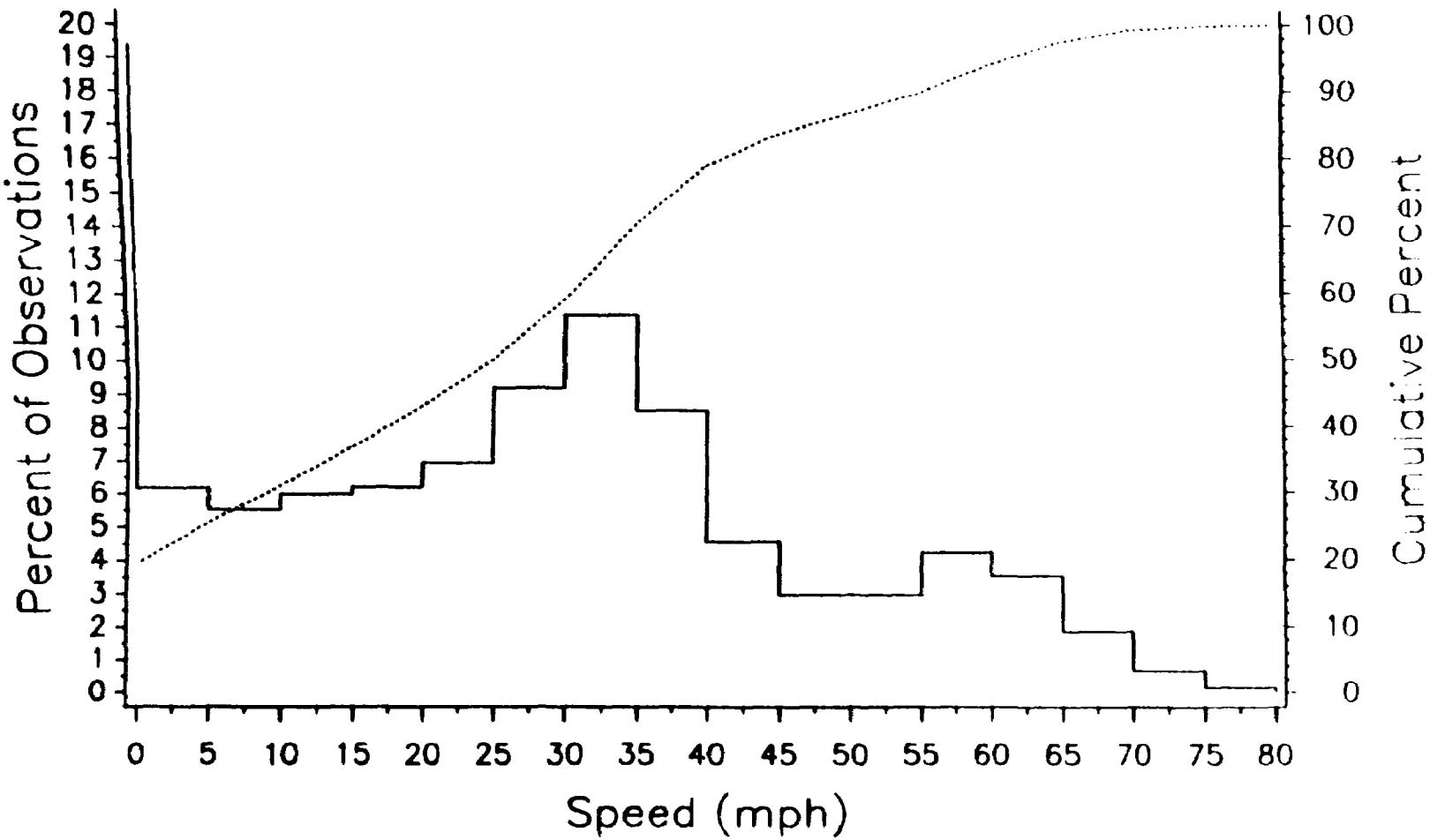
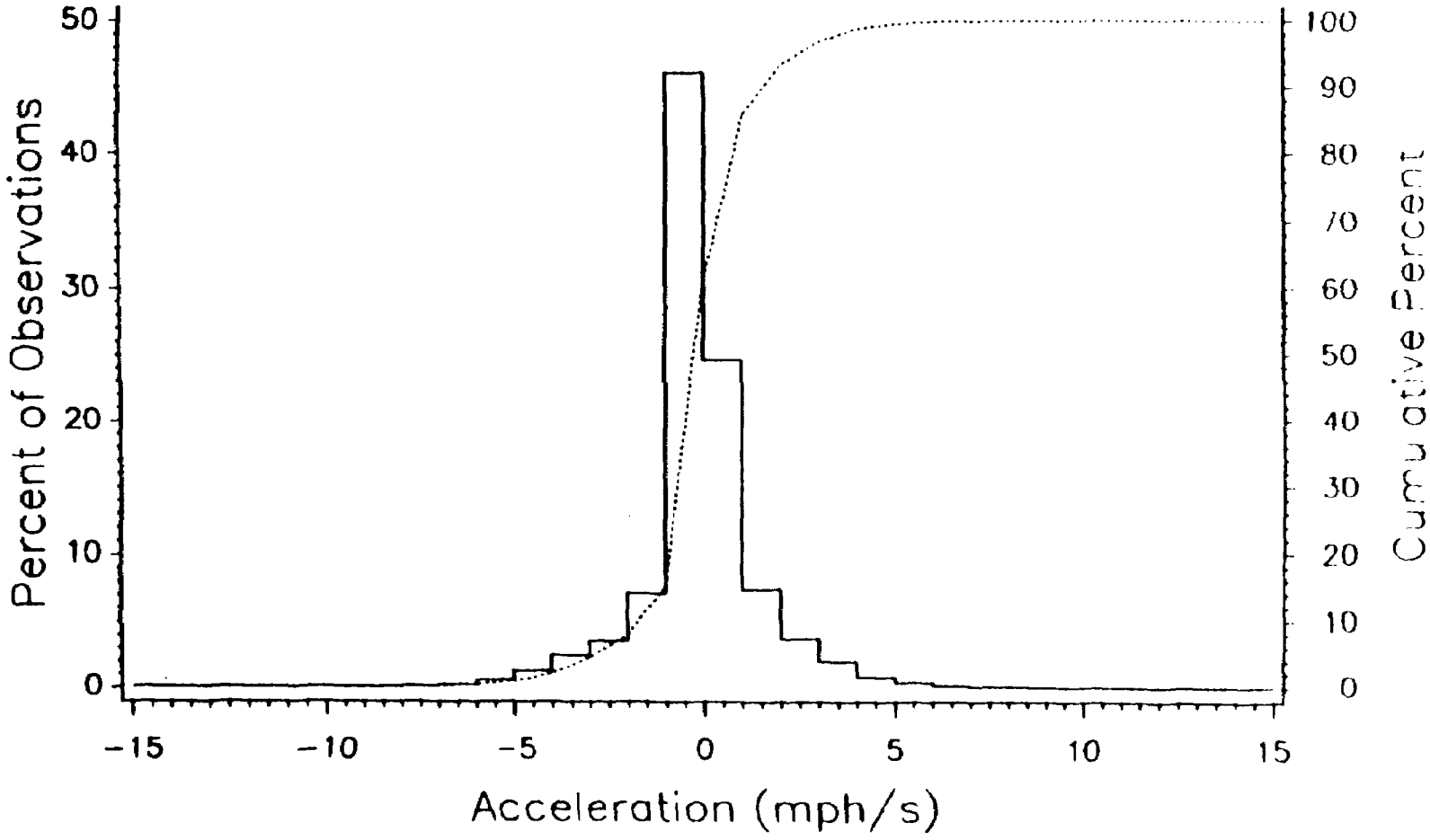


Figure 6-3. Acceleration Distribution for All Observations



accelerations, but the detailed values show that 3.75% of the acceleration observations are below -3.3 mph/s, and about 2.67% of the acceleration observations were above 3.3 mph/s. Tables B-3 and B-4 present the speed and acceleration information in tabular form.

Figure 6-4 shows the specific power distribution in classes of 20 mph^2/s. Table B-5 presents the same information in tabular form. The term, specific power, in this context relates to the increase in kinetic energy per second per unit mass. As can be seen from the figure and the table, 99% of the observations had specific powers below 240 mph^2/s. The percent of observations as a function of specific power was found to closely follow an exponential decay function. The cumulative percent of observations can be represented by the following equation:

$$Q = 100 * (1-e^{k*P})$$

where

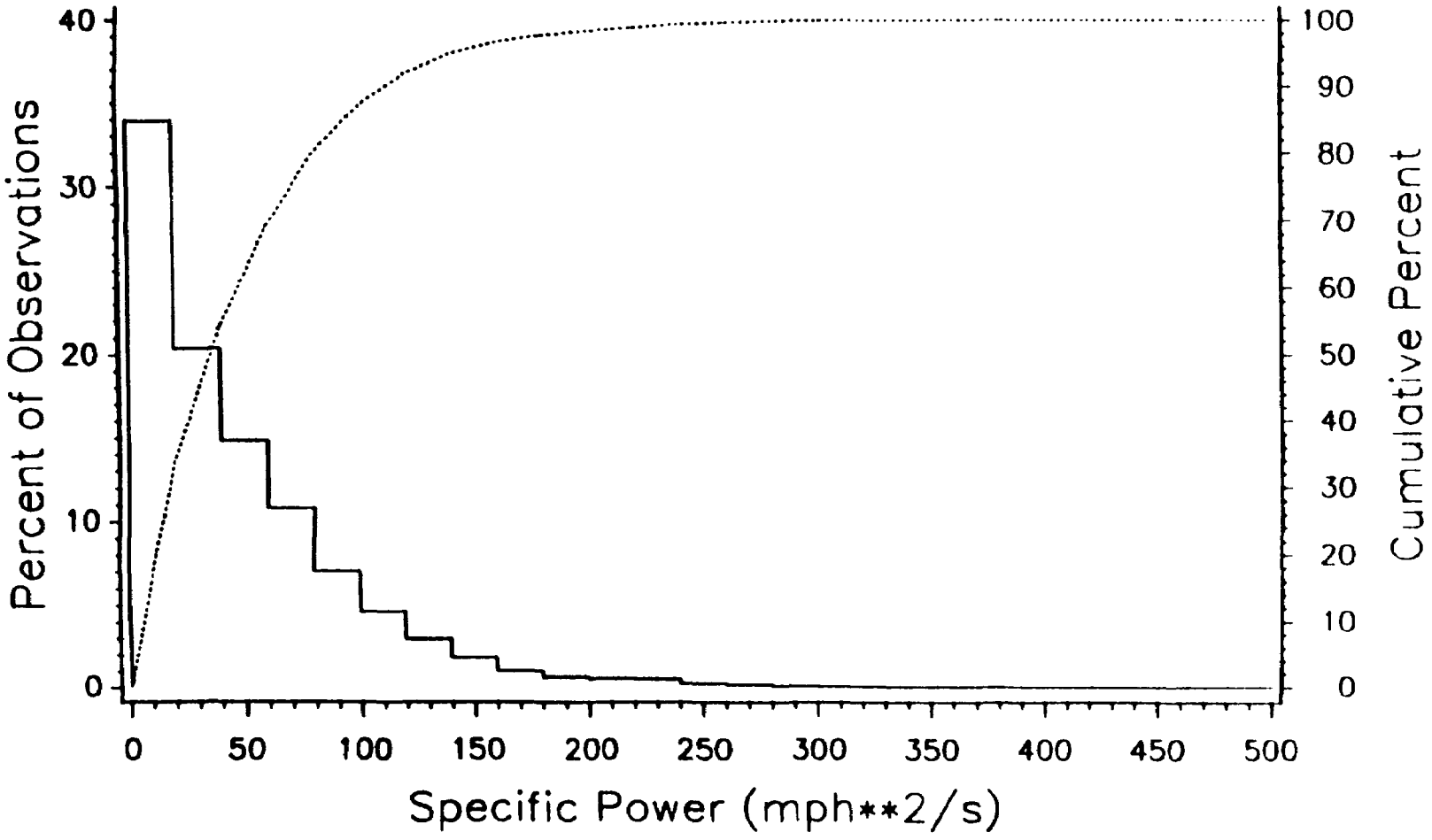
k is the decay coefficient = 0.020 s/mph^2

P = specific power in mph^2/s

For example, by using the above equation, the cumulative percent of specific power values up to 100 mph^2/s is calculated to be 86.47 percent. The corresponding measured value given in Table B-5 is 87.2 percent. This equation can also be used to compare the percent of observations between two specific power values. Because the cumulative percent of observations is modeled, the width of the classes used for the specific power distribution does not affect the equation. For example, the percent of observations between 80 and 100 mph^2/s is calculated to be 6.66% by using the equation twice. The measured value is 7.09% based on Table B-5.

Table 6-3A presents the mean, standard deviation, minimum, maximum, and count of seconds for speed, acceleration, and specific power. As shown, the average speed for the 216 vehicles was 24.7 mph, with a standard deviation of 20.0 mph.

Figure 6-4. Specific Power Distribution for All Observations



6.1.2.2 Trip Measures

As mentioned earlier, a trip was defined for this preliminary analysis as the vehicle operating time between an engine start and an engine shutdown. Because of this definition of a trip, if a vehicle's engine had false starts, each may be counted as a trip. Figure 6-5 shows a distribution of 12,073 trip times for all trips in both Spokane and Baltimore for the entire driving modes data set. About 10% of the trips were shorter than 15 seconds, and are shown by the vertical bar between 0.2 to 0.25 minutes. The rest of the trips show a smooth distribution which is close to log normal.

The minor trips have been removed to produce the distribution of trip times in Figure 6-6. The median trip length for the trip time distribution is about 7 minutes. The GM median trip time was 10.0 minutes. It is unlikely that very short trips, such as engine false starts, were recorded in the diary survey. Table B-8 shows the trip time distribution in tabular form.

Figure 6-7 and Table B-11 show the soak time distribution for the driving pattern data of all trips, and Figure 6-8 shows the soak time distribution for only the major trips. Soak time is defined as the time between the trips. This can be a useful measure for determining whether the vehicle was in a cold start mode during the start of the following trip. This information is also very useful for determining evaporative emissions. Both Figures 6-55 and 6-155 show a significant amount of short soak times, less than 0.5 minutes in duration. Between about 3 minutes and 100 minutes, the percent of soak periods remains constant at around 6 percent. A large peak of soak periods occurs between about 600 and 1000 minutes. This relates to about 10 to 16 hours and corresponds to the overnight soak after a vehicle has been parked in the evening and then switched on the following morning.

Figure 6-5. Trip Time Distribution for All Trips

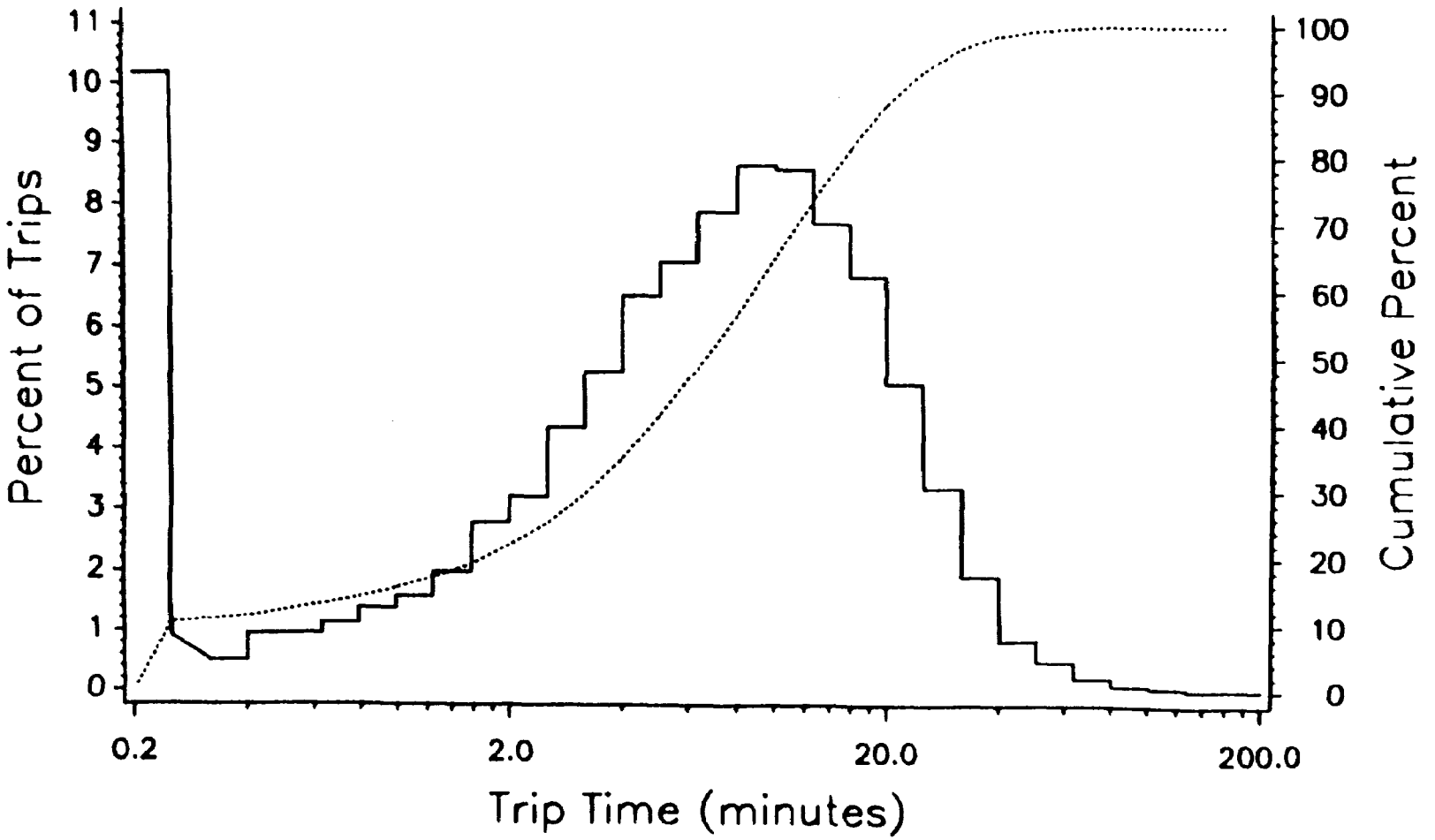


Figure 6-6. Trip Time Distribution for Major Trips Only

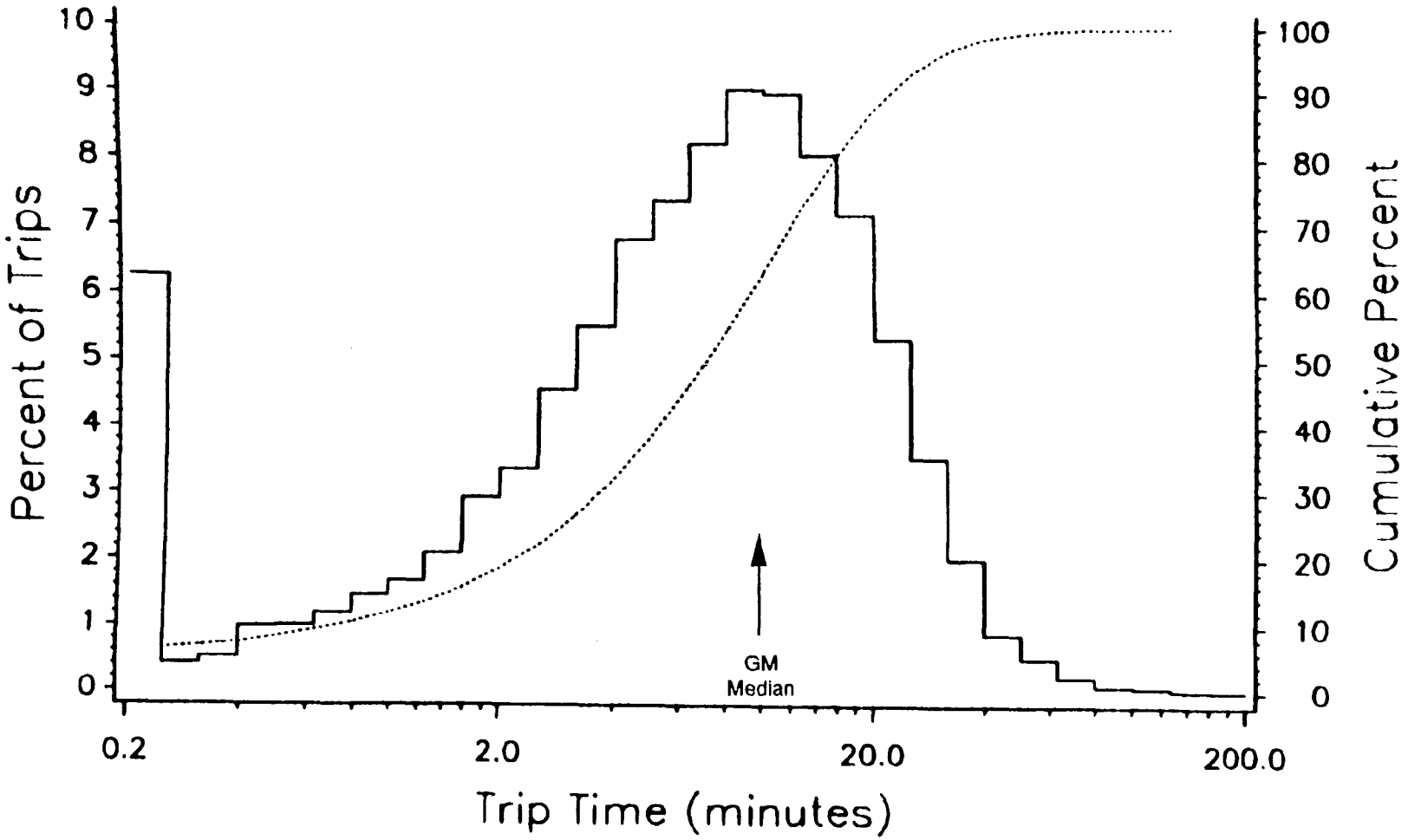


Figure 6-7. Soak Time Distribution for All Trips

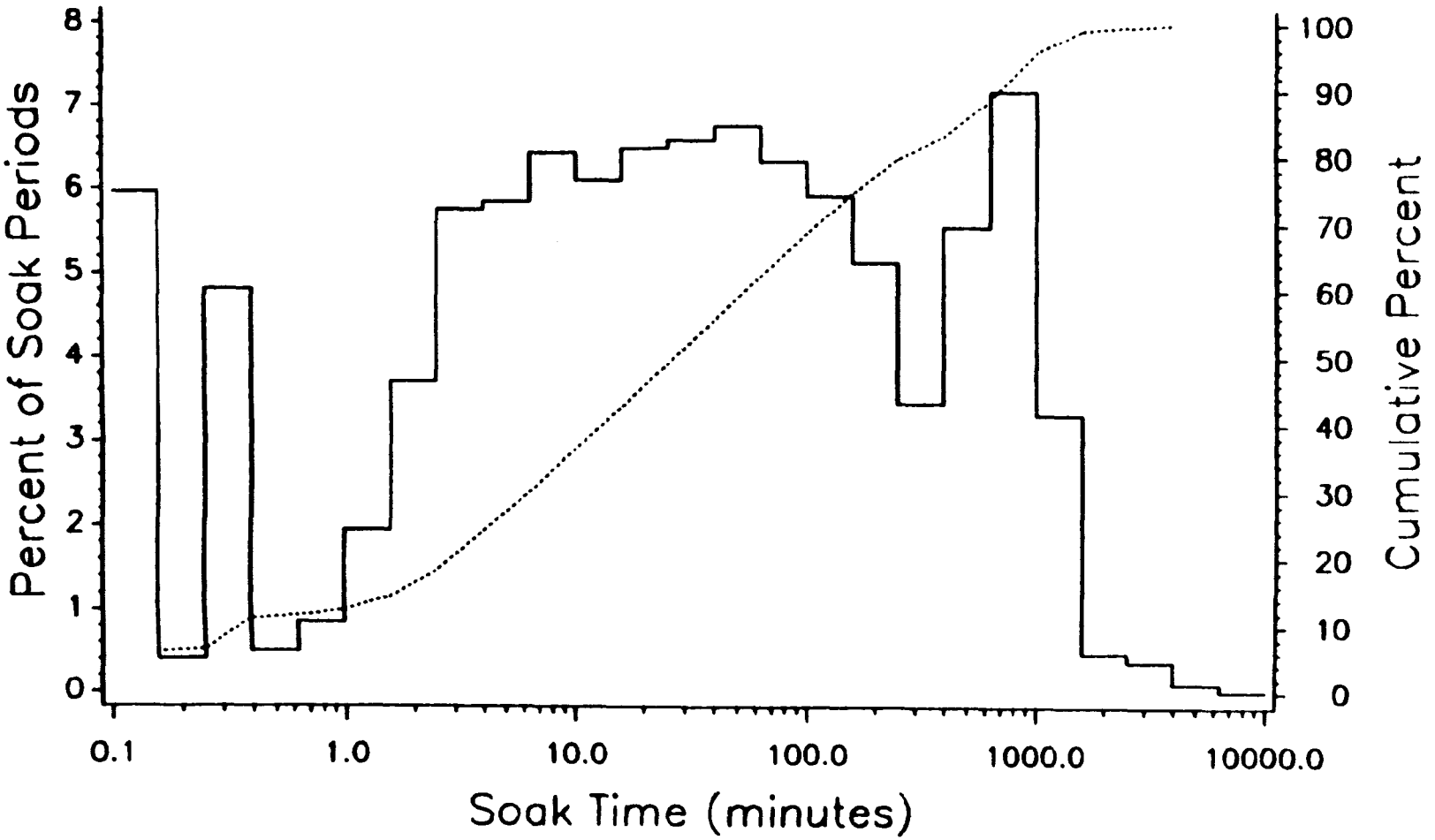
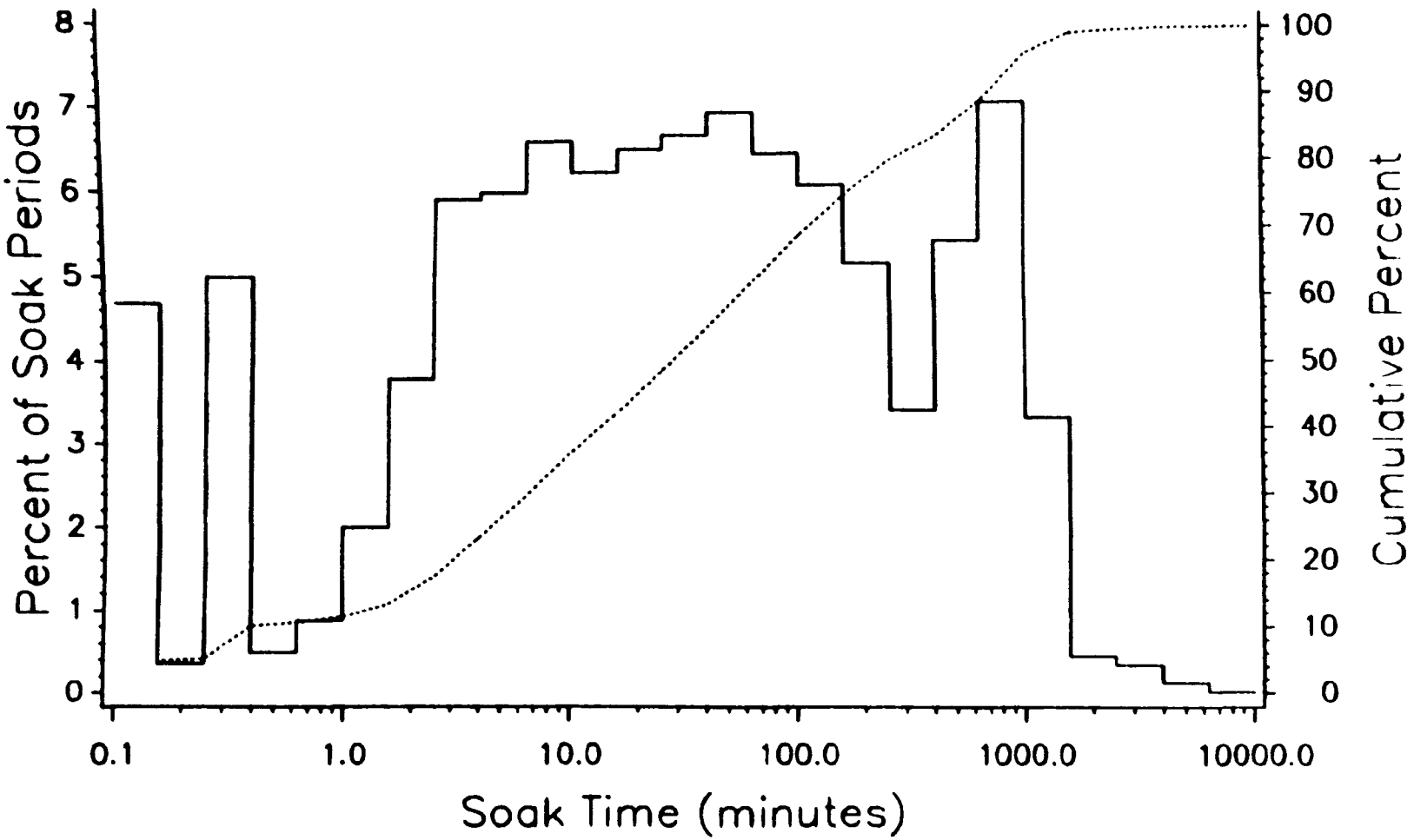


Figure 6-8. Soak Time Distribution for Major Trips Only



Figures 6-9 and 6-10 show the time spent at idle and running time distributions for the driving mode data. Both of these plots are similar to the trip time distribution and are close to log normal distributions. From these plots, we can say that for the statistical median trip of about 7 minutes, about 1 minute was spent at idle and about 6 minutes were spent at a non-zero speed. Tables B-14 and B-17 show this information in tabular form. Figures 6-11 and 6-12 show the same distributions for major trips only; the distributions are very similar to the figures for all trips.

Figure 6-13 and Table B-20 show the distribution of trip distance in miles for the driving modes data. Information for all 12,073 trips is shown in the figure and the table. Again, the short trips appear to be a significant percentage, and the rest of the plot shows a smooth single mode distribution. Figure 6-14 was obtained after minor trips were removed. The median trip distance shown by the distribution is about 2.3 miles, and the median trip distance from the GM survey was about 3 miles. In addition, the average distance for the driving modes data is about 3.9 miles, while the GM average distance was 7.1 miles.

Table 6-3B shows the unweighted trip measures for the driving modes data for all trips. Various trip measures were calculated separately for each trip. Table 6-3B presents the average and the range of variation of these trip measures. For example, the average of the speed observations from Table 6-3A for the entire data set was 24.7 mph, but from Table 6-3B the average trip speed is 18.2 mph. This is because a 2-second trip or 200-minute trip are treated equally to calculate the trip measures.

Table 6-3C shows that the average distance between stops for all the trips weighted by the number of stops was about 0.83 miles, which can be compared to 0.88 miles in Table 6-3B. This suggests that if the number of stops were high for a particular trip, the average distance between them was smaller, compared to trips with a fewer number of stops.

Figure 6-9. Time in Idle Distribution for All Trips

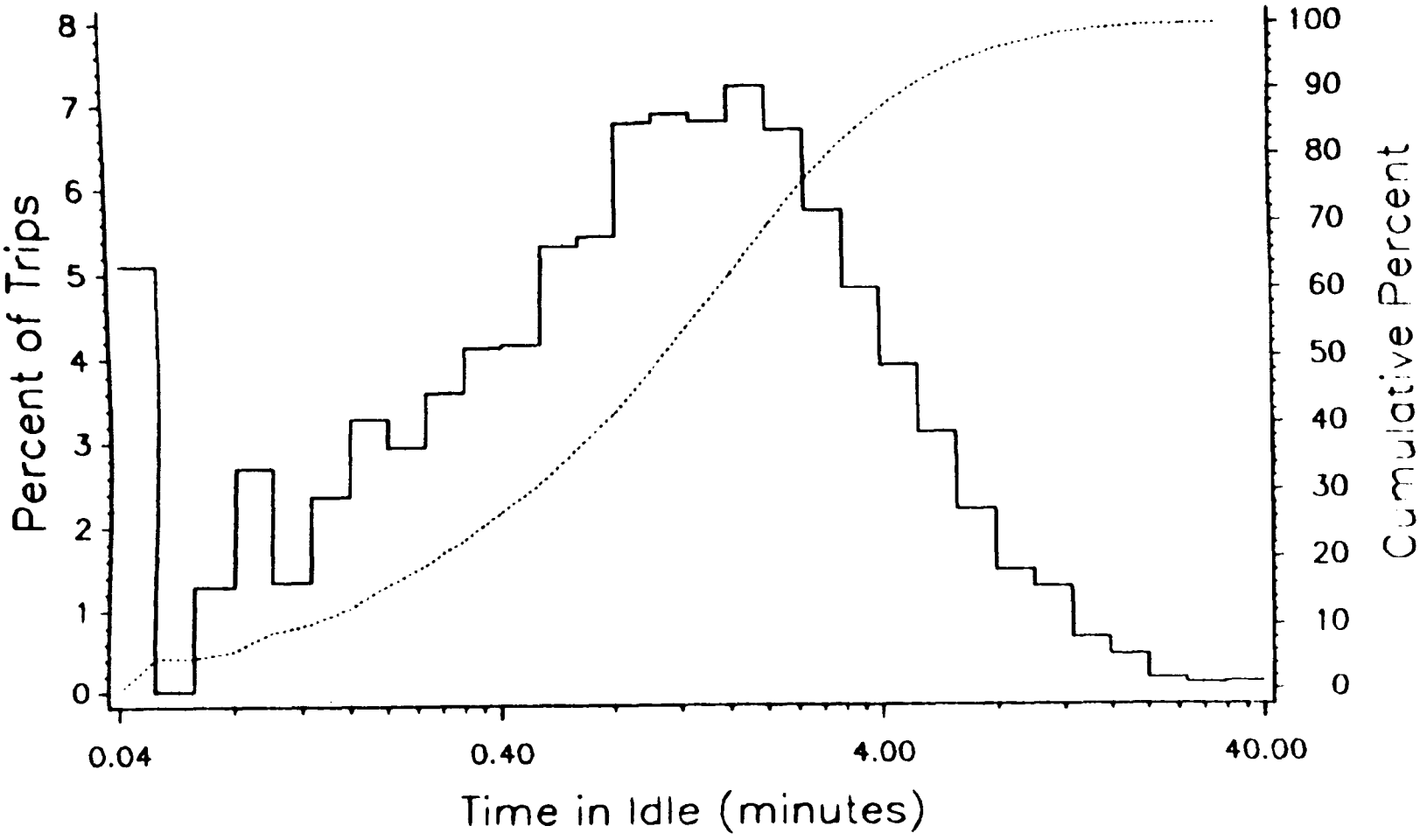


Figure 6-10. Running Time Distribution for All Trips

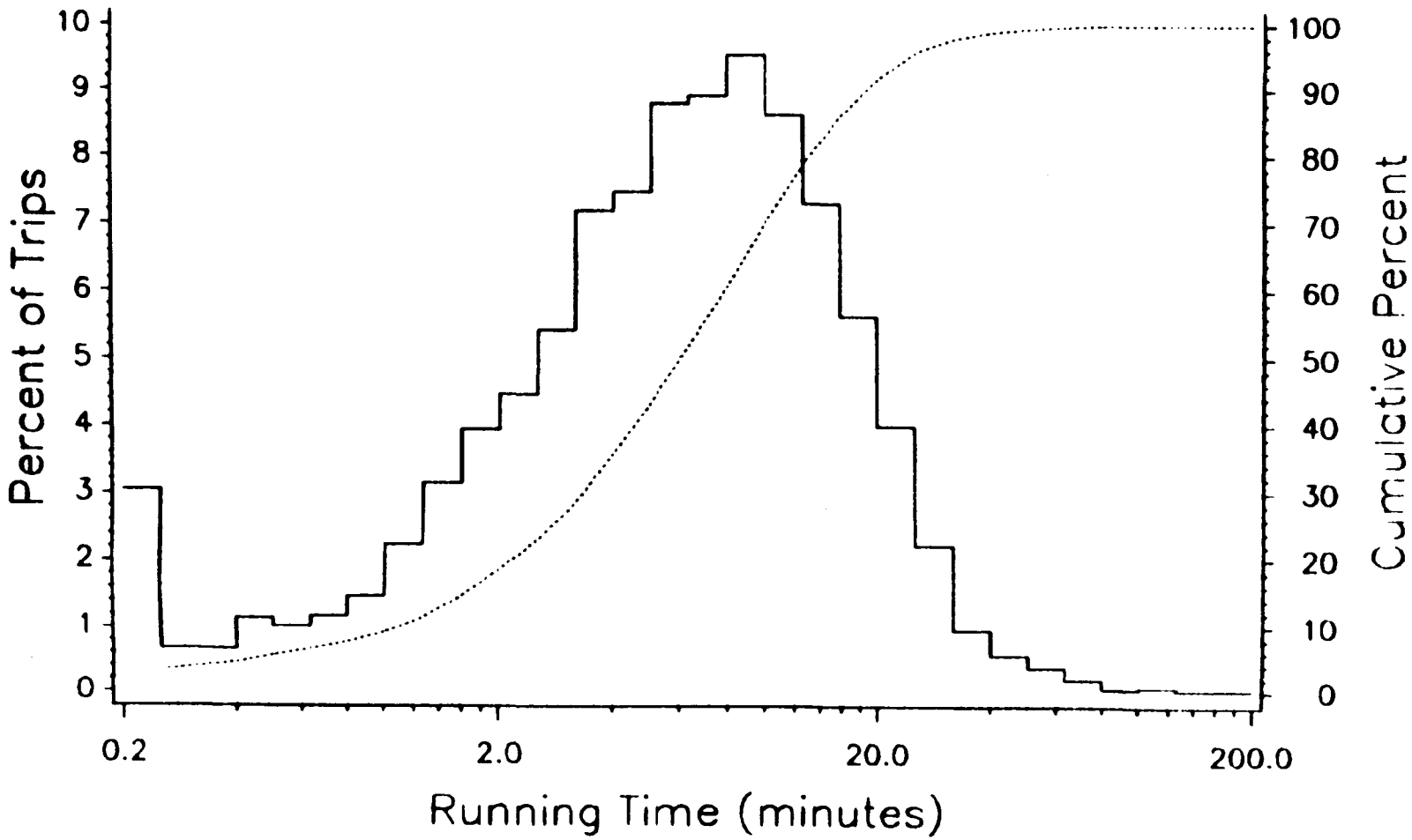


Figure 6-11. Time in Idle Distribution for Major Trips Only

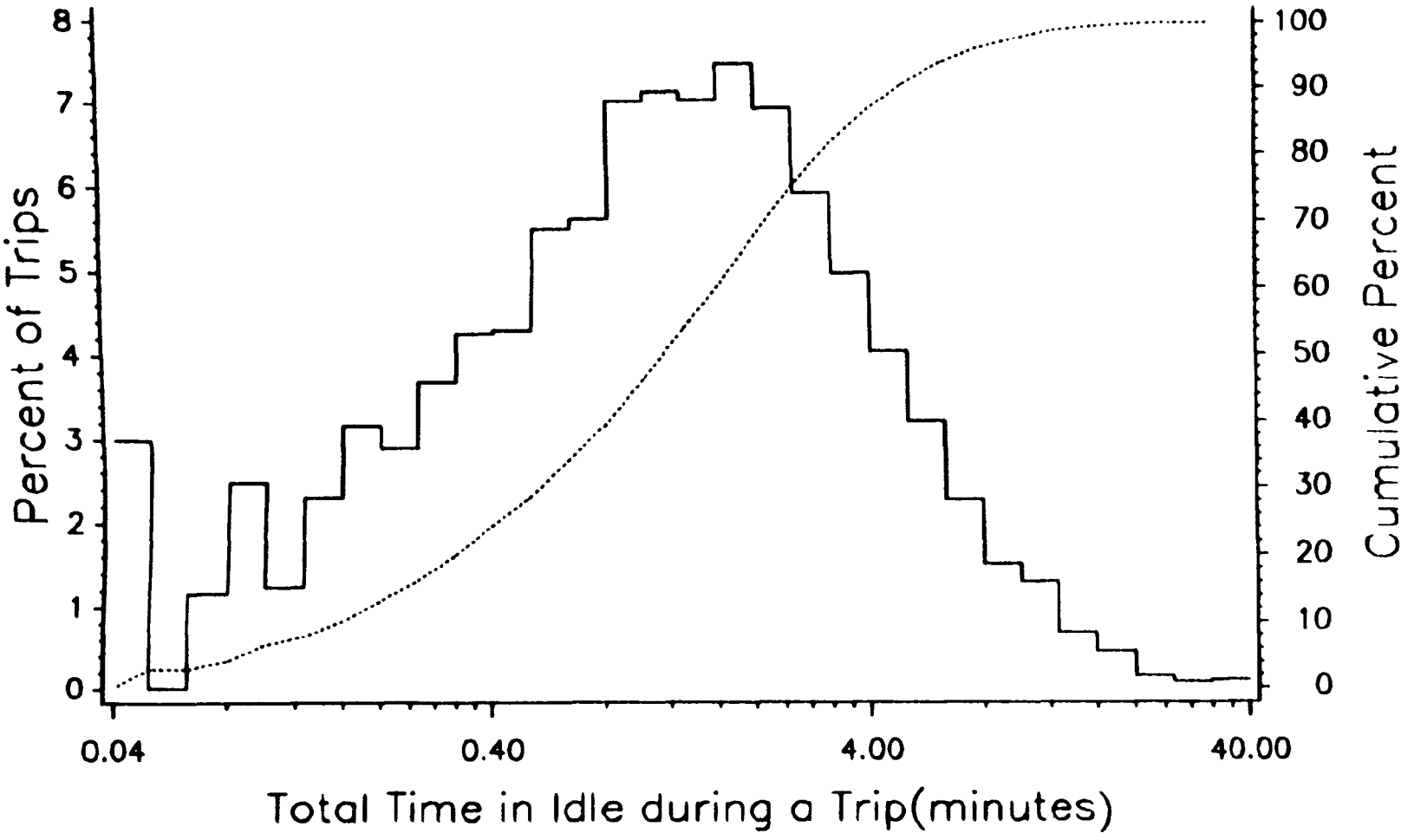


Figure 6-12. Running Time Distribution for Major Trips Only

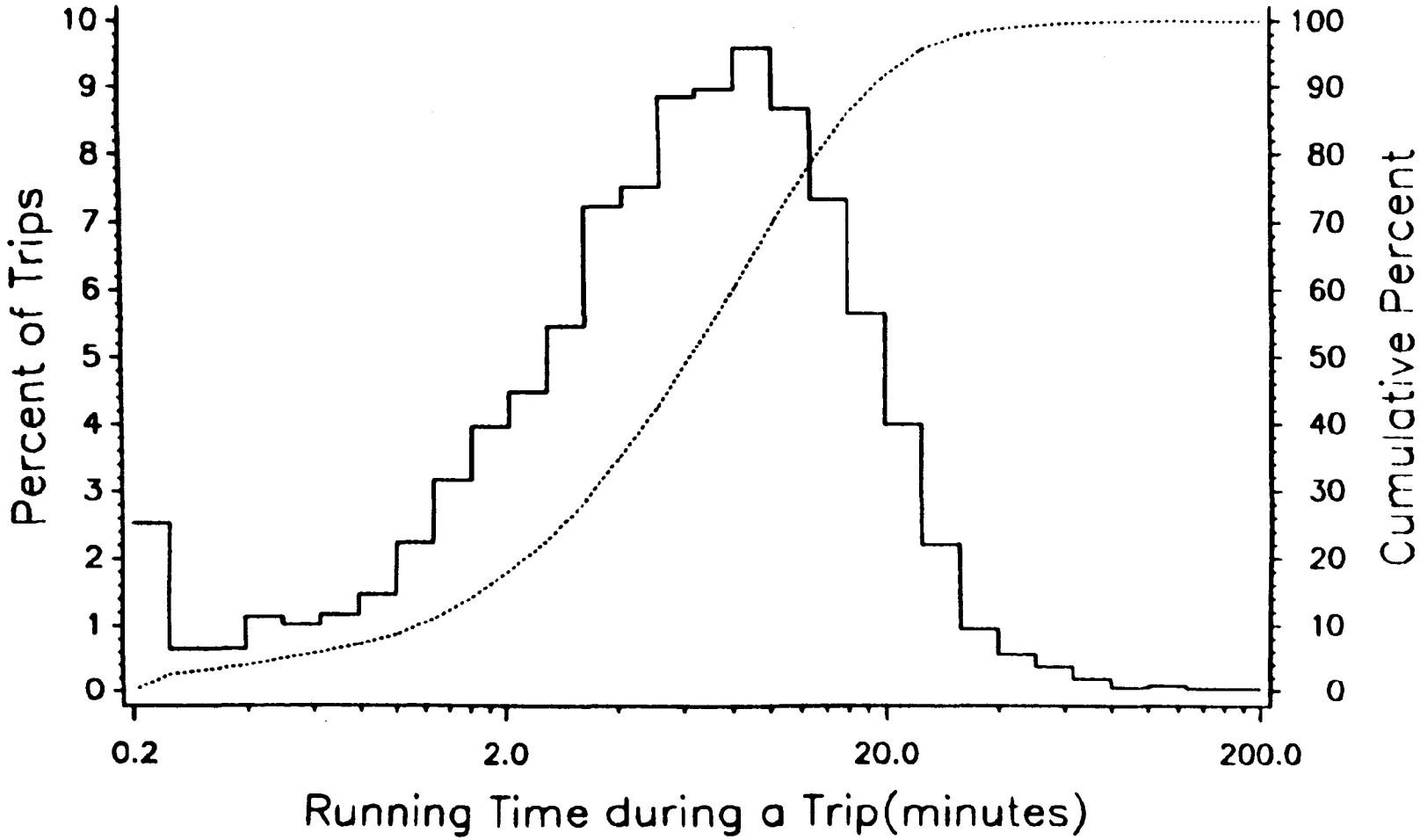


Figure 6-13. Trip Distance Distribution for All Trips

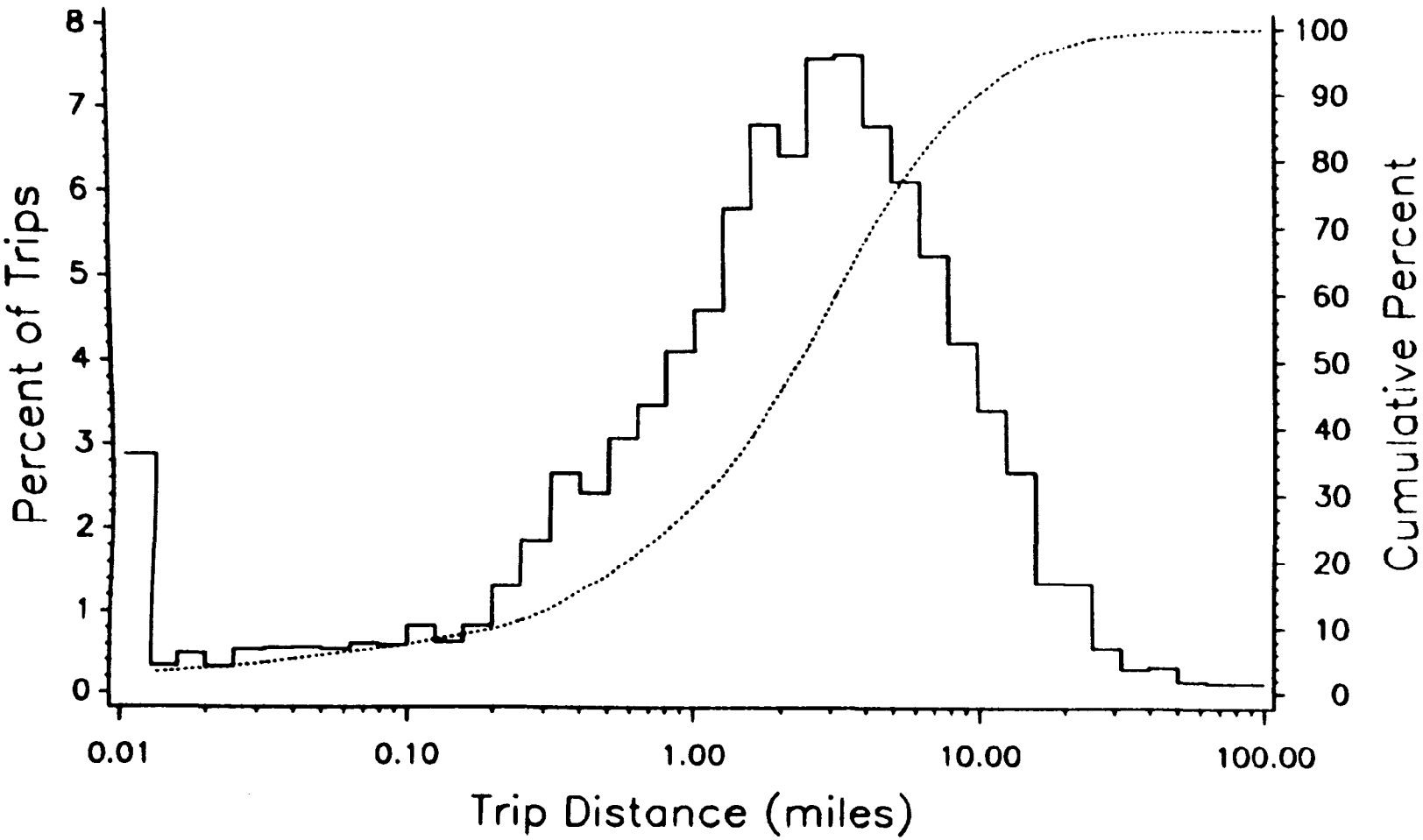


Figure 6-14. Trip Distance Distribution for Major Trips Only

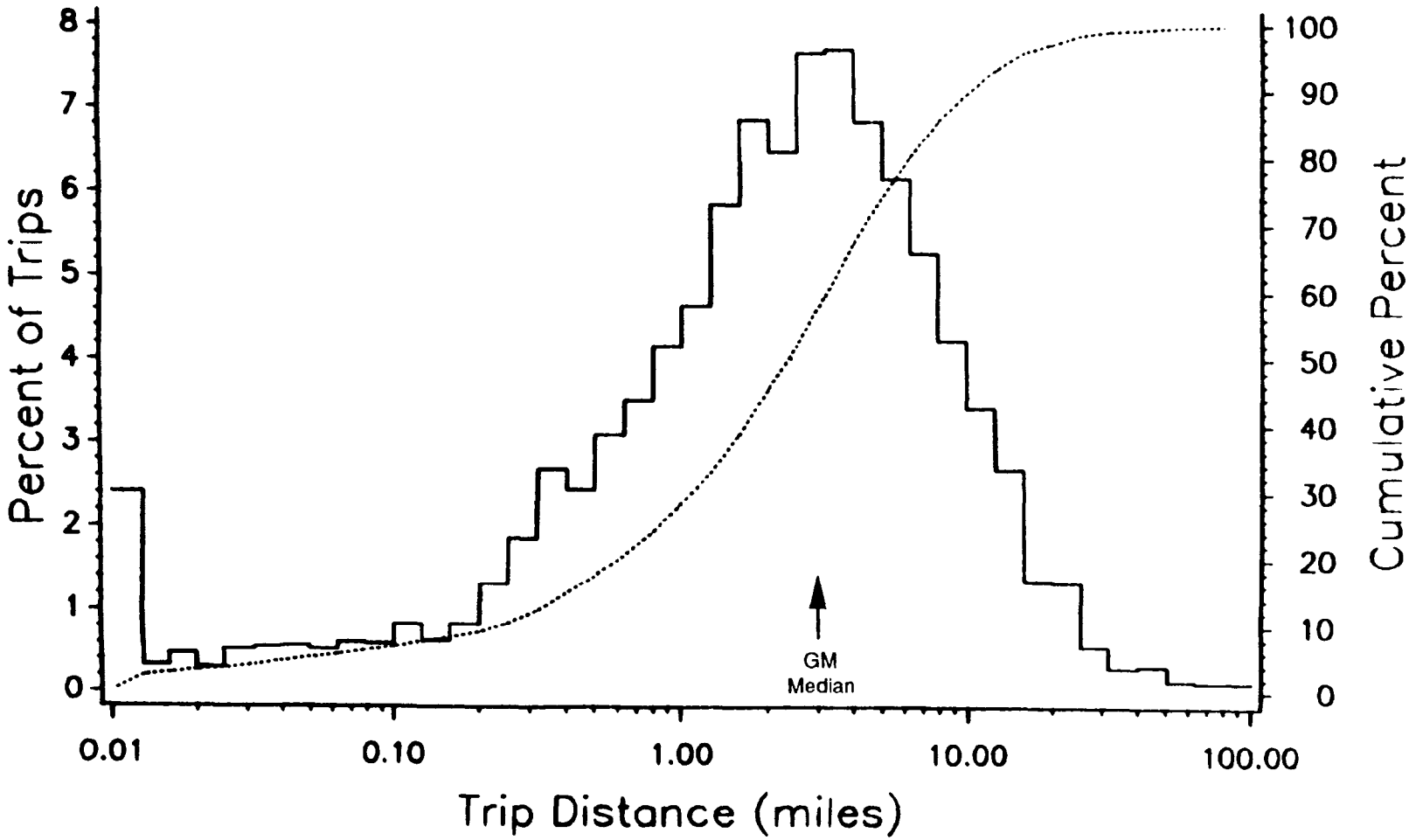


Table 6-3D shows the average means and standard deviations for average speed, average running speed, and average specific power weighted by the trip distance. As shown, the weighted average speed jumps to 30.7 mph from an unweighted average of 18.2. Table 6-3E shows the three descriptors, but this time weighted by trip time. The weighted measures show that longer trips have higher average speeds, higher average running speeds, and higher average specific power than shorter trips.

6.1.2.3 Vehicle/Driver Measures

In this section, measures that describe the operation of individual vehicles are discussed. Vehicles were instrumented for about a week in the two cities. This section presents the hourly or daily averages of vehicle operation measures.

Figure 6-15 and Table B-23 present the average distance that each vehicle drove daily. This figure represents the driving information from 216 vehicles. It was determined by first computing the total distance that each vehicle was driven for the instrumentation period and the total number of days that each vehicle was instrumented. The number of days was calculated by considering the time of start of the first trip and the end of the last trip while the vehicle was instrumented. This time was then divided by 24 hours to establish the total number of days, expressed as a decimal value, that the vehicle was used. The median daily distance driven was 22 miles for the driving modes survey. The comparable distance from the GM survey was 160 miles for a week, which is about 22.9 miles per day.

Figure 6-16 and Table B-24 show the distribution of vehicle operation per day. Vehicle operation represents the total time that the vehicle was operating on a daily basis. For each vehicle, the data point used in this distribution is the average vehicle operating time during a day. The median vehicle operation per day was about 60 minutes, which is equivalent to about 7 hours per week. In the GM survey, the weekly vehicle operation was 7.1 hours.

Figure 6-15. Daily Driven Distance Distribution

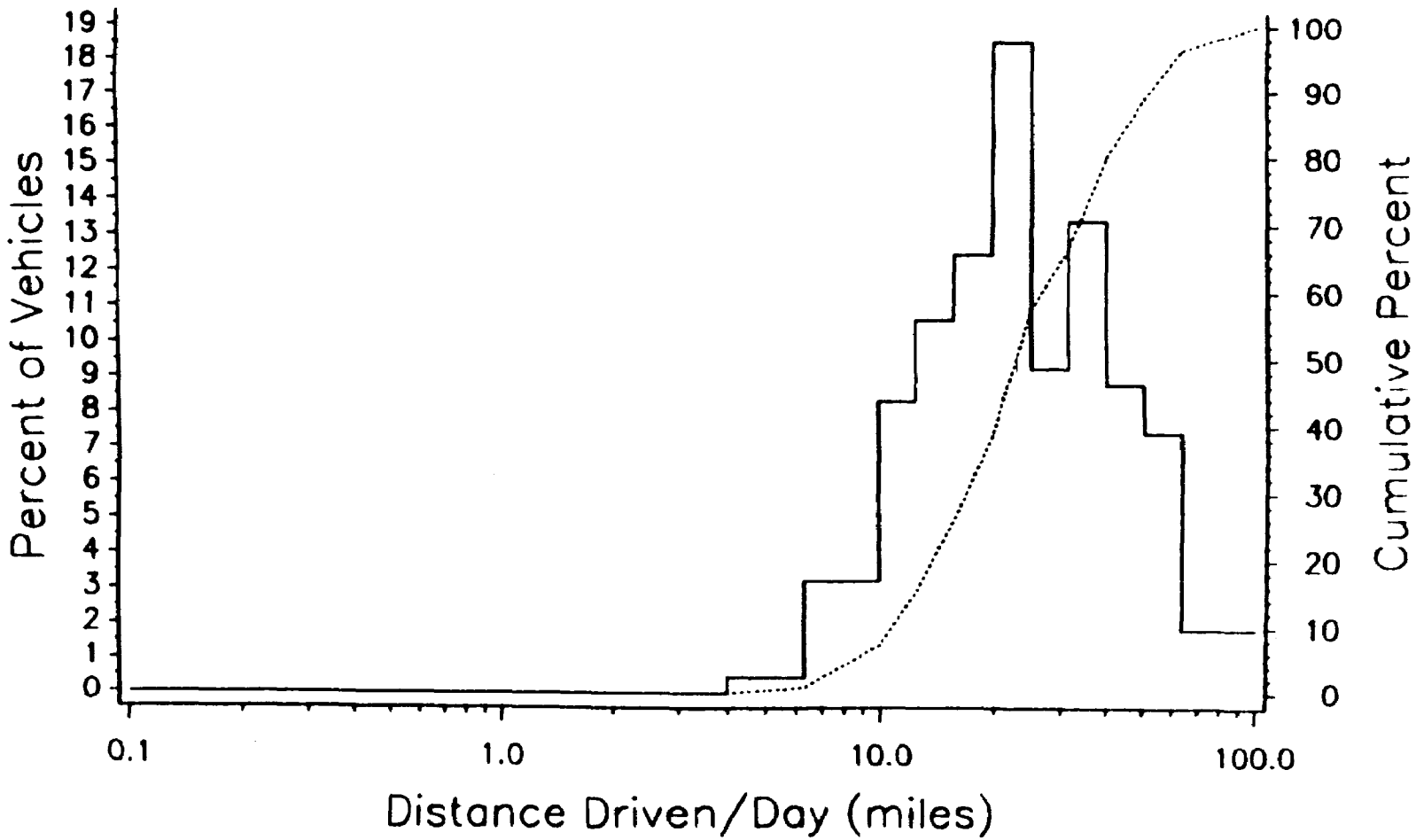


Figure 6-16. Daily Operating Time Distribution

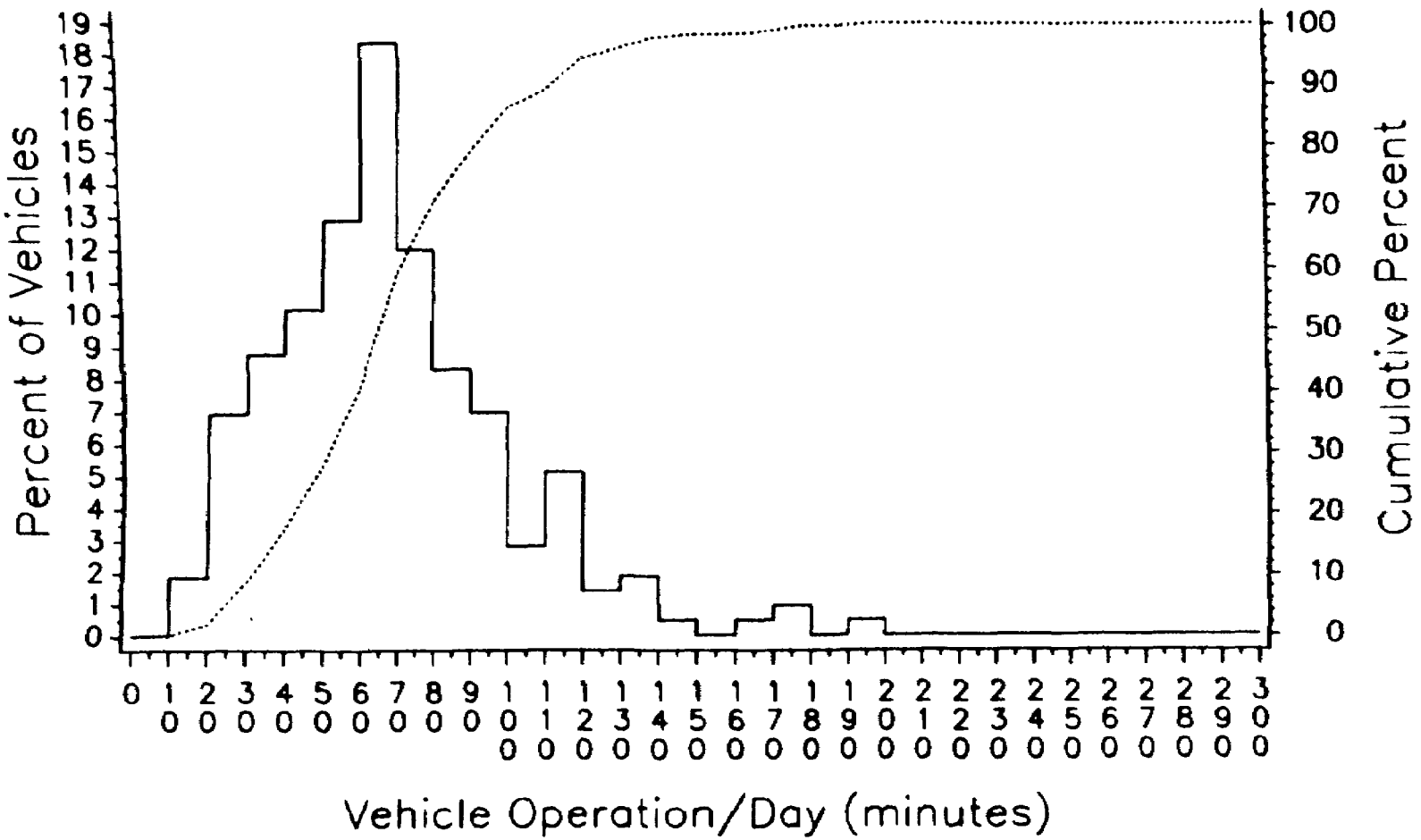


Figure 6-17 and Table B-25 show the distribution of the average number of trips per day for the 216 vehicles. The median number of trips per day was about 6.2. Figure 6-18, for major trips only, also shows a median of 6.2 trips per day, and the median from the GM survey was about 3.9 trips per day. The plot has a fairly normal distribution that relates well to the GM distribution.

Figure 6-19 and Table B-26 show the distribution of the average number of stops per hour of vehicle operation for each of the 216 vehicles for all trips. The definition of a stop is given in Section 6.1.2.1. Figure 6-19 shows that a near normal distribution of the average number of stops per hour exists for the driving modes data. The median number of stops per hour of vehicle use, when all trips are considered, is 38. Considering that the median trip length is 7 minutes, this would mean there would be about 9 trips per hour of use and, therefore, about 4 stops per trip. Figure 6-20 shows the same distribution for major trips only.

Table 6-3F shows the average vehicle operation in minutes per day, vehicle distance driven in miles per day, and the trips taken per day for the 216 vehicles. The mean, standard deviation, minimum, and maximum of these measures are also presented. These measures are weighted by the number of days that the vehicle was instrumented. All the 3-parameter vehicles were instrumented for a full week, so if a vehicle was instrumented on, for example, Tuesday, the datalogger on that vehicle was removed Wednesday of the following week. Therefore, the actual number of vehicle days would be close to eight days. For the 6-parameter vehicles, because of equipment constraints, the datalogger installed on Tuesday was removed the following Tuesday; therefore, the total number of days would be close to seven days. The 3-parameter vehicles, therefore, have a slightly higher weighting in this table.

The weighted average vehicle operation time was found to be 68.5 minutes. The average vehicle operation time from the GM survey was 72 minutes. The weighted average distance driven per day was 28.1 miles, compared to 28.7 miles from the GM

Figure 6-17. Distribution of Number of Trips per Day for All Trips

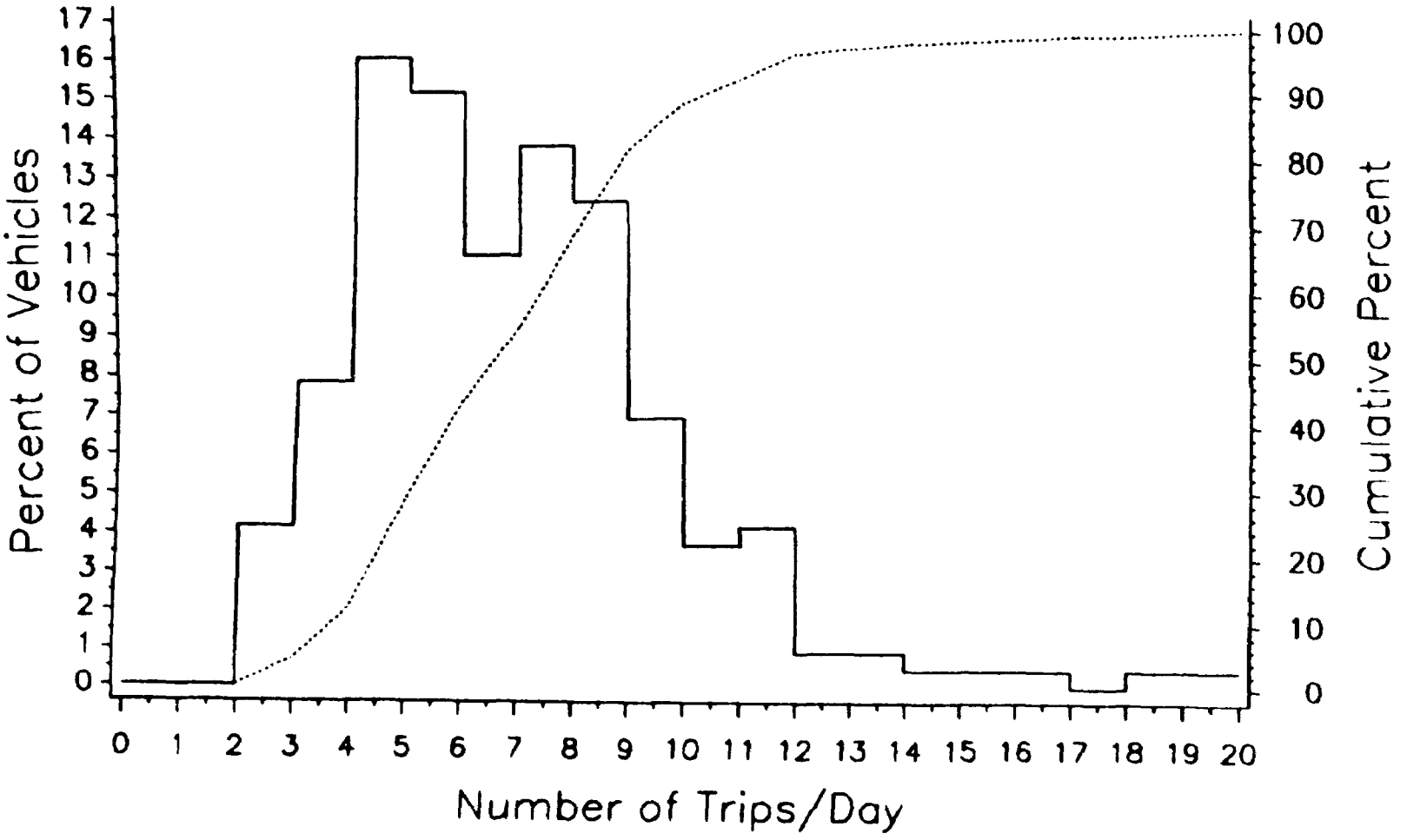


Figure 6-18. Distribution of Number of Trips per Day for Major Trips Only

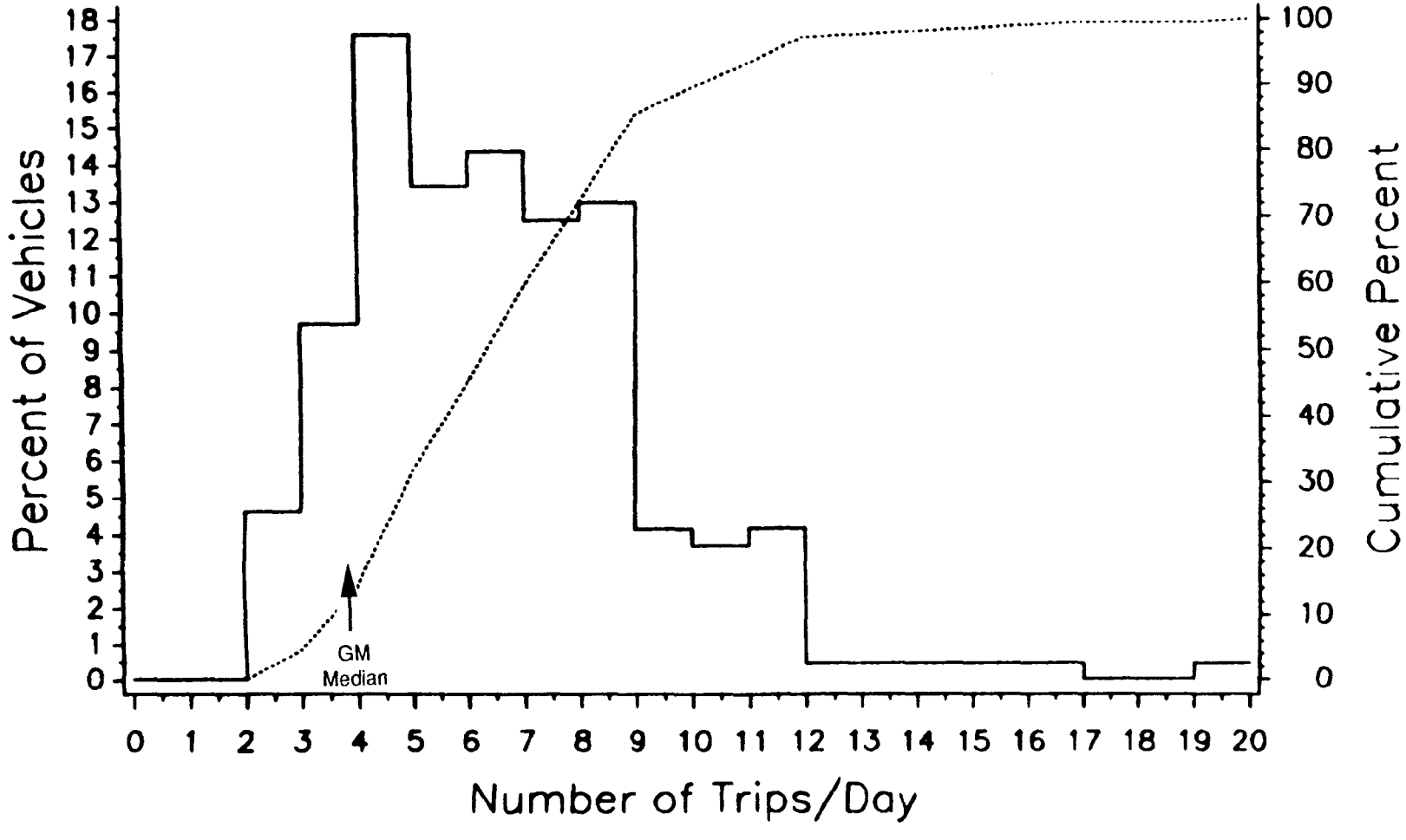


Figure 6-19. Distribution of Number of Stops per Hour for All Trips

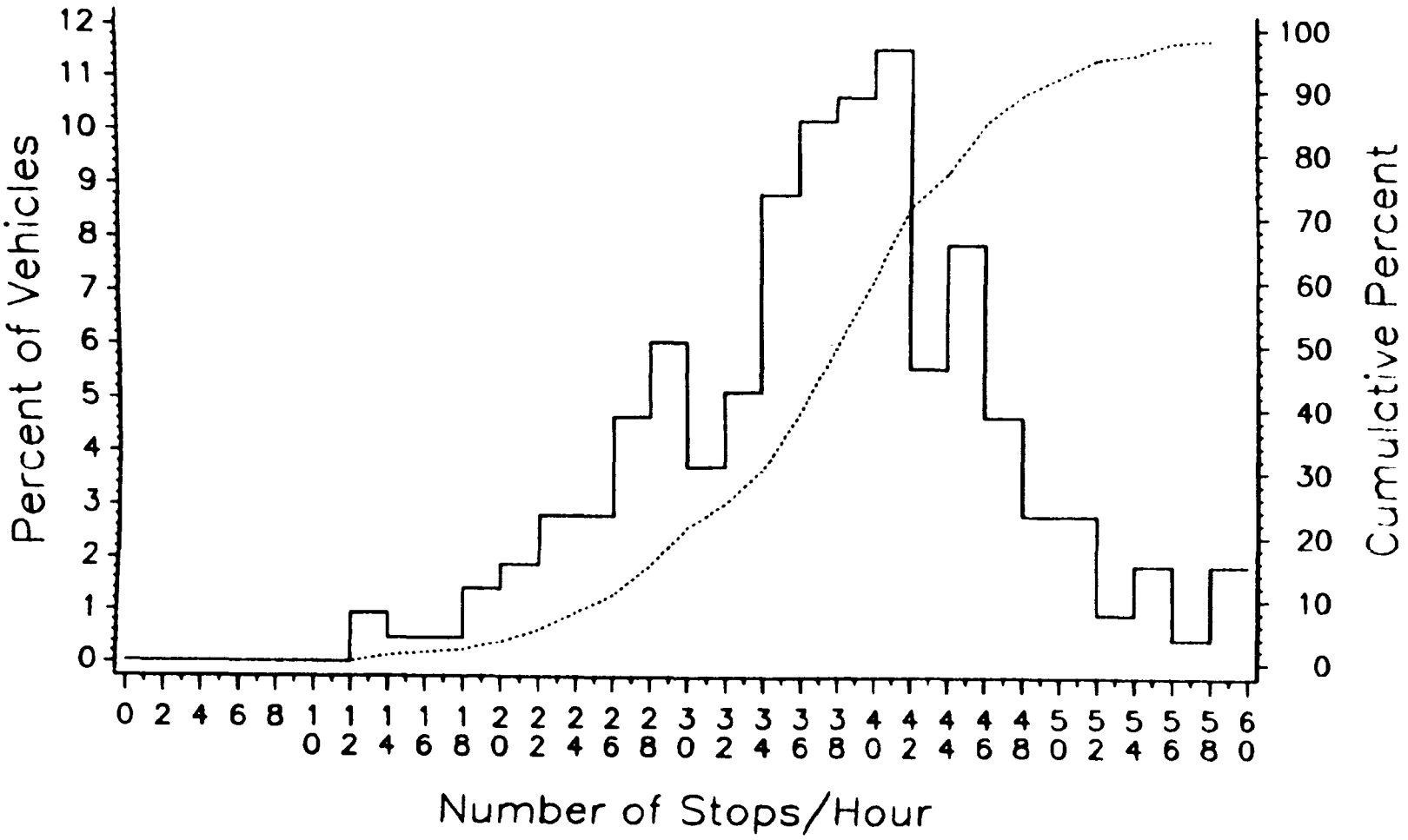


Figure 6-20. Distribution of Number of Stops per Hour for Major Trips Only

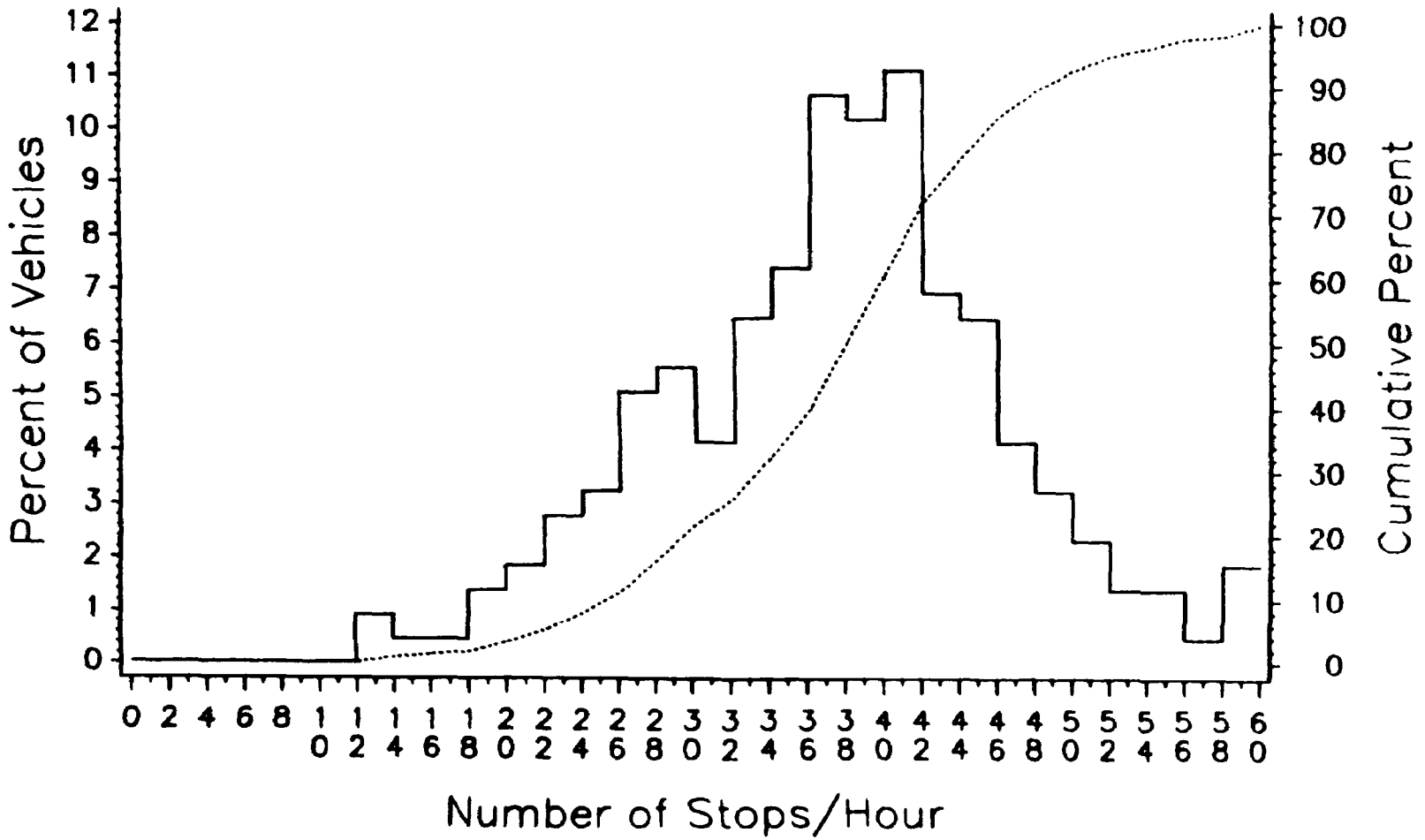


Figure 6-19. Distribution of Number of Stops per Hour for All Trips

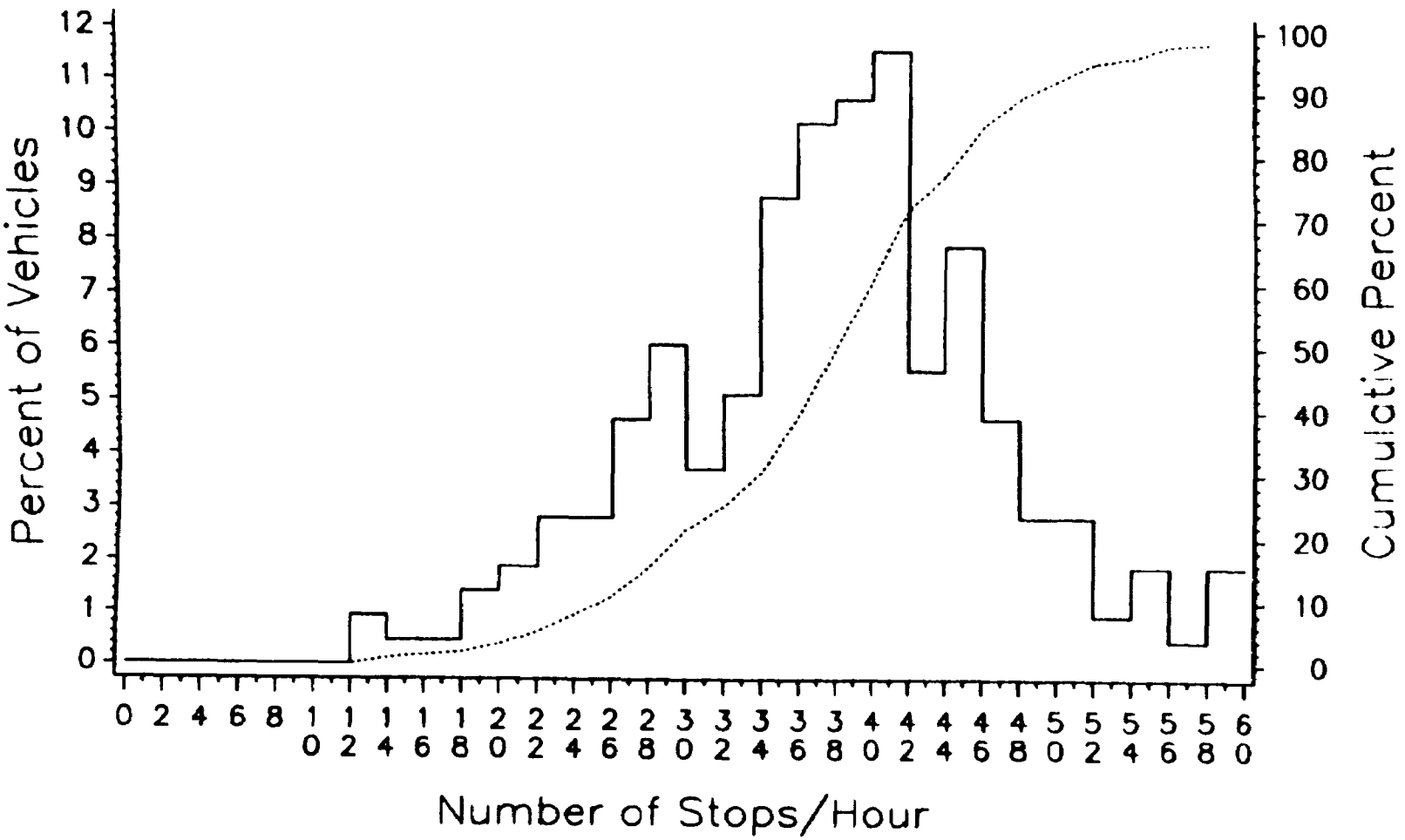
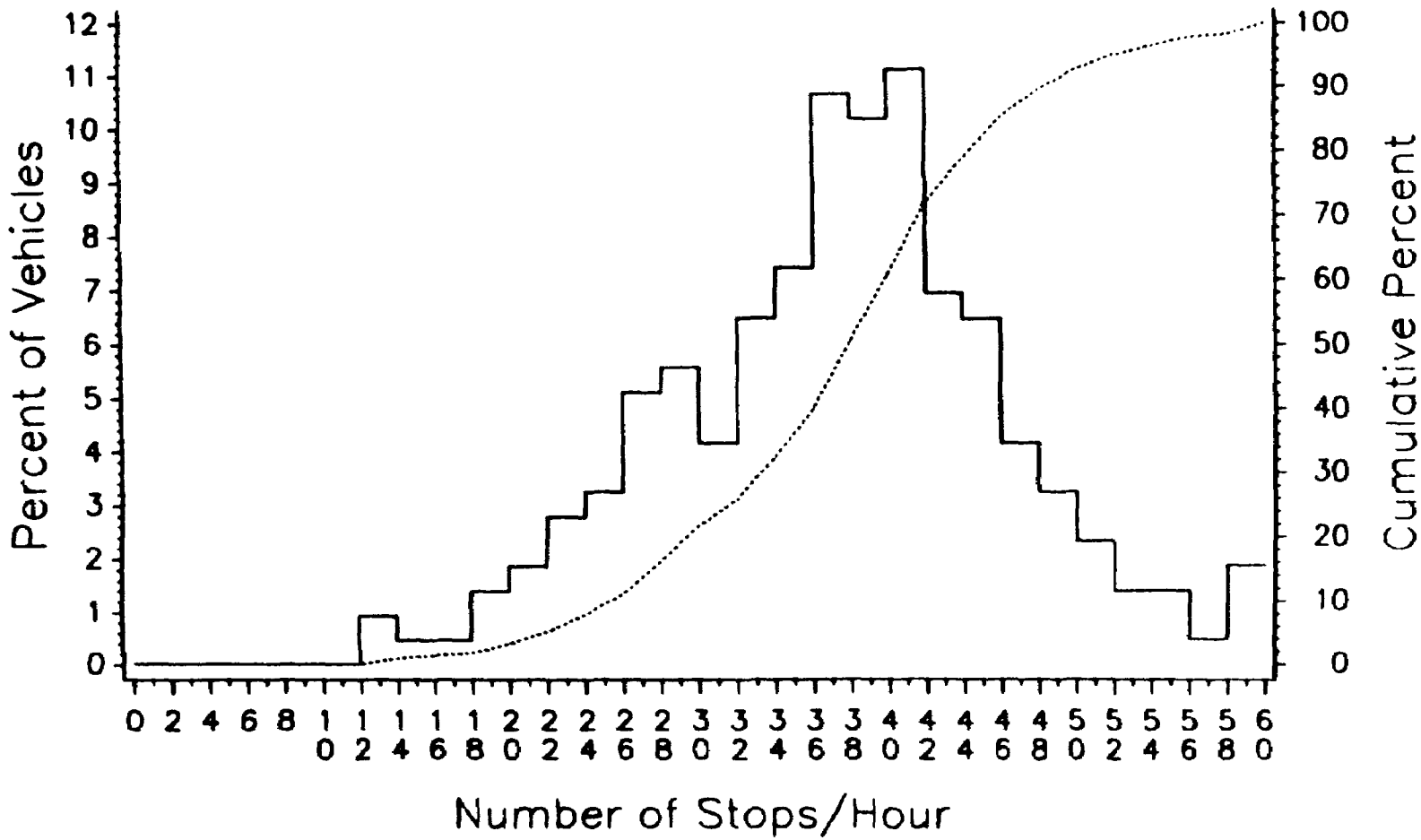


Figure 6-20. Distribution of Number of Stops per Hour for Major Trips Only



survey. The average number of trips per day was 7.1, compared with 4.1 trips/day for the GM survey.

Table 6-3G shows the average number of stops per hour of vehicle operation for the 216 vehicles. This number has been weighted by the number of hours of operation for each vehicle. Table 6-3H shows the weighted means and standard deviations for the percent of accelerations, speeds, and specific powers greater than or equal to the value shown. For example, the first line shows the average number of vehicle operation observations in which the acceleration was ≥3 mph/s. On average for all the vehicles, 3.26% of the vehicle operation observations had accelerations equal to or above 3 mph/s. These measures have been weighted by the number of hours of operation for each vehicle.

6.1.3 Comparison with Current FTP

An FTP data file was set up to simulate a vehicle experiencing a one-second trip followed by a 12-hour soak, followed by a trip of 1369 seconds representing the cold start and the hot stabilized bags of the FTP, a 10-minute soak, and then the first 505 seconds of the LA-4 representing the hot start bag of the FTP. This file was set up just like the data file from any of the instrumented vehicles. Table 6-4 shows the speed, acceleration, and specific power descriptions for the FTP. Table 6-5 shows the number of seconds spent at any given speed and acceleration mode for the FTP. Note that the column containing accelerations of 1 mph/s represents accelerations between 0 and 1. Tables B-27, B-28, and B-29 show the distribution of speed, acceleration, and specific power for the FTP. Figures 6-21, 6-22, and 6-23 show these distributions in graphical form.

Figure 6-21 for the FTP can be compared with Figure 6-2 for the driving pattern data. In general, the shape of the FTP speed curve is similar to that of the new study, but the FTP speeds are shifted to lower speeds. The similarities include the

Table 6-4

Speed, Acceleration, and Specific Power Statistics for the FTP Cycle

Variable	Units	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
MPH	mph	1874	21.2	15.94	0.00	56.70
ACCEL	mph/s	1872	0.00	1.41	-3.31	3.60
POWER	mph^2/s	739	41.84	31.72	0.00	191.84

Table 6-5

Speed/Acceleration Distribution for the FTP Cycle

SP5 AC1

Percent	-3	-2	-1	0	1	2	3	4	Total
0	0.05	0.32	0.53	18.06	0.00	0.00	0.00	0.00	18.96
5	1.34	0.27	0.59	0.43	0.27	0.91	0.59	0.43	4.81
10	1.34	0.43	0.21	0.48	0.11	0.32	0.37	1.55	4.81
15	1.01	0.96	0.32	0.32	0.43	0.43	0.75	0.96	5.18
20	1.01	0.91	0.85	1.55	1.44	1.50	0.75	0.96	8.97
25	0.48	0.91	1.39	5.29	5.34	2.46	0.91	0.21	16.99
30	0.32	0.32	0.43	6.78	6.41	1.44	0.11	0.11	15.92
35	0.00	0.11	0.75	3.26	2.99	0.59	0.21	0.11	8.01
40	0.00	0.00	0.32	2.35	1.50	0.21	0.11	0.00	4.49
45	0.00	0.00	0.53	0.00	0.00	0.32	0.00	0.00	0.85
50	0.00	0.00	0.11	1.71	0.96	0.11	0.00	0.00	2.88
55	0.00	0.00	0.21	2.78	2.46	0.11	0.00	0.00	5.56
60	0.00	0.00	0.00	1.50	1.07	0.00	0.00	0.00	2.56
Total	104	79	117	833	430	157	71	81	1872
	5.56	4.22	6.25	44.50	22.97	8.39	3.79	4.33	100.00

Figure 6-21. Speed Distribution for the FTP Cycle

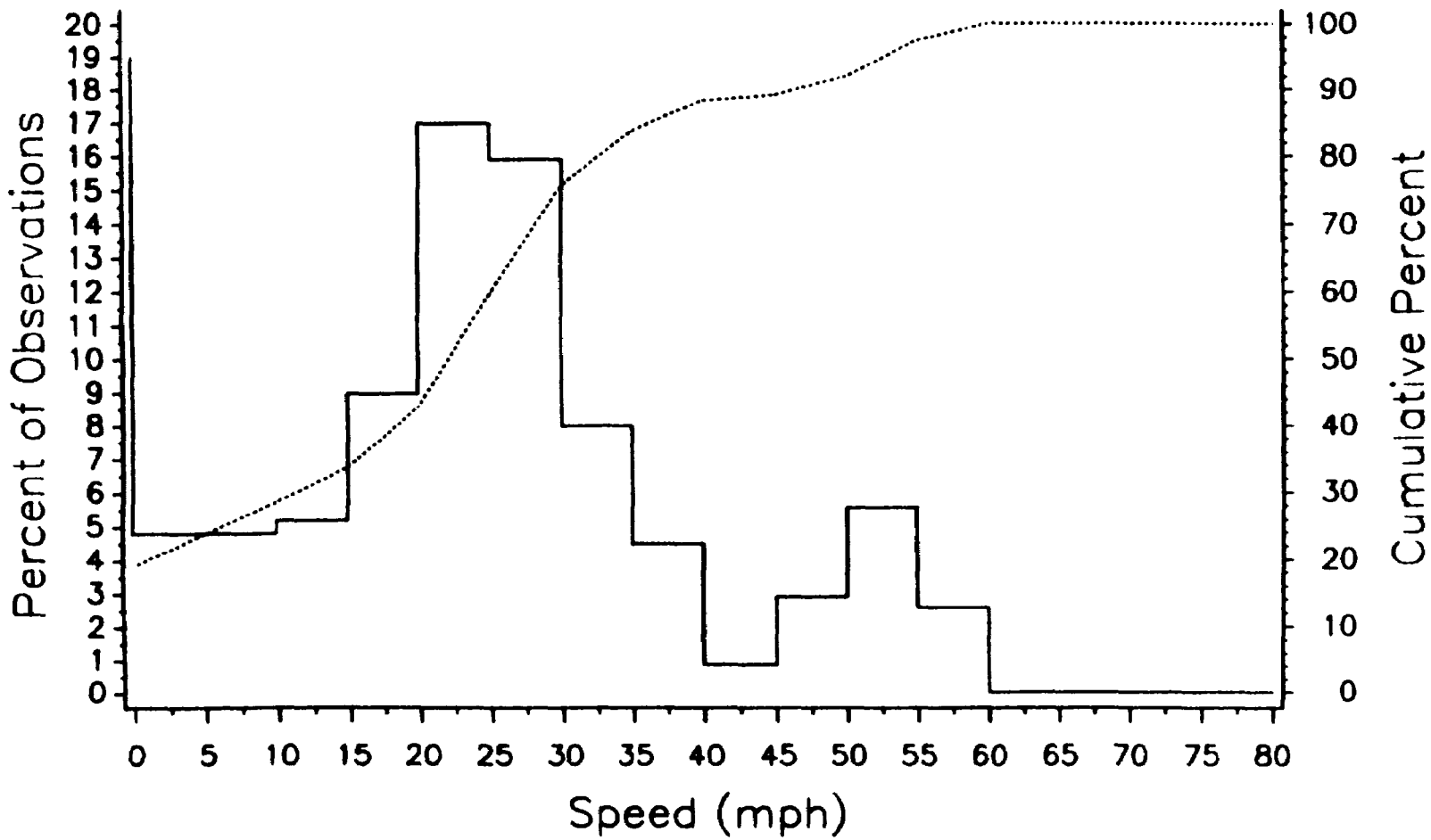


Figure 6-22. Acceleration Distribution for the FTP Cycle

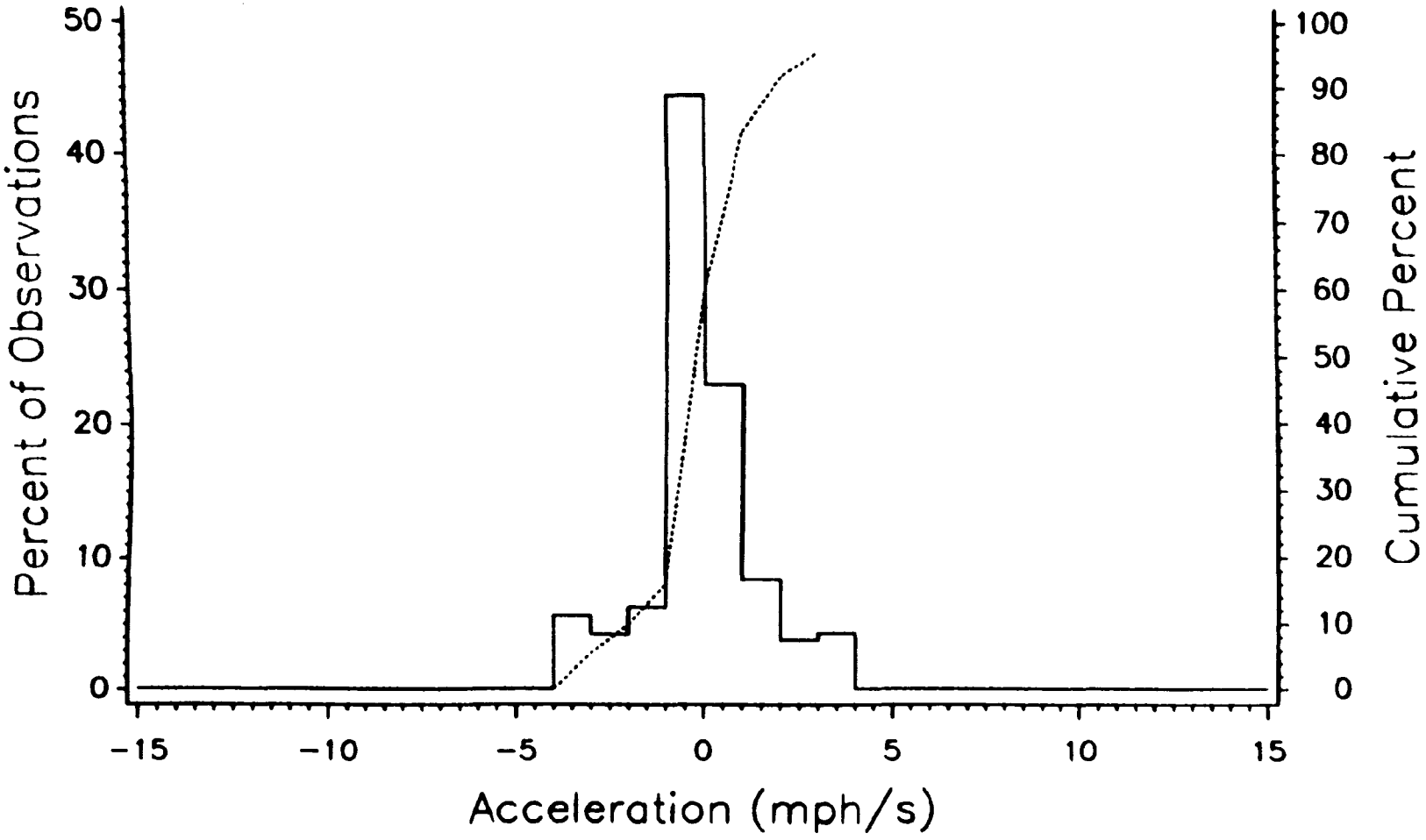
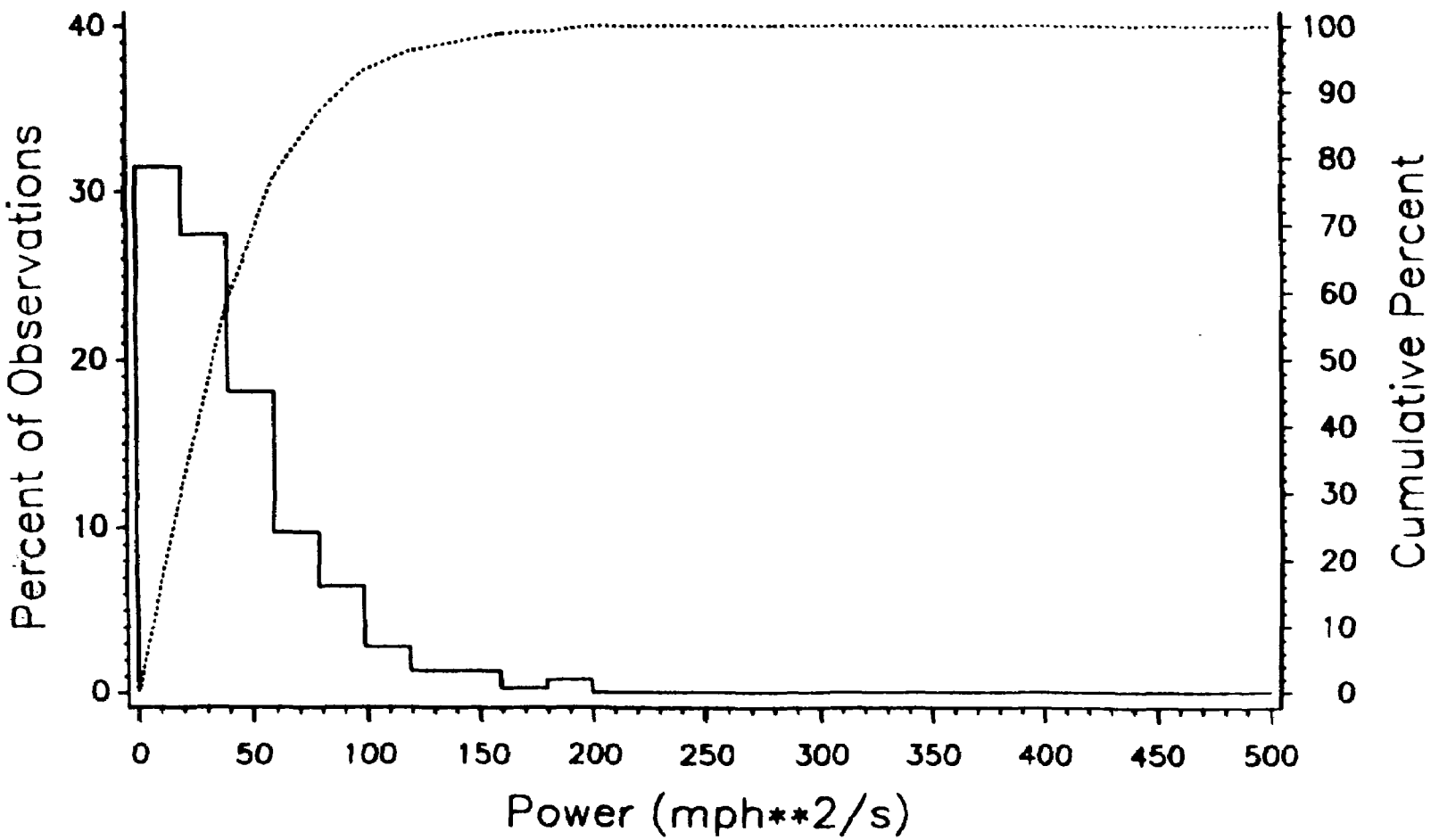


Figure 6-23. Specific Power Distribution for the FTP Cycle



similar percent of idling time and the general shape of peaks around 30 mph and around 55 mph. Some differences are the lower percent of speeds around 30-35 mph in the driving pattern data, compared with the FTP. In addition, the higher speeds (>60 mph) seen in the driving modes data are not included in the FTP.

Another interesting comparison is between Figures 6-1 and 6-24. Figure 6-24 shows an acceleration-speed contour plot for the FTP. One apparent difference is the absence of accelerations above 4 mph/s and below -4 mph/s. In addition, the general speed acceleration increase area (below 25 mph and 0-2 mph/s) seen in the driving pattern data is not well defined in the FTP. Some of the high density areas around zero acceleration and 30-35 mph and 50-55 mph are seen in both figures.

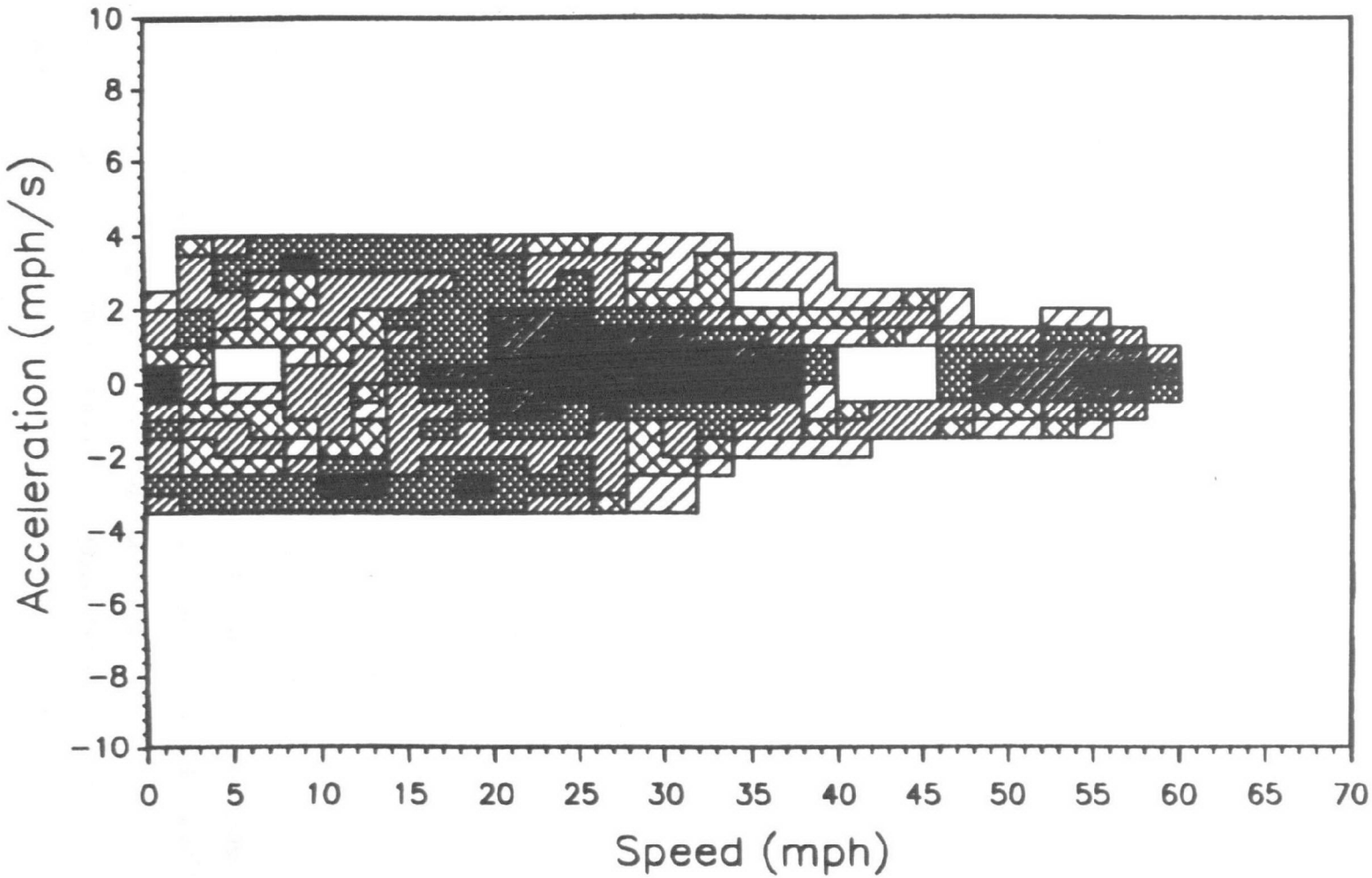
6.2 Data Biases

To assist in the evaluation of the driving pattern database, the methods of data collection were examined for data biases. Three areas were considered: speed and acceleration biases, vehicle selection biases, and any biases produced by the presence of the datalogger on vehicles.

6.2.1 Speed and Acceleration Biases

The 3-parameter datalogger software used an algorithm to convert the pulses received from the speed sensor into an average speed for each second that the engine was on. As explained earlier, the datalogger measured the time between consecutive pulses within a one-second window. The average of these times gave the average time per pulse. During the calibration, the datalogger had stored the distance per pulse, which was a characteristic of the speed sensor on that particular vehicle. When this distance per pulse calibration factor was divided by the average time per pulse in the one-second window, the average speed for that one-second window was obtained and recorded in memory at the end of the one-second time period. To demonstrate that

Figure 6-24. Acceleration/Speed Contours for the FTP Cycle



this technique provides an unbiased measure of vehicle speed, a specific numerical example will be used.

Suppose the vehicle had a speed profile for a one-second period, as shown in Figure 6-25. In this instance, the vehicle started from rest and accelerated to a speed of 8 m/s in ½-second and then the speed was constant to the end of the second. The acceleration for the first ½-second would be 16 m/s^2 and the acceleration for the second ½-second would be 0 m/s^2. Suppose that the speed sensor on this vehicle put out one pulse for each meter that the vehicle traveled. The time when a pulse was generated can be calculated from the relationship given below:

$$T = \sqrt{2 \times s/a}$$

where

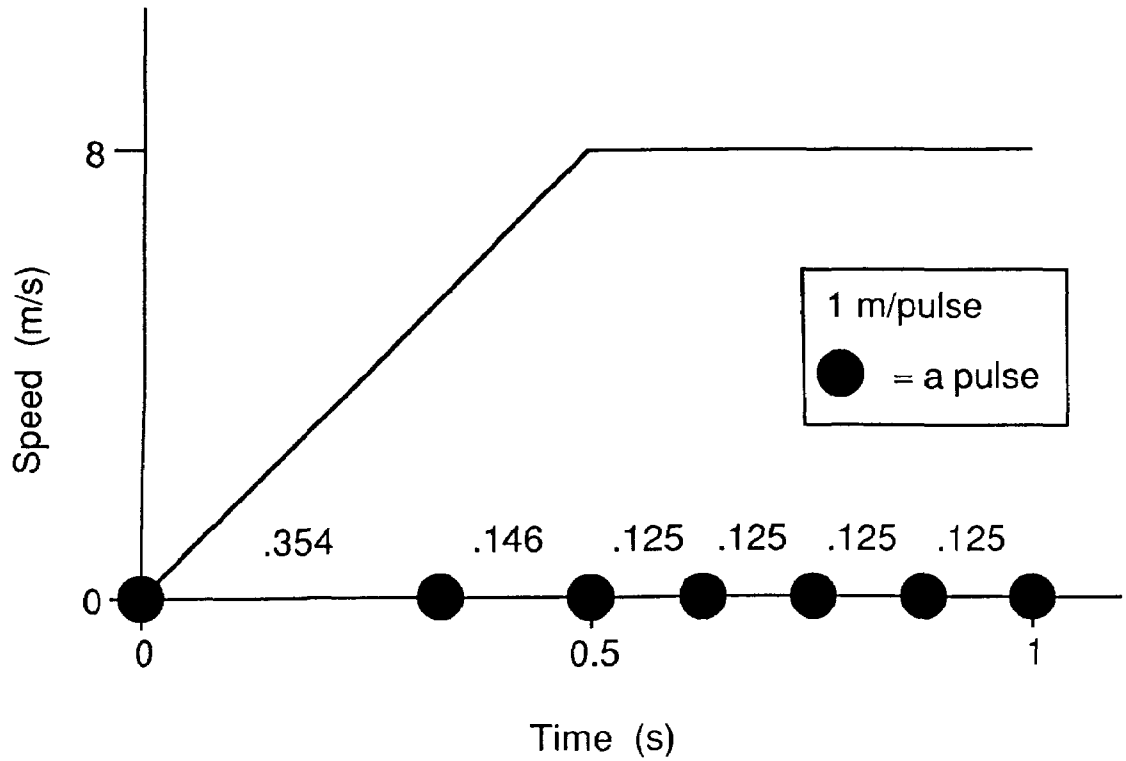
s = the distance moved since time 0,

a = the acceleration, and

T = the time required to move distance s at acceleration a from time 0.

Using this expression, the times when pulses would occur, assuming that the first pulse occurs at time 0, are shown in Figure 6-25. The pulses occur at 0, 0.354, 0.500, 0.625, 0.750, 0.875, and 1 second. The datalogger measures the time between these pulses, which are 0.354, 0.146, 0.125, 0.125, 0.125, and 0.125 seconds, and determines the average time per pulse. The average time per pulse is the sum of those differences, which is 1 second, divided by the number of spaces between pulses, which is 6, to get 0.166 seconds per pulse. When the speed sensor calibration constant of 1 meter per pulse is divided by the average time per pulse of 0.166 seconds per pulse, the result is a calculated average speed of 6 m/s. This value of 6 m/s is the same value that an observer of the speed profile in Figure 6-25 would say is the average speed of the vehicle during the one-second time period.

Figure 6-25. Speed Profile Example



This example shows that the algorithm used by the datalogger to calculate average speed for a second does not produce a bias. However, this average speed is logged in the datalogger's memory at the end of the one-second time period, when the instantaneous speed of the vehicle was not 6 m/s.

To calculate acceleration for data analysis purposes, the successive average speeds for two seconds are subtracted, and the resulting acceleration value is assigned to the last second. Bias in the calculated values for acceleration can be examined by considering the fifth wheel data, which was discussed in Section 2. This comparison is made between the accelerations calculated by the fifth wheel speed data, which were collected and averaged every 1/7-second, and the 3-parameter datalogger speeds, which were collected and averaged every second. Accelerations were calculated from both dataloggers by taking the difference between successive speed values and dividing by the time between the two readings.

The accelerations for Drive 3 for the three types of speed sensors are shown in Figures 6-26, 6-27, and 6-28. In these figures, the solid line is the acceleration calculated from the 3-parameter datalogger, and the dotted line is the acceleration collected from the fifth wheel. The plots show that accelerations range from a high of about 9 mph/s to a low of -14 mph/s. The driving for each of these drives was a hard acceleration, followed by a panic stop. The three figures showed that there was very good agreement between the acceleration calculated from the fifth wheel and the datalogger. There is approximately a one-second shift in the 3-parameter acceleration curves to times later than the fifth wheel acceleration curves, because of the backwards differencing calculation used to determine acceleration for the 3-parameter logger data. The figures show there may be a slight tendency for the 3-parameter datalogger to underestimate the acceleration rates in comparison with those measured by the fifth wheel.

Figure 6-26. Evaluation of Calculated Accelerations for the Speedometer Cable Speed Sensor

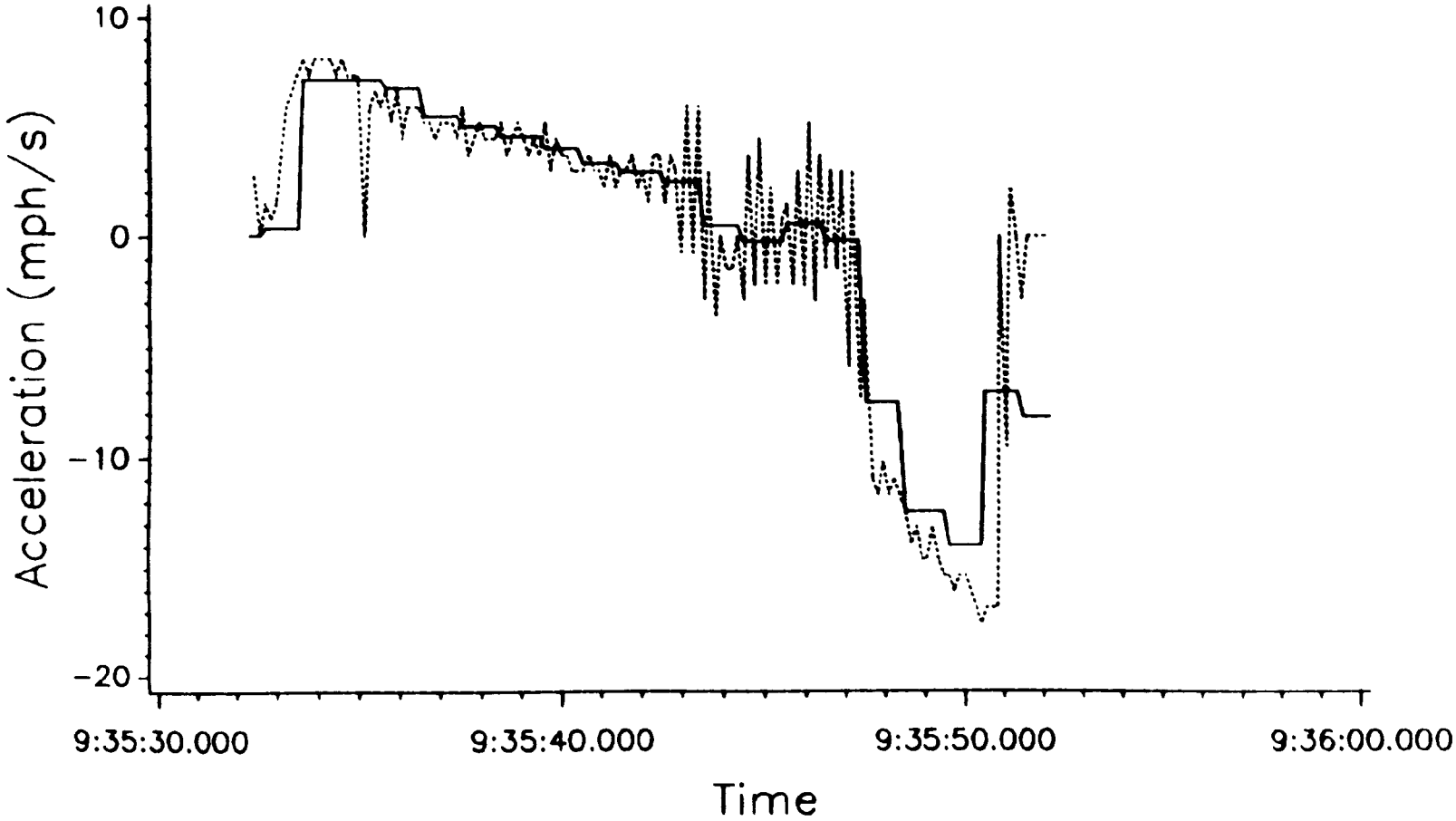


Figure 6-27. Evaluation of Calculated Accelerations for the Magnet Speed Sensor

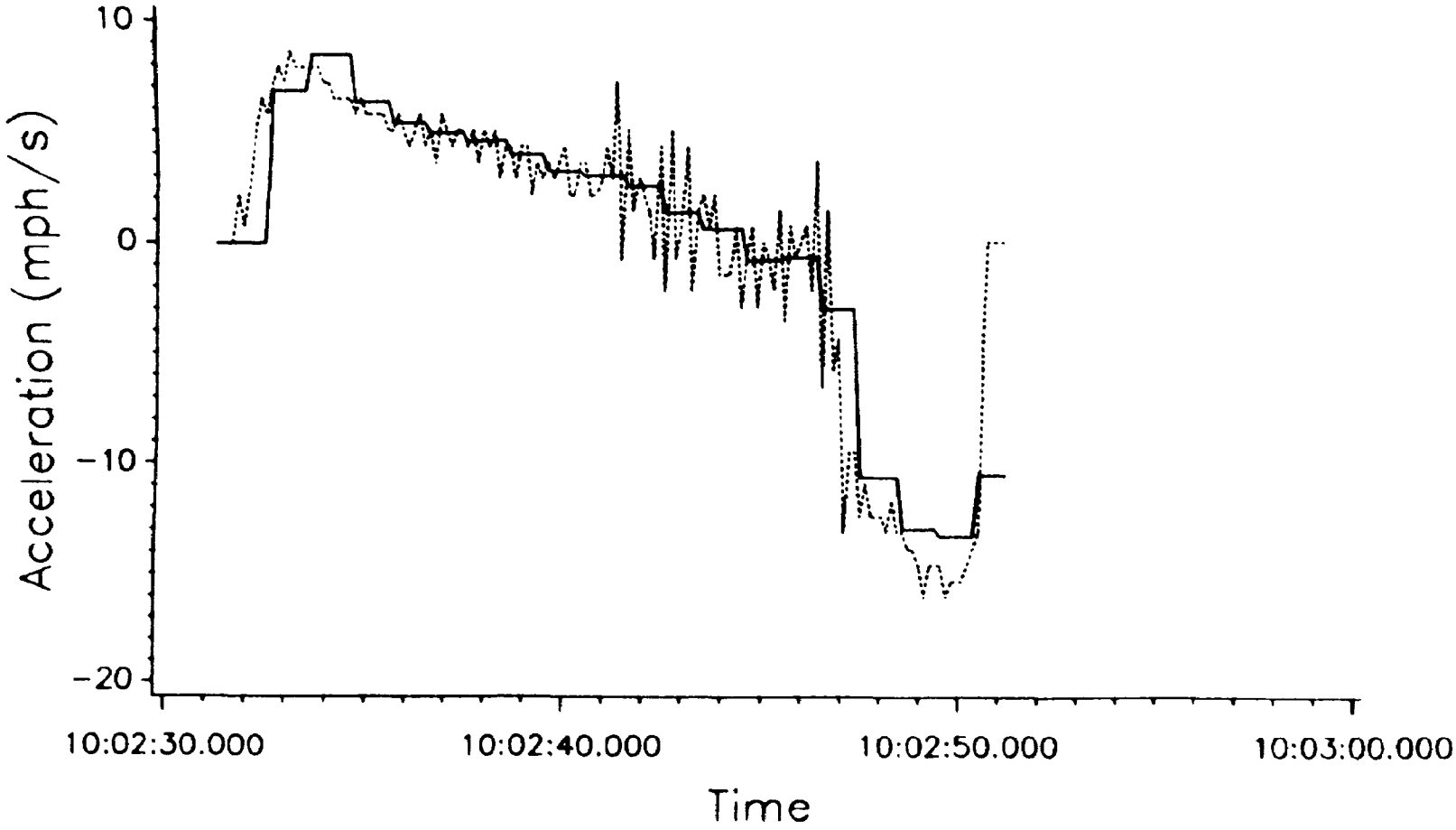
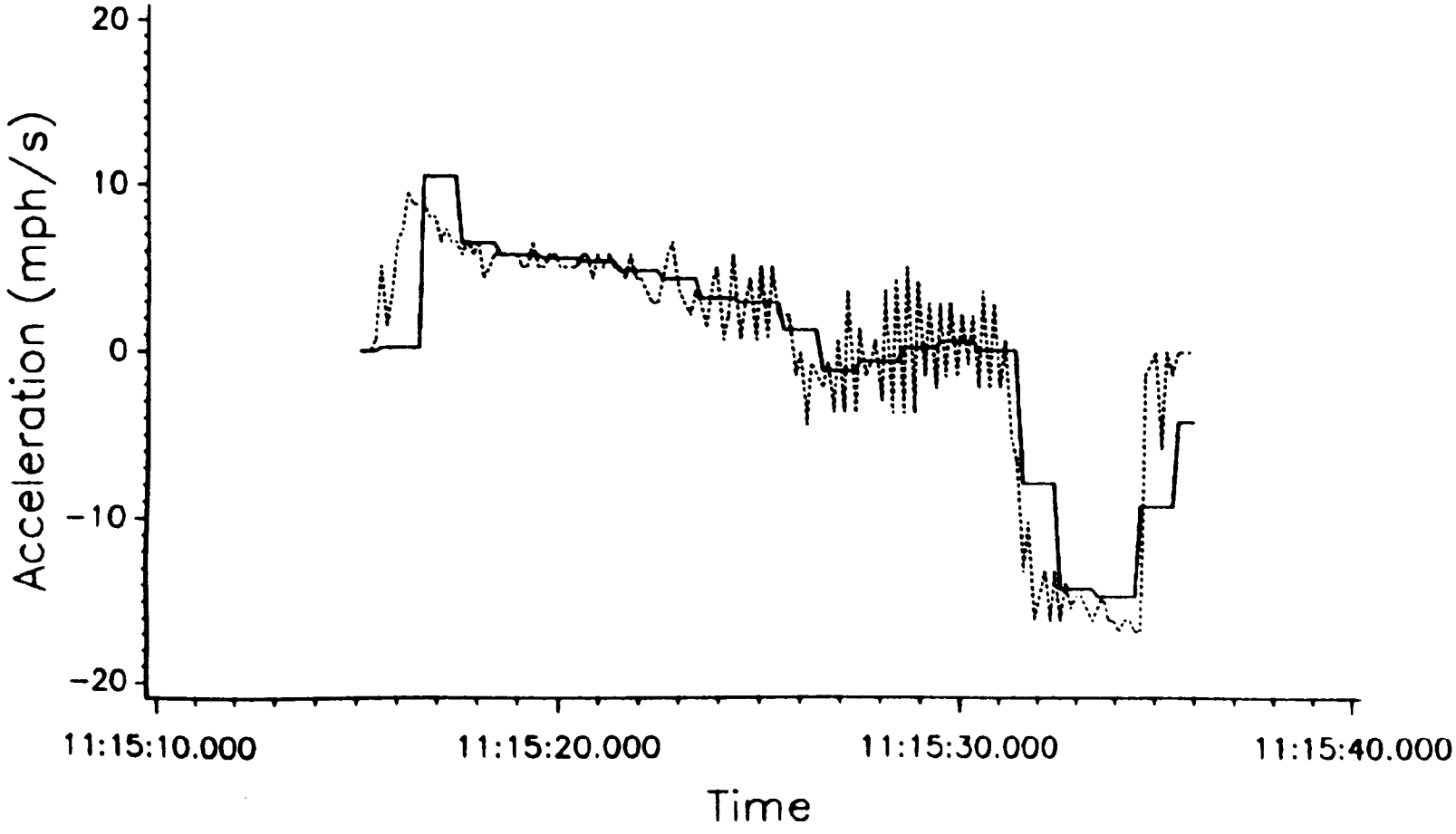


Figure 6-28. Evaluation of Calculated Accelerations for the OEM Speed Sensor



Another feature noticed in these figures is that at accelerations near 0 mph/s, the fifth wheel accelerations fluctuate greatly up and down. In comparison, the 3-parameter datalogger does not exhibit these fluctuations. The point where accelerations were 0 mph/s in the middle of the drive was when the vehicle was being driven at approximately 50 mph. The driver was attempting to keep the vehicle going at a constant speed at this point, but because the speed was high, there were significant fluctuations in speed within each one-second time window of about 1 mph. When the accelerations are calculated for the fifth wheel, these 1 mph speed fluctuations are divided by the time between successive data points of 1/7-second, and this causes the calculated value of acceleration to be very sensitive to the changes in speed of the vehicle. During the wide-open throttle and the panic stop, the driver is not controlling the speed closely. Vehicle speed is just rapidly changing in one direction.

Thus, this evaluation of the acceleration accuracy of the 3-parameter datalogger indicates that the datalogger is accurate over a wide range of accelerations.

6.2.2 Vehicle Selection Bias

For the 3-parameter vehicles, a special vehicle selection technique was developed and used in an attempt to get a representative sample of the vehicle population that came to the I/M stations in Spokane and Baltimore. As discussed earlier, it was desirable to sample the population in a representative fashion, so that different types of vehicles and different types of drivers would be represented in the sample. If the drivers of the vehicles did not want to participate in the project, or the vehicles could not be instrumented for another reason, then these original vehicles were replaced with other vehicles that were selected to have similar characteristics for classes of driver age, vehicle age, origin, and type of vehicle.

While 6-parameter vehicles were not selected randomly, it was desirable to get a sample which, in some approximate way, matched the distribution of vehicle makes in the eligible group of model year and make vehicles in the vehicle population.

Since the sampling of the population has been accomplished, it is now possible to use statistical tests to determine if these samples are representative of the population. Table 6-6 shows a list of the comparisons that will be made between pairs of distributions for both cities and for the 3- and 6-parameter dataloggers as a function of make, model year, and driver age class. This analysis was performed on SAS, using the Chi^2 Statistical Test for the categorical distributions of vehicle model, and using the Mantel-Haenszel Chi^2 Test for the ordinal distributions of model year. The results of the statistical tests are shown in the last column of Table 6-6 and indicate there were no differences between any of the distributions that were tested. Pairs of plots were made to visualize the distributions that the statistical tests compared. These are discussed below.

A tape for March 1992, giving the makes and model years of all vehicles inspected in Baltimore at the stations where dataloggers were instrumented on vehicles, was obtained from Envirotest, Inc. The tape was filtered to include only those vehicles that had passed the emissions test or had been given waivers. This resulted in a population of 17,279 vehicles. The distribution of these vehicles by make is shown in Figure 6-29 and the distribution by model year is shown in Figure 6-30. The same distributions were calculated for the vehicles that were instrumented in Baltimore with 3-parameter dataloggers. These distributions are shown in Figure 6-31 and in Figure 6-32. Comparison of the corresponding distributions for make and model year shows that they appear to be very similar and, thus, support the result of the Chi^2 statistic, which indicates that there is no reason to believe there is a difference between the distribution of the sampled vehicles and the distribution of the population. We have not yet received a tape from VTTI, Inc. for the February 1992 population inspected in Spokane, because VTTI is currently implementing major software revisions.

Table 6-6

Results of Bias Analysis for Vehicle Selection

Site	Target Vehicle Parameter Type	Distribution A	Distribution B	Parameter Compared	Probability	
					Chi Square	Mantel-Haenszel
Baltimore	3	Instrumented Vehicles	Mar 92 Population	Model Year	-	0.75
Baltimore	3	Instrumented Vehicles	Mar 92 Population	Make	0.41	-
All Sites	3	Replacement Vehicles	Replaced Vehicles	Model Year	-	0.39
All Sites	3	Replacement Vehicles	Replaced Vehicles	Make	0.14	-
Baltimore	6	Instrumented Vehicles	Mar 92 Population of 89, 90, 91 Eligible Makes	Model Year	-	0.37
				Make	0.26	-

Figure 6-29. Vehicle Make Distribution of Baltimore Eligible Population

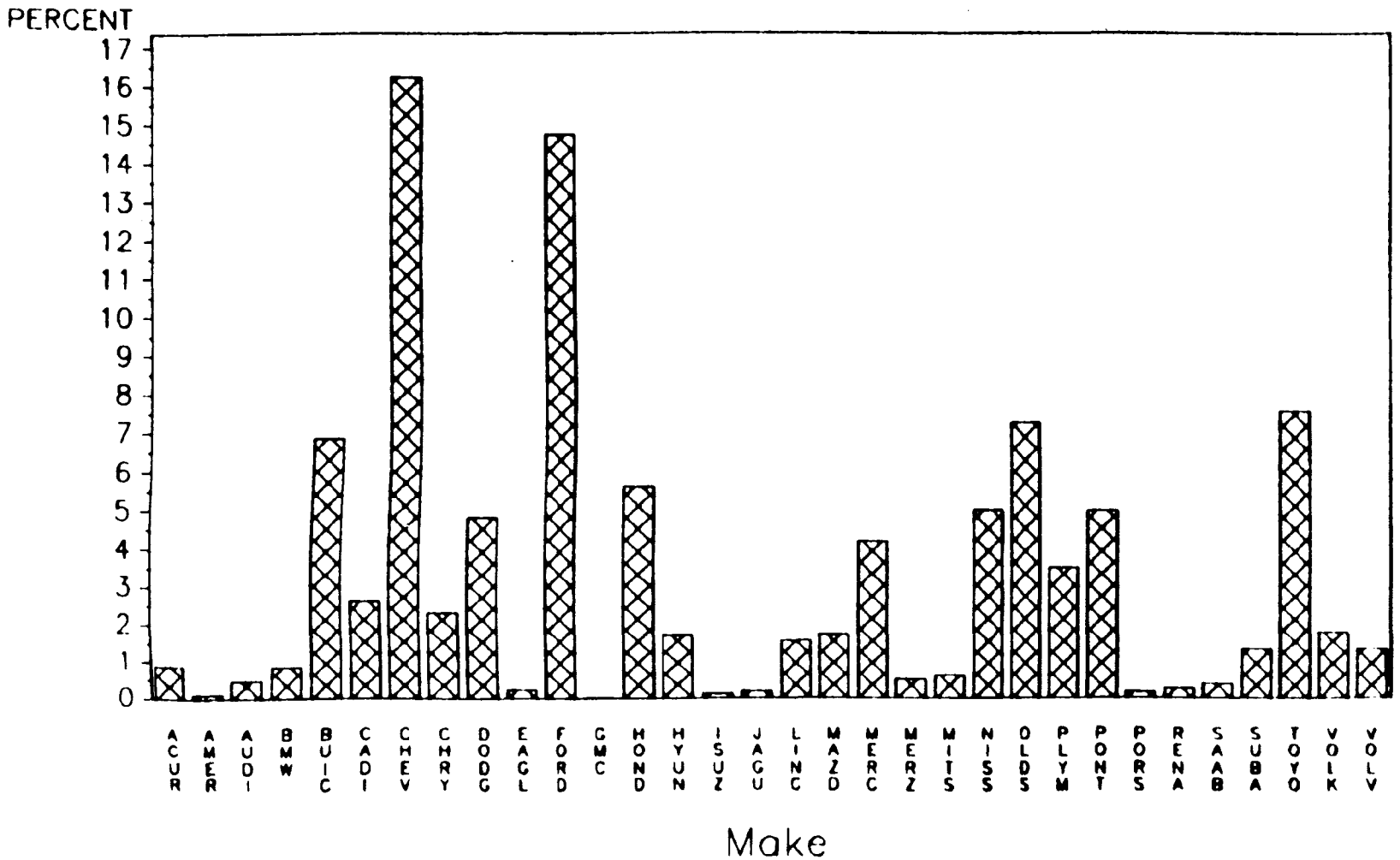


Figure 6-30. Model Year Distribution of Baltimore Eligible Population

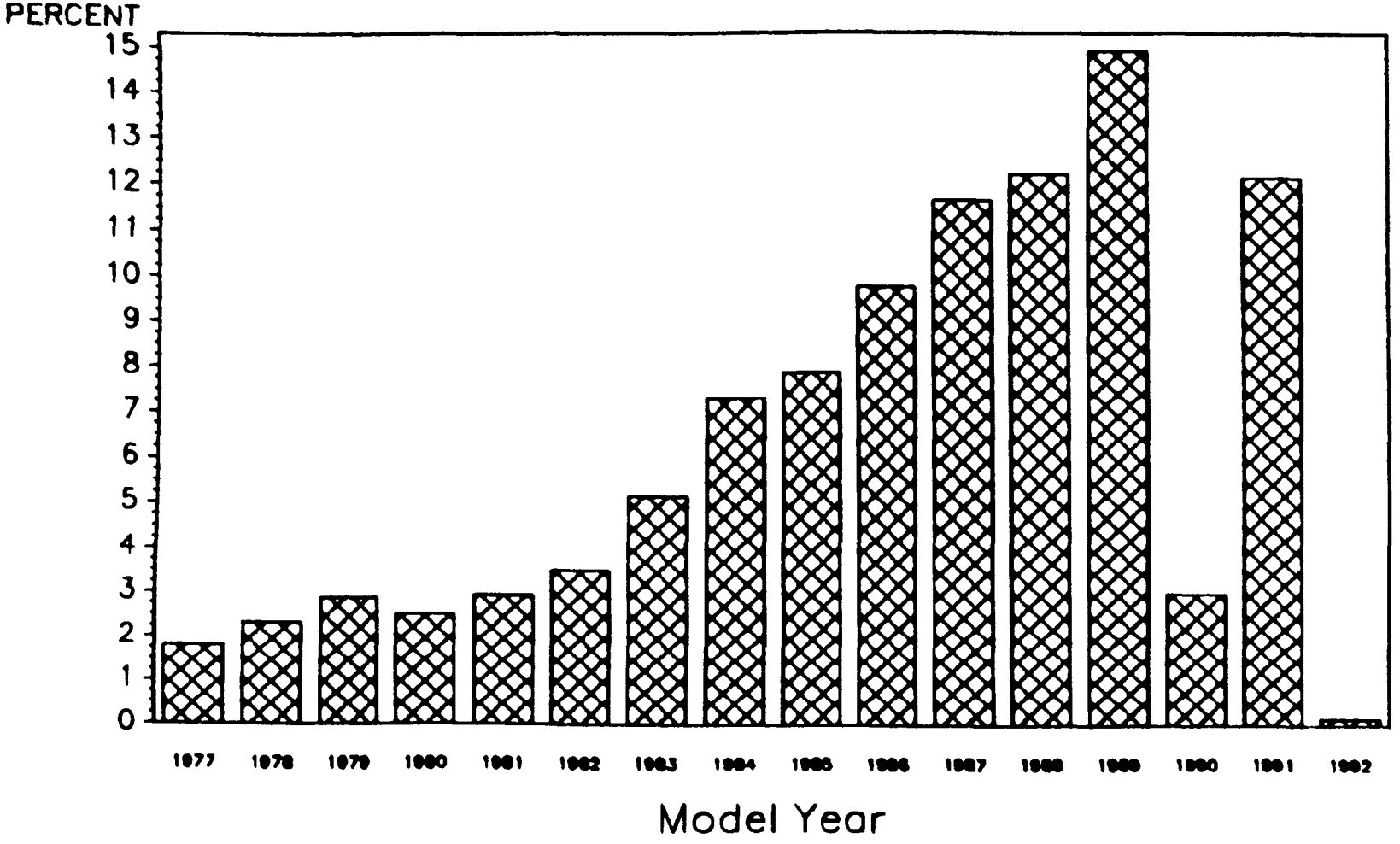


Figure 6-31. Vehicle Make Distribution of 3-Parameter Baltimore Instrumented Vehicles

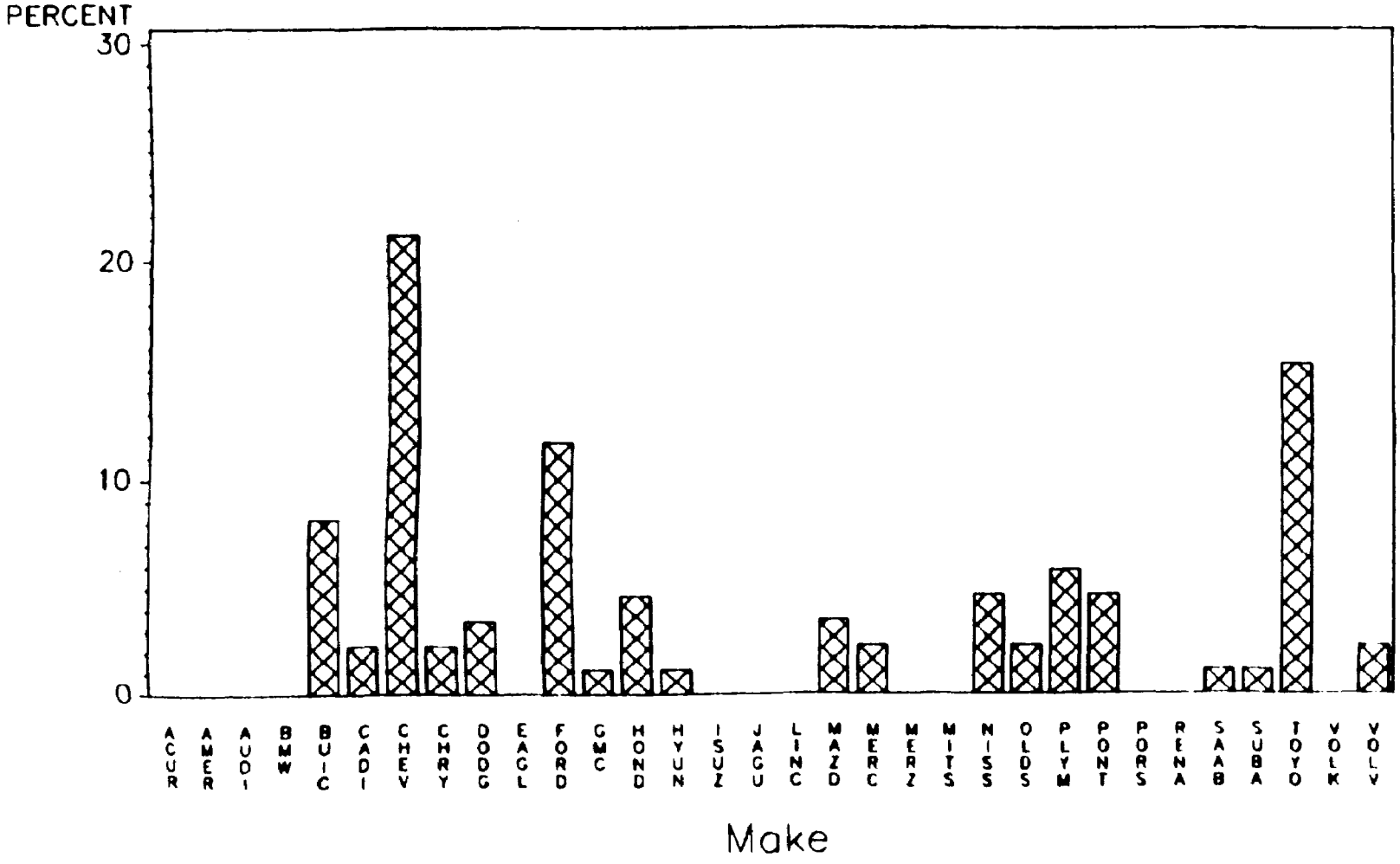
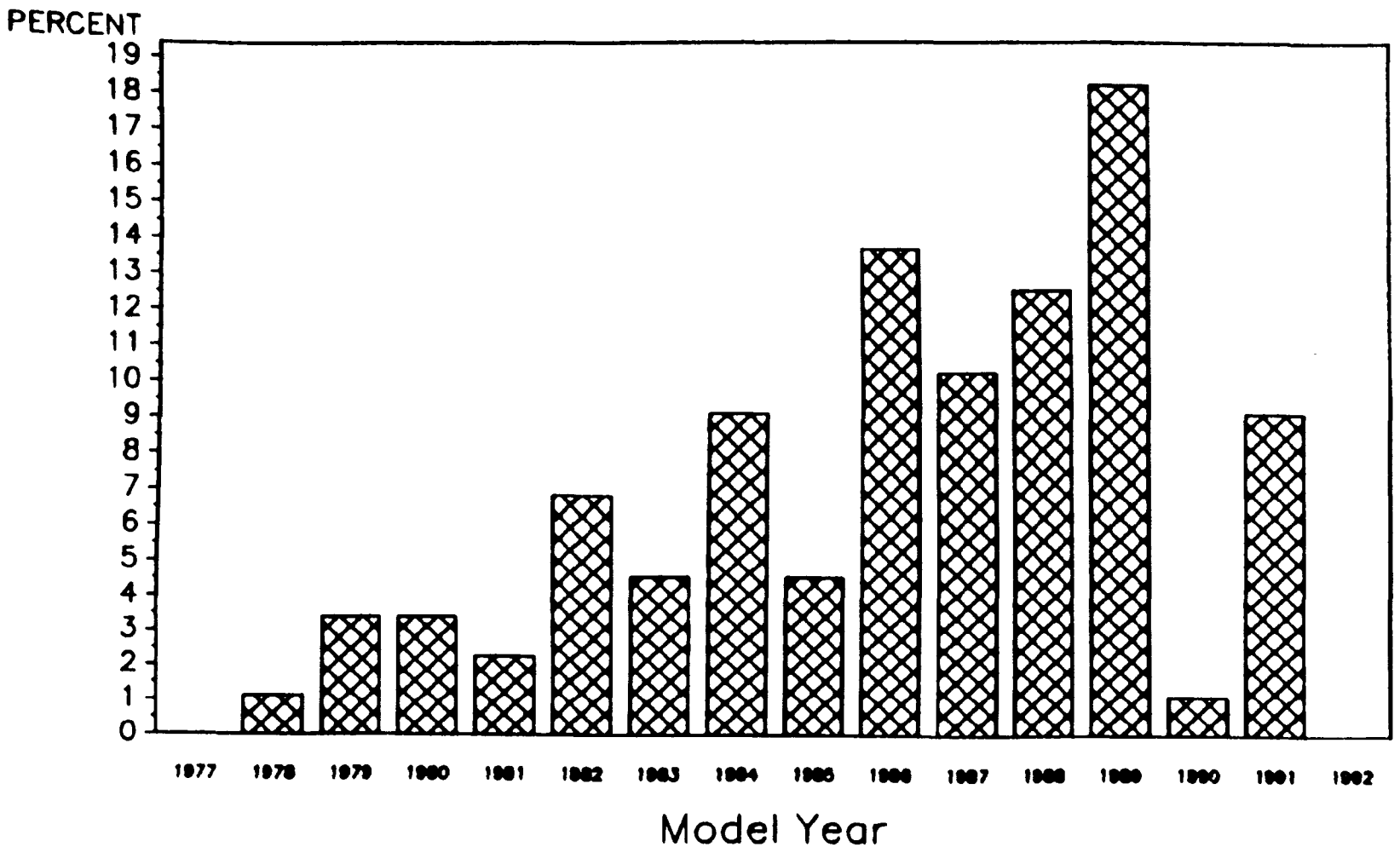


Figure 6-32. Model Year Distribution of 3-Parameter Baltimore Instrumented Vehicles



Another comparison that is important to make is that of the originally solicited vehicles, which for some reason were not able to be instrumented, with the distribution of vehicles that replaced them. There were 120 3-parameter vehicles that were solicited and could not be instrumented for one of a number of reasons, and there were 90 3-parameter vehicles that were replacements for a portion of these vehicles. Figures 6-33 and 6-34 show the distributions of vehicles that were not able to be instrumented by make and model year. Figures 6-35 and 6-36 show the same distributions for the vehicles that were finally instrumented for vehicles that could not be. Visual comparison of these distributions tends to confirm the results of the statistical tests that the distributions were not significantly different.

The 6-parameter dataloggers were placed on vehicles of the seven manufacturers for model years 1989, 1990, and 1991. The inspection/maintenance record tape for March of 1992 in Baltimore was filtered to determine the eligible makes and model years of vehicles that met these criteria. The make and model year distributions of these Baltimore vehicles which were eligible for 6-parameter installations are shown in Figures 6-37 and 6-38. The make and model year distributions for the 6-parameter vehicles that were instrumented at Baltimore are shown for comparison in Figures 6-39 and 6-40. Comparison of the population and sample distributions for make and model year using the Chi^2 statistic and the Mantel-Haenszel statistic indicate that there is no significant difference between these distributions. However, the distribution comparisons for make do not appear to be all that similar. The sample would have been expected to have more Toyotas, more Fords, and fewer Dodges than it had.

6.2.3 Datalogger Presence Bias

One of the disadvantages of performing a private vehicle instrumentation study is that there is a question of whether the driver of the vehicle drives differently because he knows he is being monitored. This is not a problem for a chase car study. To try to get an estimate of whether people drove differently because they knew

Figure 6-33. Vehicle Make Distribution of Solicited 3-Parameter Vehicles That Were Replaced

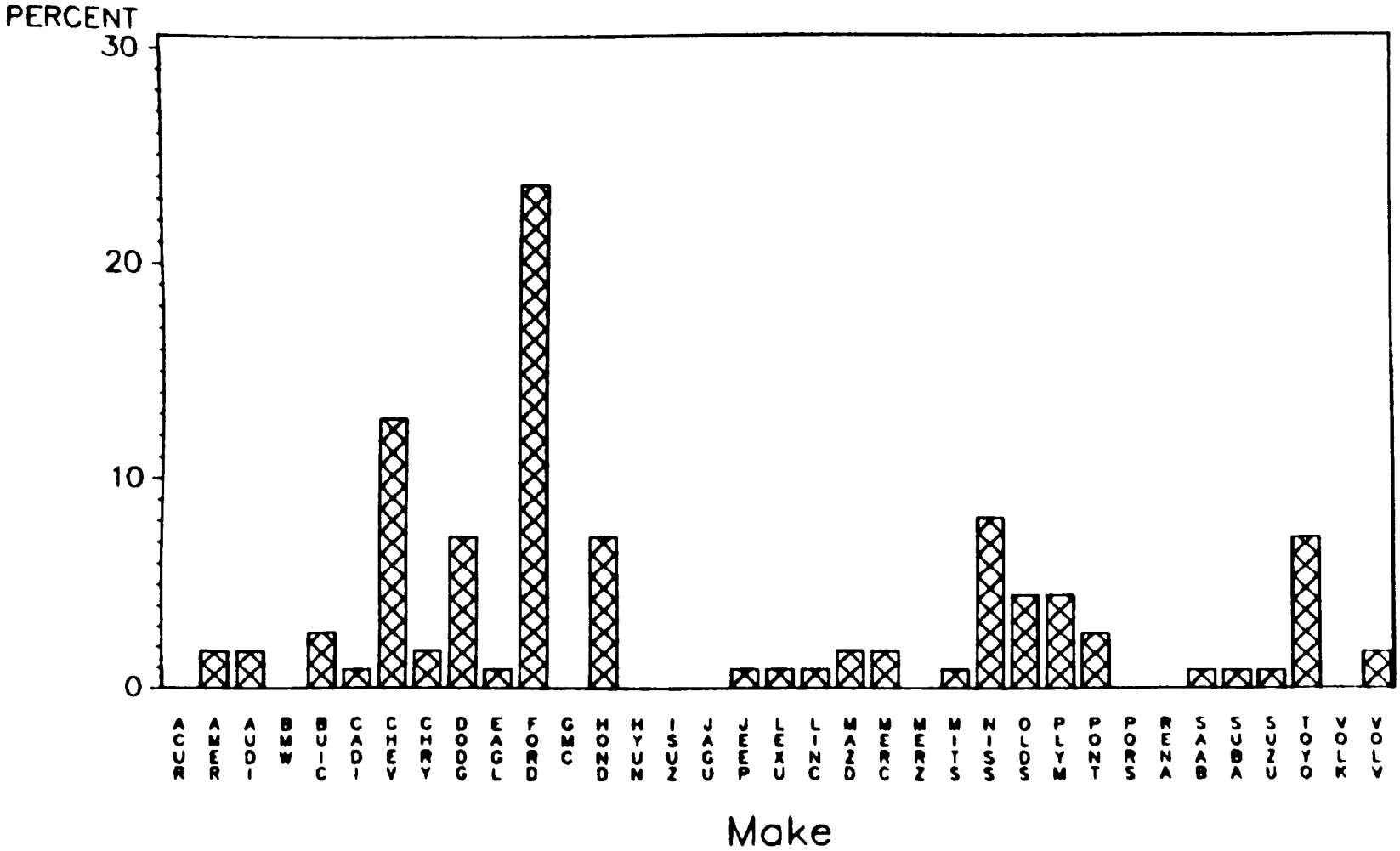


Figure 6-34. Model Year Distribution of Solicited 3-Parameter Vehicles That Were Replaced

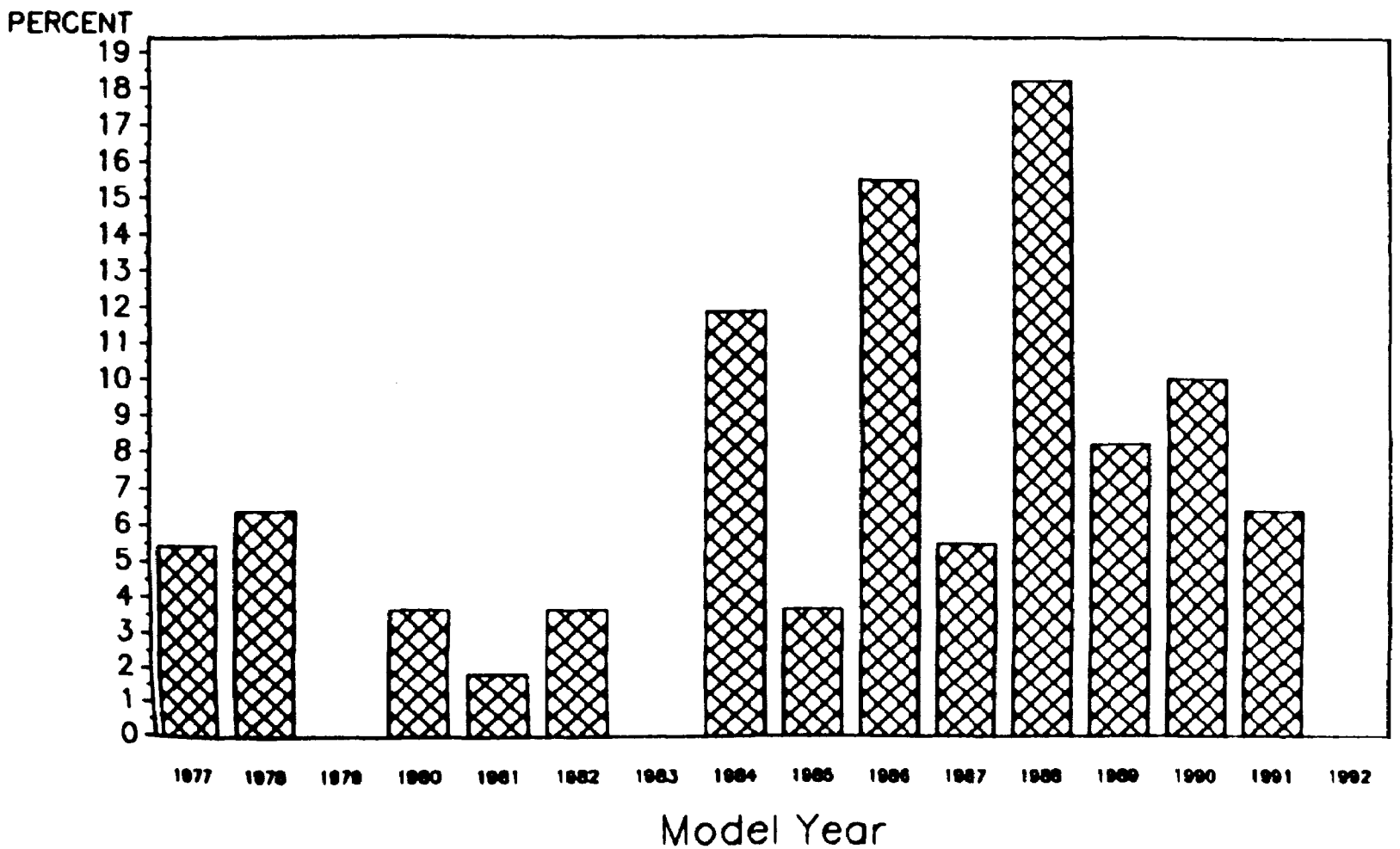


Figure 6-35. Vehicle Make Distribution of 3-Parameter Replacement Vehicles

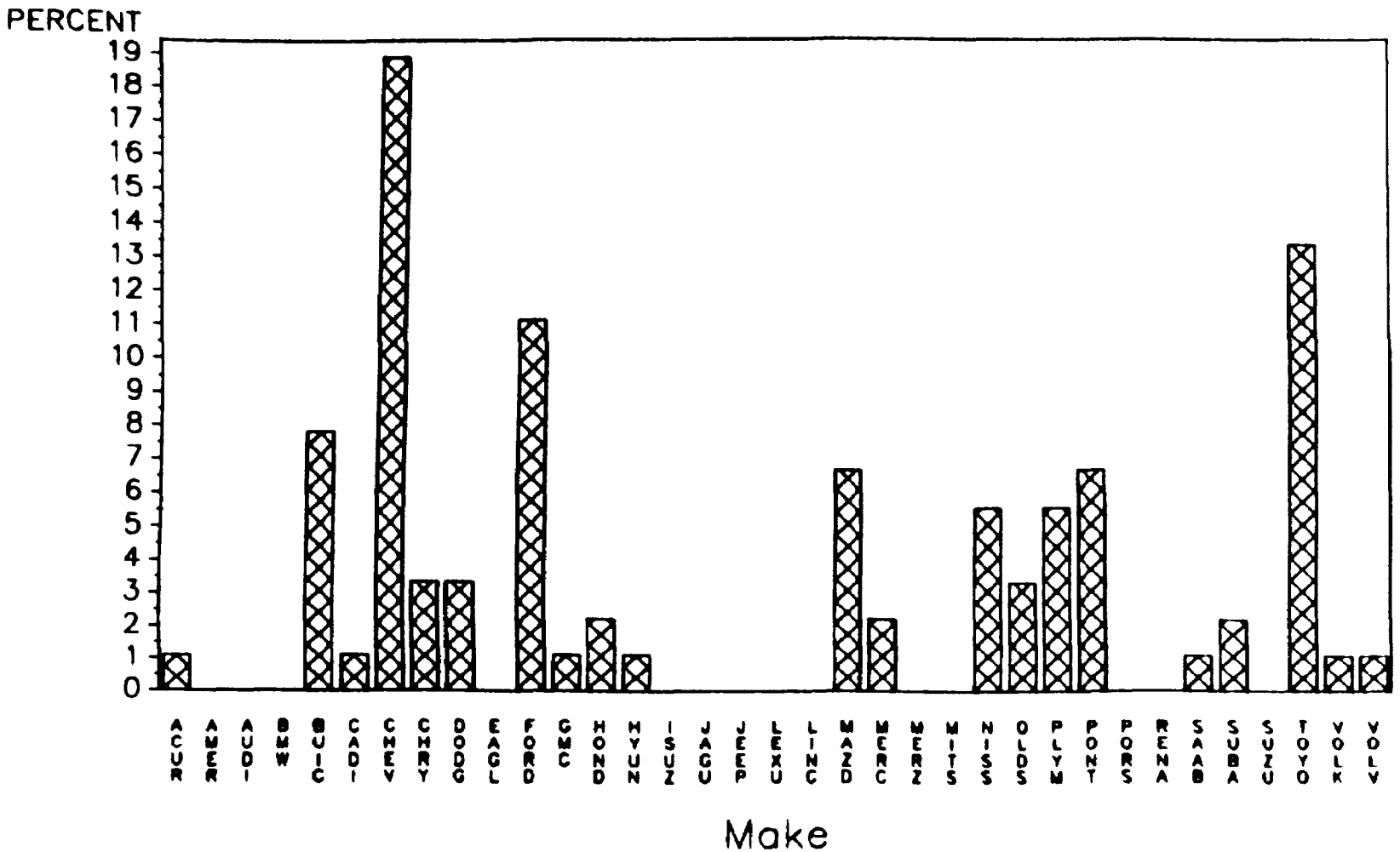


Figure 6-36. Model Year Distribution of 3-Parameter Replacement Vehicles

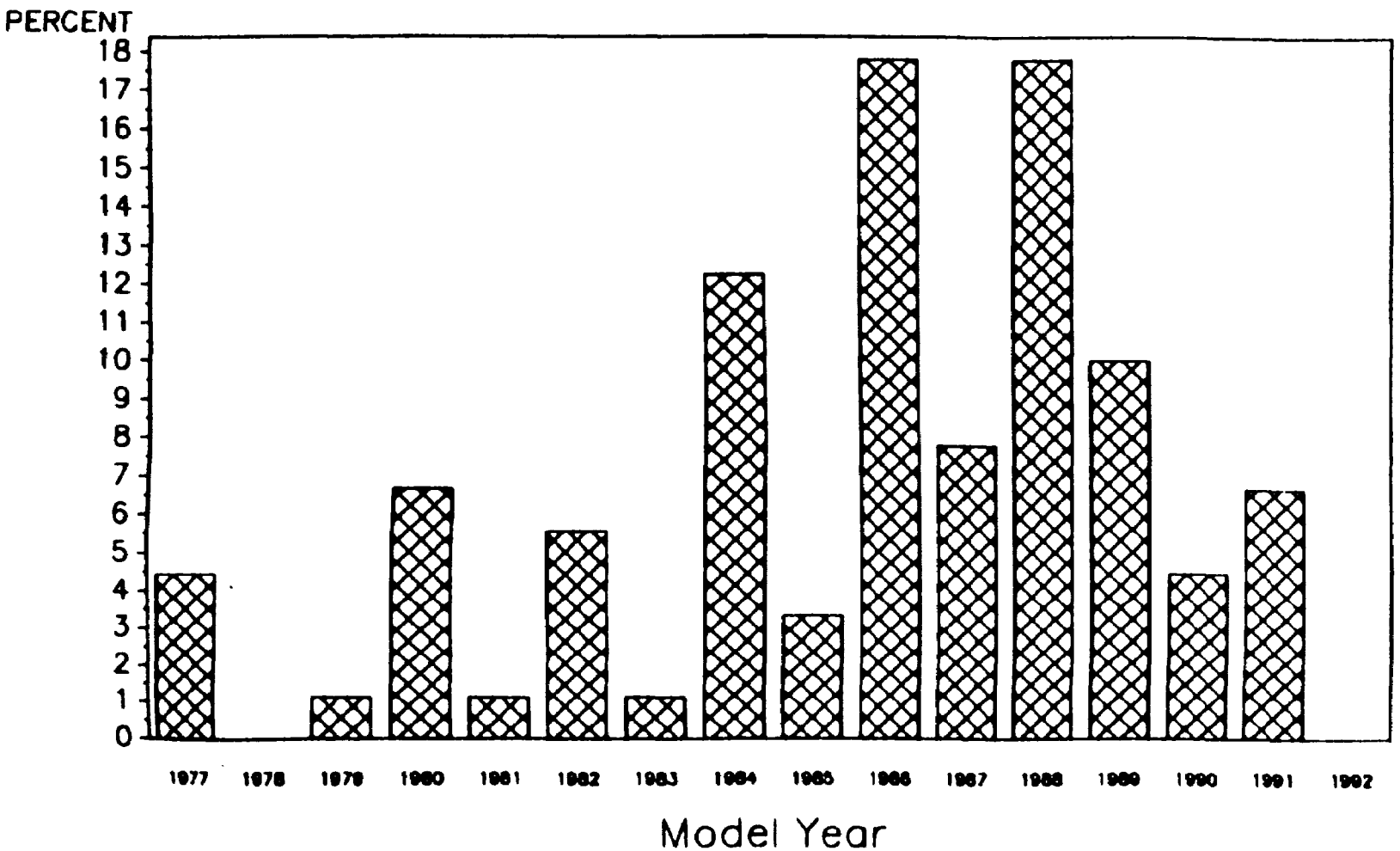


Figure 6-37. Make Distribution of 6-Parameter Eligible Baltimore Population

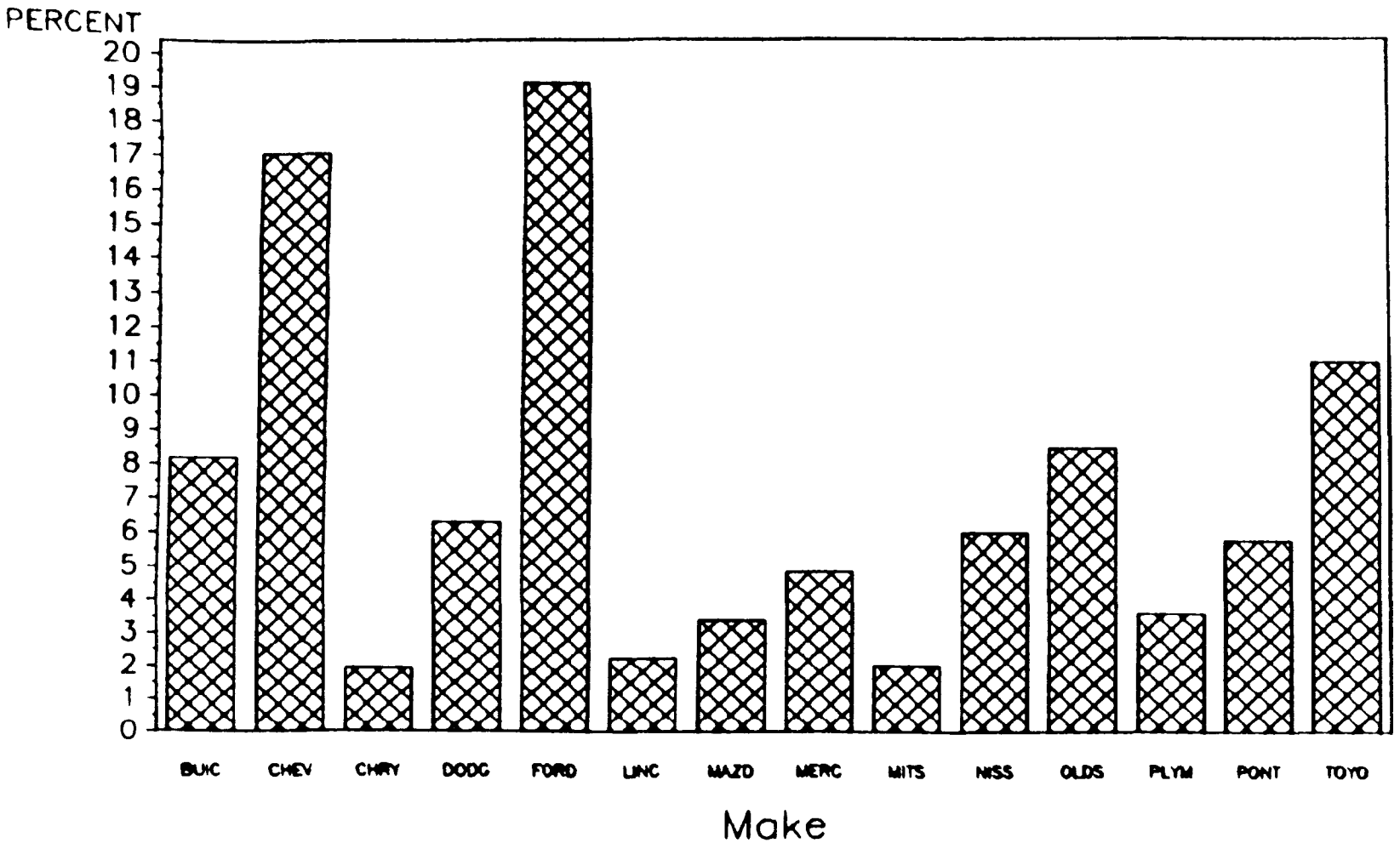


Figure 6-38. Model Year Distribution of 6-Parameter Eligible Baltimore Population

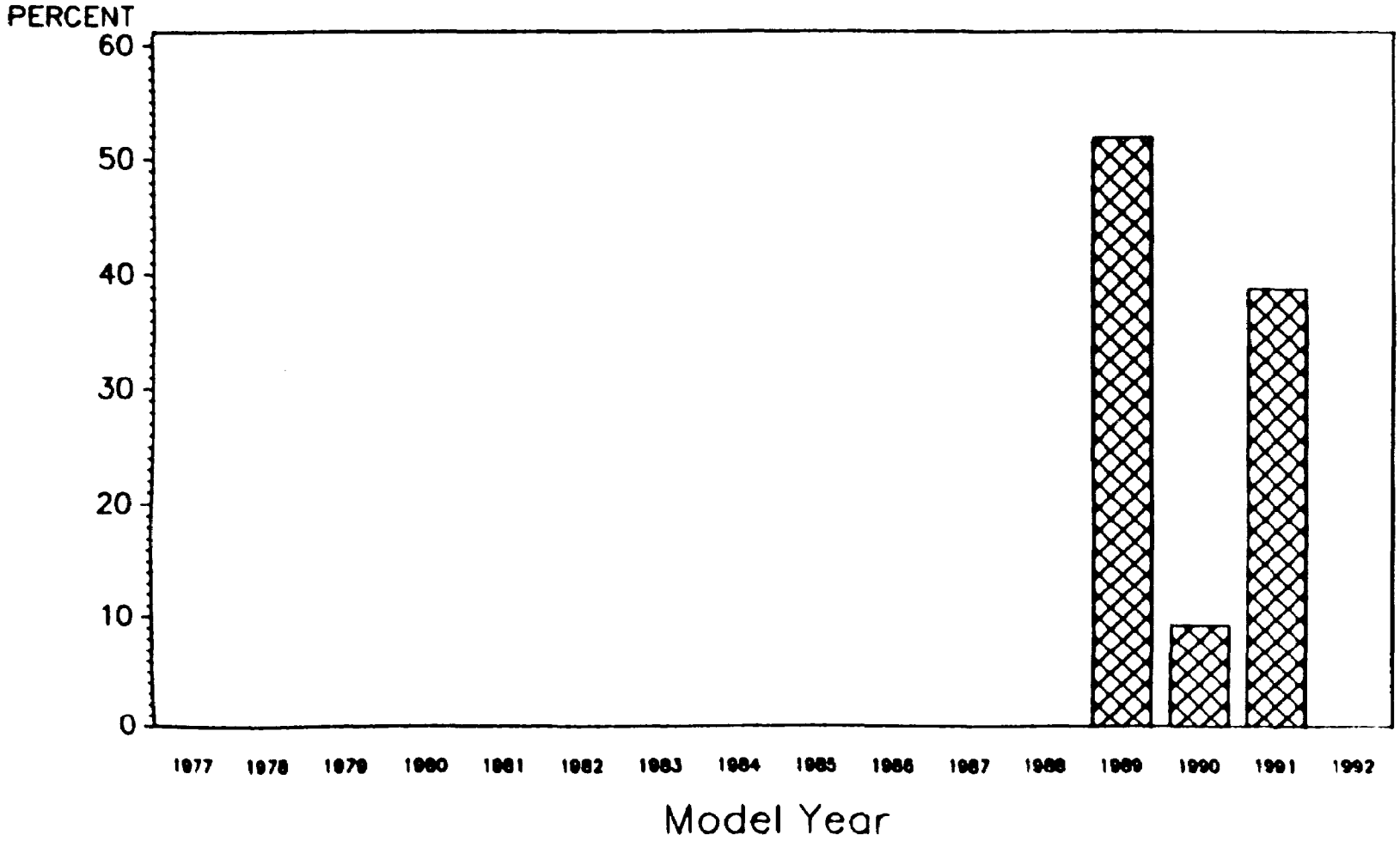


Figure 6-39. Make Distribution of 6-Parameter Baltimore Instrumented Vehicles

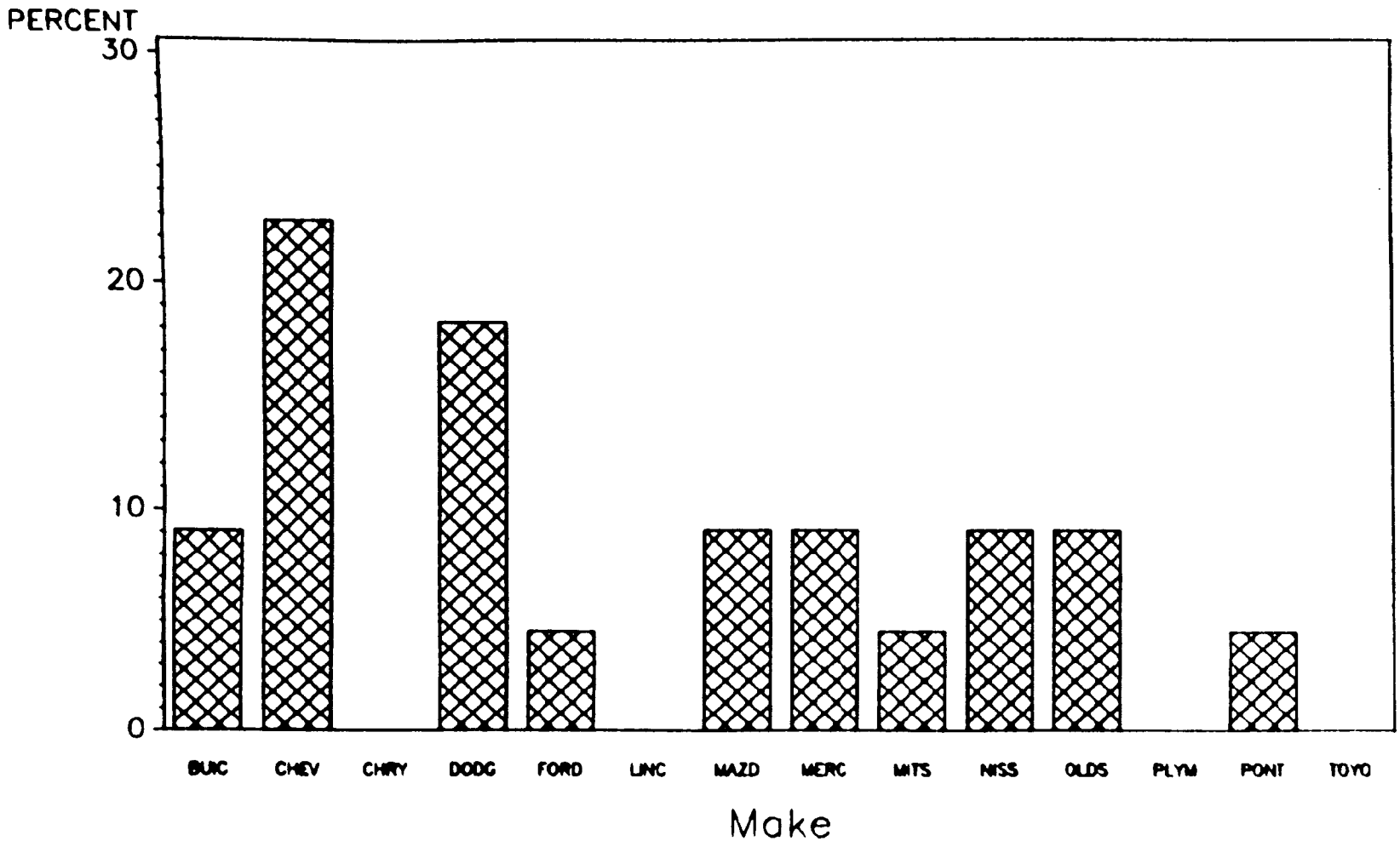
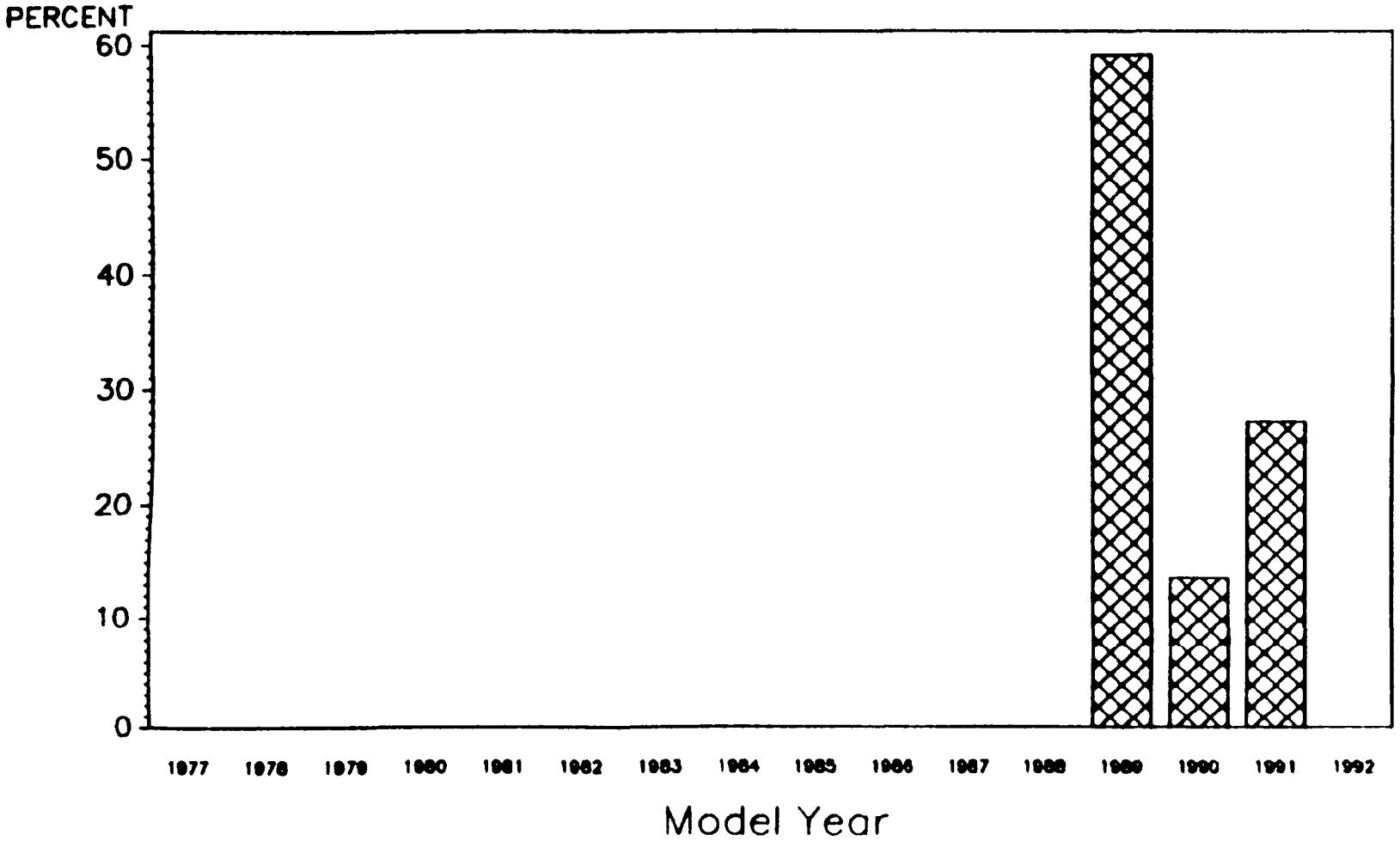


Figure 6-40. Model Year Distribution of 6-Parameter Baltimore Instrumented Vehicles



dataloggers were on the car, the data was analyzed by observation phase during the week.

The idea here is that it is possible that, after a certain length of time, the driver of the vehicle may forget that the datalogger is on the vehicle and, therefore, would drive in a normal fashion. The observation phases were picked such that two evenings passed before the second observation phase began. The observation phase parameter had two levels. The first phase occurred between the time the datalogger was installed on the vehicle and late in the night of the first full day of driving with the datalogger on the vehicle. The second observation phase occurred from the end of the first observation phase to the end of the data acquisition period for that vehicle.

The driving patterns database was analyzed by observation phase for all trips (minor and major). The results of this analysis are included in Volumes 2 and 3. For the purposes of discussion, a few of the results are shown here in the body of the report. Three pairs of plots are shown to compare the effect of observation phase on the acceleration/speed contour, the trip duration, and the soak duration.

The acceleration vs. speed profiles for the two observation phases are shown in Figures 6-41 and 6-42. These contours appear to be very similar. The maximum and minimum accelerations occur at the same speeds and have approximately the same values. The shadings on the different portions of the contours occur in approximately the same place. One noticeable difference, which may or may not be significant, is that in the second observation phase, there may be more observations at speeds higher than 65 mph.

A comparison of the trip times for the two observation phases can be made by looking at Figures 6-43 and 6-44. The distribution in the second observation phase appears to be smoother. This is probably because there are more observations in the second observation phase. However, the general shape of the distribution--the height of

Figure 6-41. Acceleration/Speed Contour for First Observation Phase

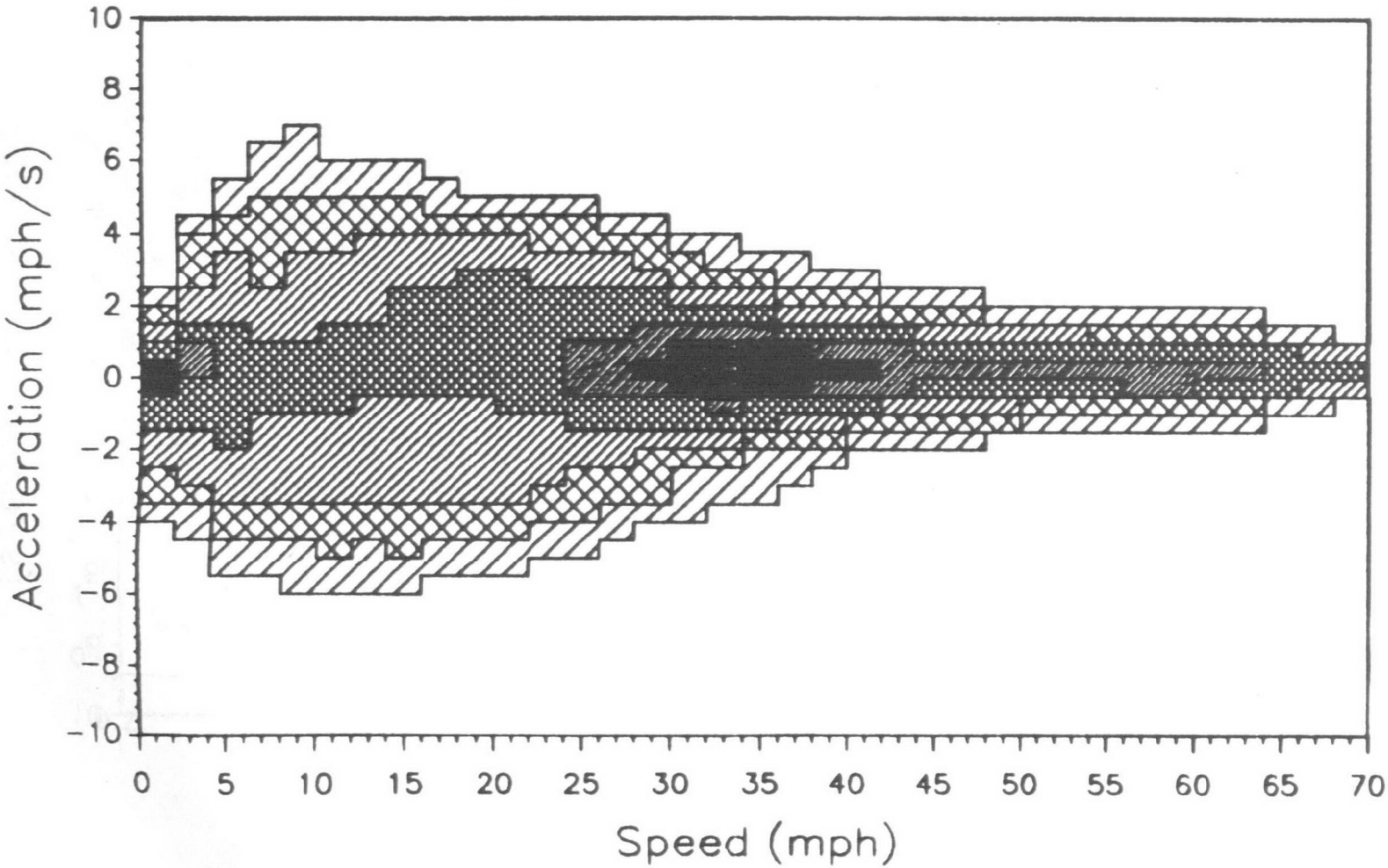


Figure 6-42. Acceleration/Speed Contour for Second Observation Phase

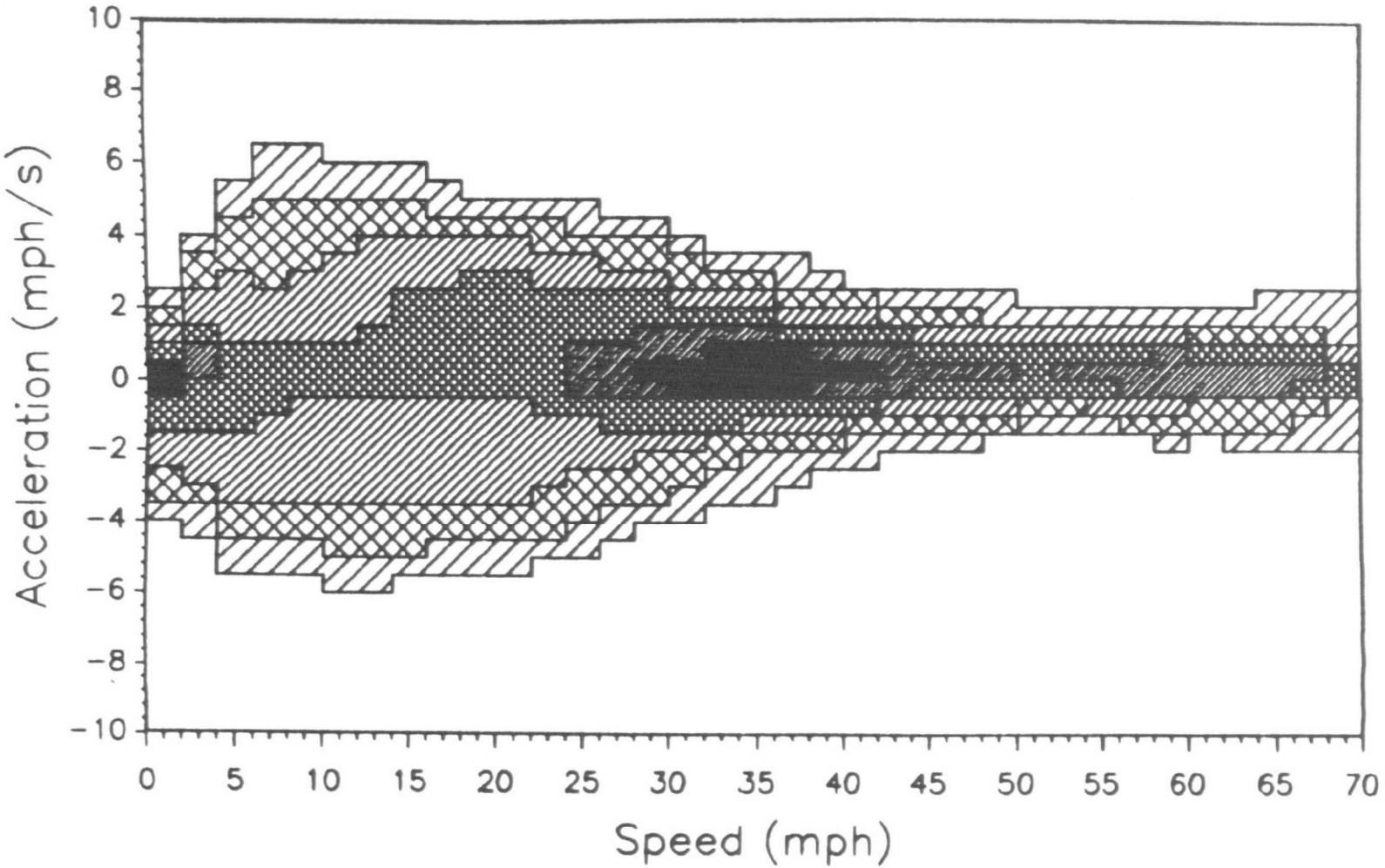


Figure 6-43. Trip Time Distribution for First Observation Phase

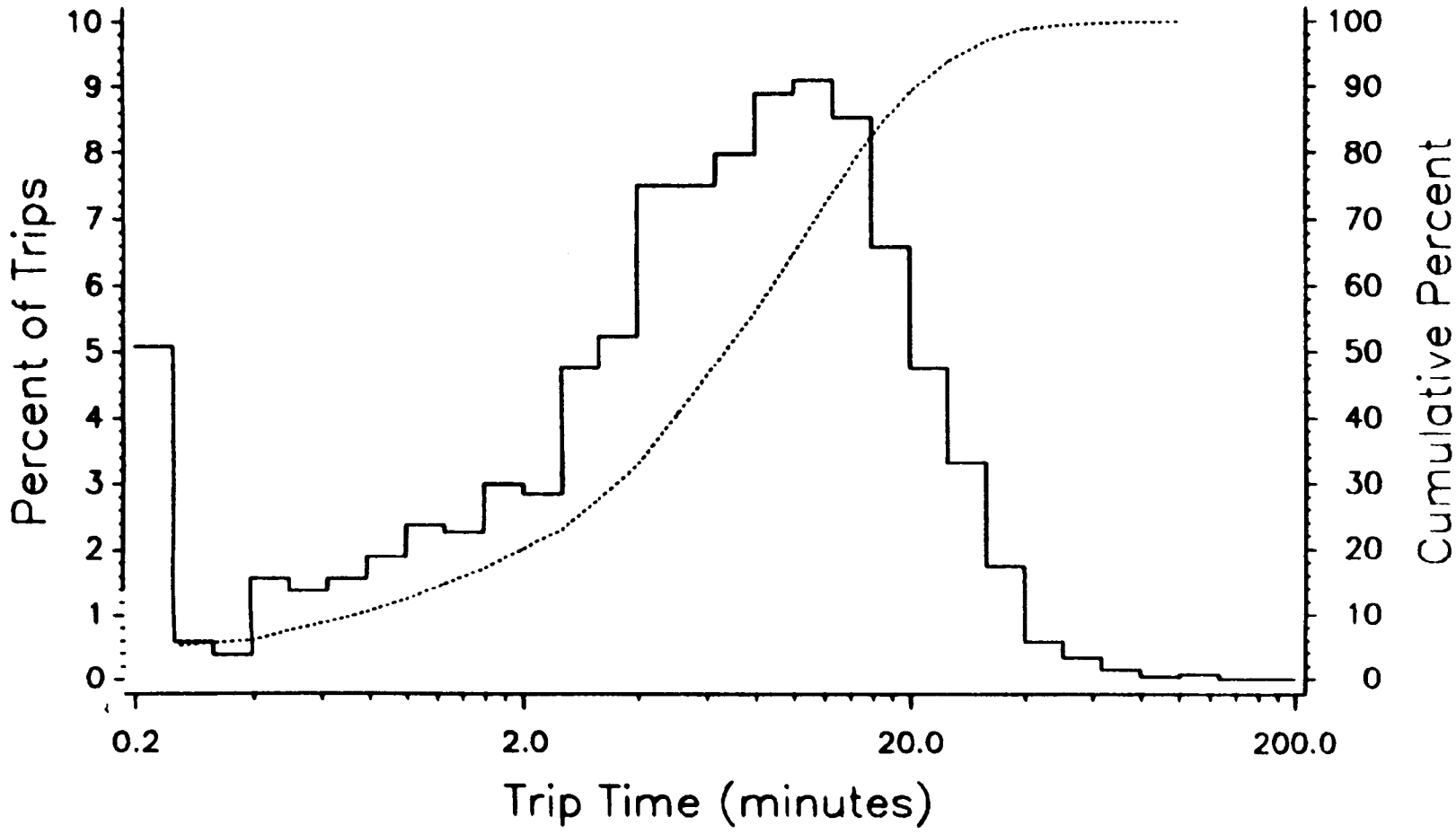
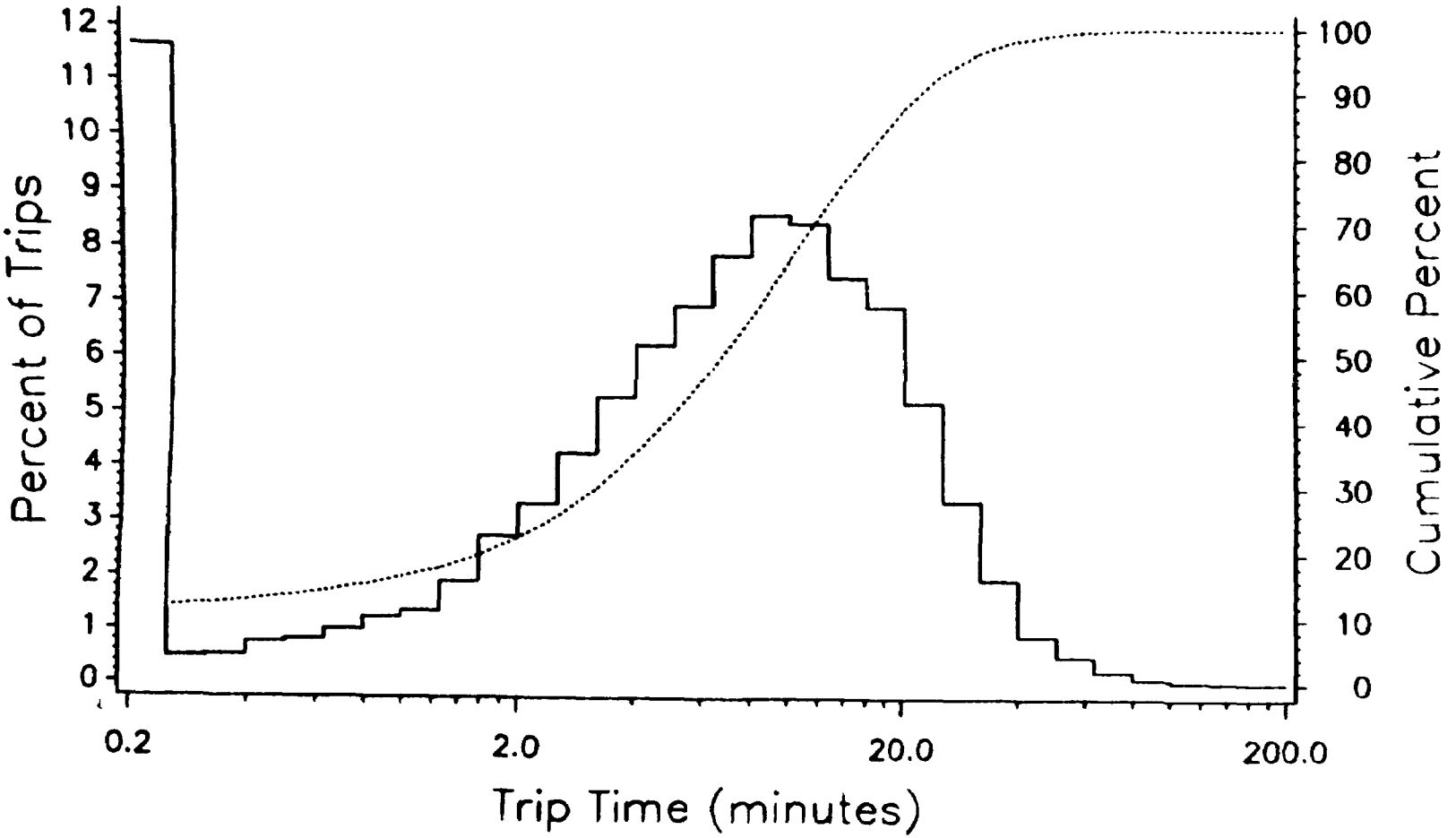


Figure 6-44. Trip Time Distribution for Second Observation Phase



the peak, the location of the peak, and the width of the peak--are similar for both phases. Thus, there is no apparent difference in the lengths of trips between the two phases. This might be expected, since it may be unlikely that people would change the trips they take just because a datalogger is on their vehicle.

A comparison of the soak times before trips is made for the two observation phases in Figures 6-45 and 6-46. There are some differences between these distributions. The most obvious one is that the overnight soak periods which have a peak around 800 minutes are less prevalent compared to the non-overnight soak times (between 3 and 100 minutes) than in the second observation phase. There also appears to be a large number of short soak times in the second observation phase around 0.3 minutes, which is not present at all in the first observation phase.

Additional comparisons can be made for the first observation phase vs. the second observation phase by considering the other plots and the calculated statistics which are shown in Volumes 2 and 3. Based on a visual examination of these, it does not appear that there are any major reasons to believe that driving during the first observation phase was different than driving during the second observation phase.

6.3 Options for the Advanced Analysis and Simulation of Driving Patterns

Several authors have published studies of the data analysis of light-duty vehicle driving patterns (6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16). Two options are presented below for data analysis and for the simulation or selection of driving cycles that could be used in a new Federal Test Procedure. The first option discusses the use of advanced statistical techniques for analyzing and characterizing both the details of trips and the soak behavior of vehicles in the driving pattern database. The final result of this advanced statistical analysis would be the selection of existing driving segments in the database that would represent the driving of the vehicles in the database as a whole. Because these selected driving segments would have all of the fine structure that real

Figure 6-45. Soak Time Distribution for First Observation Phase

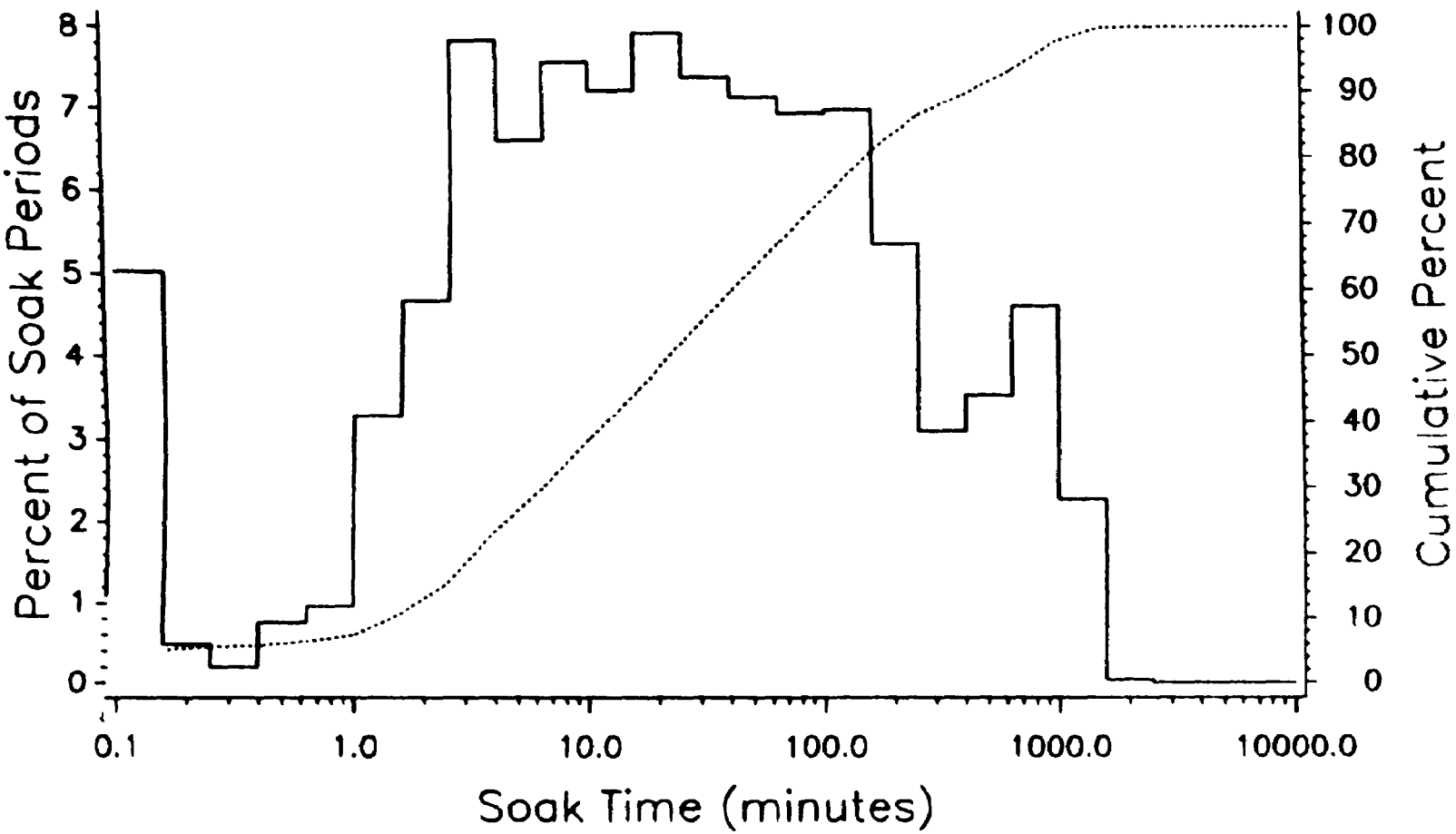
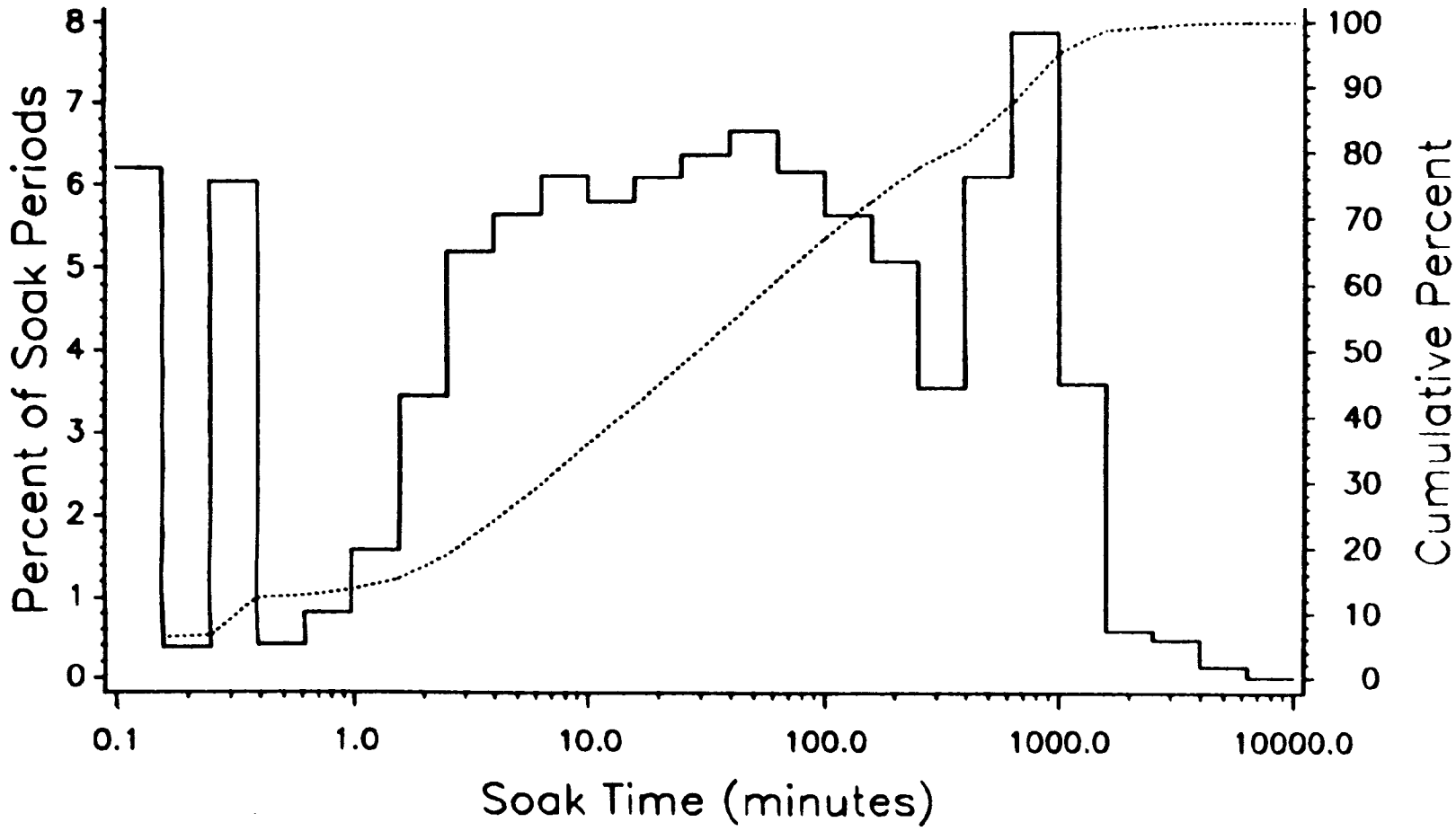


Figure 6-46. Soak Time Distribution for Second Observation Phase



vehicles display, an informed selection of the segments has a good chance of being representative of the driving behavior of all the vehicles as a whole. However, it is not at all obvious that a single driving segment for a particular vehicle is the best way to simulate overall driving. There may be great advantages in using two or more driving cycles in a new Federal Test Procedure.

Another approach to developing driving cycles is also presented in the following paragraphs. This approach uses a combination of signal processing analysis followed by neural network simulation of the soak and detailed speed behavior during trips of all of the data in the database to arrive at a system for simulating driving cycles that are representative of overall driving behavior. The simulations produced by such a system would have all of the features exhibited by the database as a whole; however, none of the simulations would be exactly like a driving segment contained in the database.

The test of whether driving segments selected from the database using advanced statistical techniques or simulated driving cycles produced by a signal processing/neural network system are representative of the driving patterns in the database must be made by using any and all statistics to compare the resulting candidate cycles with the driving pattern database.

6.3.1 Advanced Statistical Analysis

The summary statistics calculated earlier in the section for the driving patterns database and for the current FTP cycle can be used to evaluate candidate driving cycles. However, to get a better understanding of driving behavior and, perhaps more specifically, the long time period driving behavior, other, more advanced statistical techniques must be used. Since these techniques lead to better understanding, they should lead to a more insightful basis for constructing or choosing candidate driving cycles that are representative of the driving pattern behavior in the database.

The discussion below provides two advanced statistical techniques that could be used to select trips and soaks which could be demonstrated to be representative of observed driving patterns.

6.3.1.1 Identifying Types of Trips

To determine the trip or trips to be used for a new certification test procedure, it is desirable as a first step to determine the distinct types of trips that occur with reasonable frequency. The method of addressing this issue will be to examine the trips for which speed vs. time data are available in the database. The objective will be to divide these trips into subsets, or clusters, so that the trips in each cluster are basically similar but differ somewhat in detail.

Radian's preliminary analysis of the data from EPA's Operational Characteristics Study (17) suggests that there are at least two types of trips. The two types of trips identified in that study had the following characteristics:

- **Type A.** In each trip in this set, there was at least one period of 100 seconds or more with speeds near 65 mph without a sustained acceleration or deceleration. A "sustained acceleration" was defined as an interval with monotonically increasing speed with a total change in speed of at least 20 mph. A "sustained deceleration" was defined analogously. In this set of trips, there were also periods of rapid alternation between acceleration events and deceleration events.

- **Type B.** In each of this set of trips, there was an absence of either very long or very short intervals between acceleration events.

The general features of the speed vs. time curves were visually similar within either type and were clearly different between the two types. It was shown that either the average or the standard deviation of the time between acceleration events would have been an adequate measure by which trips could have been divided into two

groups. These two measures were used for illustration only and were not intended to represent a full characterization of the trips. The FTP currently used for emissions tests is essentially of Type B (17).

While a visual examination of plots of speed vs. time is very important, it is not feasible to examine every trip in the database from the current study in this way. In the following section, quantitative measures that can be used as a basis for dividing trips into "clusters" or "types" are discussed. Some of these sets of measures involve large numbers of variables. Following that section, a method (principal component analysis) for reducing the dimensionality of the mathematical space that must be handled without significant loss of information is discussed. Next, the grouping of the trips into clusters with similar features is discussed. This operation is called cluster analysis.

Both principal component analysis and cluster analysis have been widely used, and a body of literature exists for each. The major emphasis in this section, then, will be placed on selecting a meaningful set of measures that can be used to characterize the automobile trips.

Characterizing Measures for the Trips--There are many quantitative sets of measures that could be used to characterize vehicle trips. We will discuss two general classes of sets. First are measures defined on the basis of engineering judgement. It would be ideal to define a small set of measures of this type that contained all the essential information about the trips. The danger, however, is that an essential feature of the trips might not be quantified by the engineering measures. Second are larger sets of measures intended to avoid this difficulty. These types of sets will be called "nonprejudicial," since there is probably a greatly reduced chance that *a priori* judgement will limit the information contained in them.

In any case, selection of the characterizing measures should not be strictly based on the emission properties of existing automobiles. Changes in the design of

future cars may alter the relationship between speed and acceleration, and emissions. The goal is to develop measures that characterize the speed vs. time profiles in a general way, but not necessarily in a way closely related to the emission properties of current automobiles.

Sets of Trip Measures Based on Engineering Judgement--There are many possible sets of measures. As discussed earlier, either the mean or standard deviation of the time between acceleration events would have been adequate to distinguish between trips of Types A and B, defined in Section 6.3.1.1. These measures, however, were intended only to illustrate the fact that trips can be quantitatively clustered in meaningful ways.

Maurin and Crauser (6) characterized French driving patterns with the following set of measures:

- The trip duration;
- The distance covered;
- The average speed;
- The maximum speed;
- The number of extrema, relative to speed;
- The idling time;
- The percentage of the time the speed was relatively stable (acceleration within specified limits);
- The percentage of the time the speed was between 0 and 15 km/h;
- The percentage of the time the speed was between 15 and 45 km/h;

- The percentage of the time the speed was between 45 and 75 km/h; and
- The percentage of the time the speed was greater than 75 km/h.

While the measures above seem to be reasonable, it would be interesting to include a more detailed characterization of the accelerations and possibly of the combinations of speeds and accelerations that occurred during the trip. It is true, however, that the number of extrema in speed implies the number of separate acceleration or deceleration events. These observations illustrate the fact that any set of measures based on engineering judgement may fail to reflect some important characteristic of the trips, which leads to the next topic, nonprejudicial sets of measures.

Nonprejudicial Sets of Measures--One set of nonprejudicial measures characterizing the trips would be the ordinates of the bivariate distribution of speed and acceleration. An example of this type of bivariate distribution is presented in Figure 6-1. While engineering judgement was not used in detail to specify every measure in the set, this set of measures is consistent with engineering judgement, since it is reasonable to expect that combinations of speed and acceleration will affect emission rates.

The bivariate distribution characterizes the frequencies of occurrence of different conditions but does not explicitly characterize the time ordering of events. This information is, at least to some extent, inherent in the distribution, however. Consider, for example, a speed maintained for one or more extended intervals during the trip. This can only occur if the bivariate distribution includes a relatively high frequency of occurrence of this speed concurrent with accelerations that are small in absolute value.

Notice that the bivariate distribution shown has 35 levels in speed and 50 levels in acceleration, resulting in 1750 cells. Thus, the set of measures consists of 1750 variables. Ways of reducing the dimensionality without significant loss of information are discussed in the following subsection.

Frequency-domain techniques offer a different approach. In this context, frequency-domain methods are those based on the Fourier transform, and the word "frequency" should not be confused with "frequency of occurrence" of events in the bivariate distribution discussed above. Use of the power spectrum is one approach that has an intuitive appeal. There is a good chance that the power spectrum would provide a meaningful characterization of the trips. It would be possible to include: 1) the power spectrum and phase, or 2) both the real and imaginary components of the Fourier transform in the set of measures. If frequency-domain methods are employed, we recommend that the spectrum be used as a first step to determine whether meaningful trip clusters can be obtained on this basis. If not, an alternative approach could be devised. The mathematical intractability of phase for our purposes is circumvented, however, by the use of the bivariate distribution instead of frequency-domain methods to determine a set of characterizing measures.

Methods for Reduction of Dimensionality--Regardless of the method used to characterize the trips, it is likely that the number of variables selected will be larger than the minimum needed to represent the essential information. Even a set of measures based on engineering judgement may contain some redundancy.

Consider, for example, the bivariate histogram shown in Figure 6-1. Notice that, to a large extent, adjacent cells tend to be similar; i.e., usually both are higher than average or both are lower than average. That is, the frequencies of occurrence represented in adjacent cells do not contain independent information. Moreover, certain cells will always or almost always have zero frequencies. Cells with the lowest speed category and with negative accelerations with large magnitudes provide one example. Cells with the maximum speed category with accelerations with the largest absolute values represented are another example.

Thus, it is evident that the number of truly independent dimensions of information is less than 1750, the number of variables associated with the bivariate

distribution shown in the figure; the ordinate corresponding to each cell is a separate variable. One way to address this issue is to eliminate certain cells altogether and to combine other groups of adjacent cells.

Principal component analysis is a more general approach that would apply in the case of any of the methods discussed above for characterizing the trips. Principal component analysis is often used when the variables are not statistically independent; therefore, groups of two or more variables, to some extent, contain redundant information. Principal component analysis produces a smaller, derived set of variables that are statistically independent and that contain the essential information represented in the original set of variables.

The first step in principal component analysis is to determine the linear combination of the original variables that has the largest variance (for each principal component, there is a normalization constraint on the coefficients -- otherwise the variance of a component would be unbounded). This linear combination is a new variable and is the first principal component. The second step is to determine the linear combination of the original variables that has the largest variance of any combination statistically independent of the first principal component. The second linear combination is the second principal component. Successive linear combinations are determined, each statistically independent of the preceding ones.

There are as many principal components as original variables. Suppose, however, there are 1750 original variables, but that virtually all of the essential information can be expressed in ten appropriately selected independent dimensions. One would expect, then, that the first ten principal components would adequately represent the original set of variables.

The variances of the principal components can be used to determine the number of components that must be used to retain, for example, 95% of the original

variance in the system. The original variance in the system equals the sum of the variances of the original variables, which also equals the sum of the variances of the complete set of principal components. It may seem that the sum of the variances of the original variables would not be meaningful if those variables had different units (e.g., speed and acceleration). This problem is resolved by transforming each variable to a pure number with zero mean and unit variance. Subsequent analysis, then, can be performed using the retained principal components in place of the original variables.

Earlier in this section, a set of 11 measures used in a study reported in the literature was presented. While it is obvious that the 1750 variables associated with the bivariate distribution contain redundancies, it is less obvious that this set of 11 variables contains significant redundancies. Nevertheless, an analysis revealed that 80% of the variance in the system can be retained by employing the first four principal components.

Cluster Analysis--Cluster analysis is used to divide a set of objects into subsets, or clusters, so that the objects are similar within the clusters and so that there is a meaningful difference between any two of the clusters. Here, each object is one of the trips in the database. Each cluster, then, will correspond to an identifiable type of trip, such as Type A or Type B, discussed above.

Cluster analysis requires a value or vector of values, which characterizes the different trips. As discussed above, there are many possible choices for this vector. One example is the set of retained principal components derived from the bivariate distribution of speed and acceleration. More generally, the vector would consist of the subset of the principal components required to retain the essential information in whatever set of original variables had been used.

To divide the trips into clusters, it is necessary to define a quantitative measure of the degree of dissimilarity between any two trips. This measure is necessary to determine whether two trips are similar enough to belong in the same cluster or

whether they should be placed in different clusters. The Euclidean distance between two vectors of principal components is one possible measure of dissimilarity. Cluster analysis is widely used, and documentation is readily available (18). For this reason, the computational details of the different types of cluster analysis will not be discussed here.

6.3.1.2 Selection of Trips for Driving Cycles

It is desirable to be able to select one or more trips to be used in a given emissions test. Two approaches will be considered. First, randomly selecting trips from the database is discussed. Second, generating trips by modeling is discussed.

Selection of Trips from the Database--Suppose that a trip corresponding to a specific one of the clusters is required for an emissions test. Suppose further that there are N trips in the database corresponding to this cluster. One approach, then, would be to randomly select one of these trips to be used in the test.

This approach would apparently satisfy the objectives stated in Section 6.3.1.1 reasonably well. We assume that the trips in the cluster are similar in general features but differ in specific details. For example, the maximum acceleration, idling periods, and periods of steady speed would not occur at the same times within the different trips within a cluster.

This approach is simple, and it has certain advantages over modeling. The trips represent actual trips; there is no concern about whether some feature has not been retained through the modeling process. The shape of the speed vs. time curves during sustained accelerations, for example, will retain the features and the variability within trips and among trips actually observed in the field.

On the other hand, the number of trips for a given cluster is limited to those in the database, unless further testing is performed to add to the database. Modeling, discussed in the next subsection, provides a way to address this issue.

Generation of Trips by Modeling--Monte Carlo simulation has the advantage of being able to generate unlimited numbers of trips that vary in specific detail but that have similar general features. It is very important, however, to test the method thoroughly to ensure that the trips it generated possess the desired general features. This can be achieved in part by visually comparing speed vs. time plots for sets of actual and modeled trips. The comparison of various quantitative measures is also important. Statistical hypothesis tests can be performed to determine whether the actual and modeled trips differ significantly with respect to average speed, average acceleration, and even the statistical distribution of speed or acceleration.

After a trip has been randomly generated for an emissions test or other use, it is desirable to test the trip to ensure that it is not a probabilistic anomaly that is not representative of the type of trips of interest. To give an extreme example, many types of Monte Carlo models allow a very small but non-zero probability that the entire trip is spent idling. It would be possible to compute a number of quantitative measures (e.g., average and standard deviation of speed and acceleration) to determine whether they fall within a reasonable set of limits determined from the trips in the cluster of interest in the database.

Two general approaches for modeling are discussed here. In the next section, an approach is discussed that is based on identifying specific types of features, or events, that occur within a trip. Examples of these events include idling, sustained acceleration, sustained deceleration, and traveling at a relatively steady speed. These events can be called "lumped features," since each represents the combined speed vs. time data for a period of time during which a specific type of activity is taking place. In

the following section, an approach is discussed that does not require the identification of lumped features. Other approaches are briefly discussed in the last section.

Modeling Based on Lumped Features--The first step in the approach based on lumped features is to identify the features to be used. Second, it is necessary to identify occurrences of these features in the trips from which the model is to be derived. Because of the large number of trips in the current data base, this would probably require the development of software that searched each trip to identify the features present and their times of occurrence.

The next step is to develop a model that generates trips that have the general features of those in the database. One approach is to use a Markovian transition model. In this type of model, a series of states (or lumped features) is generated in their order of occurrence; the complete set of events, then, defines the trip. Given the set of transition probabilities for all states that can possibly follow the current state, the next state can be randomly generated. If the current state is idling, for example, the possible following states might include sustained acceleration and low and variable speed.

Features of certain states have to be characterized from the database. The generation of an acceleration event requires the duration of the event, the final speed, and the shape of the speed vs. time curve during the acceleration.

A Monte Carlo model of the type discussed above was developed by Smith (7), who found that all decelerations followed the same general curve. He identified three different acceleration curves, however, depending on the total change in speed and depending on whether the automobile was initially at rest or not. Smith's study did not accomplish all the goals proposed here, however, since clustering to identify different types of trips was not part of his study.

Modeling Without Identifying Lumped Features--An alternative to the approach above is to generate a speed vs. time history by a Monte Carlo approach without identifying the lumped parameters. An advantage to this approach is that a greater variety in the small details of the features results. The shapes of the acceleration curves, for example, would not be limited to the finite number of shapes selected for inclusion in the model in the lumped features approach.

In the approach discussed in this section, the speed for the next time point is randomly generated on the basis of the speeds at the current and past times. First, it is clear that an autoregressive moving average (ARMA) model would not work. An ARMA model has the following form:

$$s_{i+1} = \sum_{k=0}^{m} a_k \, s_{i-k} + e_{i+1}$$

where

s_i = speed at the ith time point,

a_k = kth coefficient in the model, and

e_i = random component introduced at the ith time point.

This model generates a stationary time series, i.e., one whose statistics do not change with time. This model would not be expected to produce a nonstationary time series with distinct idling periods, acceleration periods, periods with relatively constant speed, etc.

A transition model is a better choice. If the current speed is zero, for example, a realistic probability that the speed would again be zero at the next time point would be used. Unlike the ARMA model, this scheme would produce idling periods. It is clear, however, that a Markovian model would be inadequate. A transition model is Markovian if the next state depends only on the current state and the transition probabilities, and not on past states. That is, a Markovian model is memoryless.

To see why a Markovian model would not work, consider the case in which the current speed is some intermediate value, e.g., 18 mph, which is not normally sustained for any period of time. Suppose this state is reached by an acceleration from 0 mph. If a Markovian model is used, there is nothing to tell the model that an acceleration is taking place; therefore, the next speed should be greater than the current speed. Thus, this type of model would not be expected to produce sustained accelerations or sustained decelerations.

Suppose the model randomly generates the next speed, basing it on the current speed and one or more previous speeds. The two or more resulting speeds on which the transition is based, then, would include information about the direction of change of speed. If speeds i-2, i-1, and i are 20, 22, and 24 mph, respectively, then the probability that the next speed will be 26 mph is high. Slight variations in the rate of acceleration are possible, however, assuming these variations exist in the actual trips from which the model is derived.

A disadvantage of this approach is that, in order to build a transition matrix, you must discretize the speeds. As the number of speed categories increases, in one sense, the effects of discretization are mitigated, which is desirable. Increasing the number of categories also increases the size of the transition matrix and decreases the sample size in each discrete category. Thus, several considerations must be balanced when determining the size of the speed categories, or bins.

Increasing the number of past speeds on which the transitions are based, increases, to a point, the validity of the model. Past some point, one would expect diminishing returns. Increasing the number of past speeds used would also increase the size of the transition matrix.

The size of the transition matrix could easily get out of hand. Suppose speed was divided into 30 bins and that the next speed was a function of the current and

past speeds. The total number of entries in the transition matrix, then, would be 30^3, or 27,000. It is clear, however, that most of the transitions would be nonsensical. If the current and past speeds were both 0 mph, for example, the possibility that the next speed would be 60 mph could be ruled out, assuming a reasonably small time step, such as one second. Perhaps the transition matrix could be designed so that, for each current and past speed, only the most likely m following states were represented. If there were 30 speed bins, and if m were 6, then this mechanism would reduce the size of the transition matrix from 27,000 to 5,400 entries.

Other Approaches--The above discussion is intended only to provide a few of the multitude of possible ideas about Monte Carlo modeling. Many approaches that are entirely different from those discussed above are possible, as are combinations of the different approaches discussed to create a hybrid approach.

One example is to combine the lumped features model with ARMA techniques. The transition model based on lumped events could be used to identify the sequence of broadly defined events, their durations, and certain other characteristics. Within a period of relatively steady speed, however, an ARMA model could be used to model the small variations in speed that would be expected.

If the Monte Carlo modeling is undertaken, further ideas will be considered before the model is completed. Inevitably, refinements of the model will be achieved during the testing process. It is important that the final model be sufficiently detailed to produce realistic trips. Unreasonable complexity beyond that needed to achieve this goal, however, should be avoided.

6.3.1.3 Characterizing Soaks

The term "soak" will be used to refer to a period during which a car is not in use. The duration of a soak equals the time the engine has to cool after its recent

use. The temperature of the engine when it is next turned on affects the emissions during startup of today's vehicles. It is well known that start-up emissions are greater during a cold start. The soak duration, therefore, is an important factor when designing a new FTP.

Characterizing Soak Durations--The database contains the results of tests of 216 automobiles lasting one week each. Twelve thousand soaks occurred during these tests; therefore, the sample size is large and it should be possible to characterize the statistical distribution of the durations very well (See Figure 6-7).

It is important to characterize the distribution of short soak durations accurately. It is known that the rate of change of the temperature of an object is a monotonic function of the difference between its temperature and the temperature of its surroundings. Thus, the rate of change of the temperature of the car's engine is greatest just after it is turned off. As the engine continues to cool, the rate of change of temperature decreases (in absolute value). Thus, there might be an important difference between a 15-minute and a 30-minute soak. The difference between a three-hour duration and a three-hour-and-15-minute duration is not as important, although, as before, there is a 15-minute difference between the two durations.

Differences between soak durations beyond 12 hours are usually considered unimportant, because the vehicle's engine should have essentially reached the ambient temperature for any reasonable set of circumstances (ambient conditions, etc.). The database contains for 6-parameter data the coolant temperature up until the time the engine was turned off. The temperature when the engine was just turned on is also known. These temperatures can be used to determine the coolant temperature rate of cooling after engine shutdown. This will be useful in determining the soak time categories for modeling.

Given these preliminary comments, the statistical distribution of the soak durations is believed to be of primary importance. There are various ways to characterize this distribution. One representation is based directly on the set of observed soak durations. First, the durations must be ordered:

$$t_1 \leq t_2 \leq \ldots \leq t_n$$

where n = 12,000, the number of soak durations (t_i) in the database. Then the correct way to construct the empirical cumulative distribution on the basis of the complete set of points is as follows:

$$P(t \leq t_i) = i/(n+1)$$

where P() denotes the probability of occurrence of the indicated event.

Notice that, by this method, we correctly avoid claiming to have estimated the absolute maximum or the absolute minimum of the distribution on the basis of a finite sample. The maximum, for example, is a value t_{max} such that $P(t \leq t_{max}) = 1$. In the approach above, the probability associated with the largest value in the database is $n/(n+1)$. Since this probability is less than one, we have not represented t_n as the absolute maximum of the distribution. Actually, there is no apparent reason to say there is an absolute maximum soak duration. The statistical details of this method for estimating an empirical cumulative distribution function are discussed by Gumbel (19).

This approach is appealing in that no information from the original data set is discarded. It is unappealing in that storing the cumulative distribution requires a large amount of information. However, the information can be compressed to some extent, since the maximum soak duration of practical interest is known to be 12 hours.

Alternatively, it would be possible to define a set of bins and count the number of soak durations in each bin. A probability distribution could then be determined on the basis of these counts. As discussed above, small differences between durations become decreasingly important as the duration increases. On the basis of this consideration alone, it might be advantageous to use a small bin size for small soak durations and a larger bin size for larger durations. For example, bins based on a log time scale, as shown in Figure 6-7, might serve this purpose.

The specific features of the data set should influence the selection of bins, however. It has been observed that the distribution of soak durations has a broad plateau from about 3 minutes to 100 minutes and a second peak near 700 minutes. The latter corresponds to overnight soaks. It might be advantageous to select one or more smaller bins near 700 minutes, for example, to characterize the peak near that point.

Before the actual set of bins is determined, it should be verified that the bins are sufficiently narrow to represent the essential information from an engineering point of view. The bins should not be so narrow, however, that there are very few data points in each bin; given the large database with 12,073 soak durations, however, this does not appear to be a limiting factor.

Suppose, then, that n_i data points fall in Bin i. The probability of occurrence of a soak duration within the limits of Bin i is n_i/n, where $n = 12{,}073$. Calculation of the probabilities for all bins, then, would produces a description of the distribution of soak durations.

This representation of the soak durations is very appealing in that the amount of information that must be stored is much smaller than the original database. On the other hand, some information is lost when data are binned. If the bins are sufficiently narrow for practical purposes, however, the loss of information should not be important.

Another possible way to represent the distribution, which is mentioned here for completeness, is as a theoretical type of distribution (normal, log normal, etc.). A log-normally distributed variable is nonnegative and has no upper bound; soak durations have both of these properties. The log normal distribution is positively skewed; that is, the random variable has a predominance of moderate values, occasional values much larger than the mean, and an absence of corresponding values much less than the mean. The first step in determining whether such a distribution is appropriate is to plot a histogram of the soak durations and determine whether it has the appearance of the standard distribution. If so, a formal hypothesis test (e.g., a Kolmogorov-Smirnov test) is performed to determine whether the empirical distribution matches the theoretical distribution within random variability and within the practical requirements.

As mentioned above, however, the histogram of soak durations has a broad plateau between 2 minutes and 200 minutes and a peak near 700 minutes. In view of these features, we believe that the use of a theoretical type of distribution will probably not be feasible.

Other Considerations--Another consideration is the time of day the soak duration occurs. Whether a soak occurs during daytime or nighttime has an important effect on evaporative emissions but not on emissions from the tailpipe. The concern here pertains to tailpipe emissions.

Another consideration pertains to the type of trip that follows soaks of different durations. A drive to work would typically (but not always) follow a long, overnight soak, for example. However, a drive to work could be a seven-minute drive from one's home to a nearby office or a 45-minute drive across a major city. It seems that almost any type of trip could follow a soak of any duration.

6.3.1.4 Selection of Soak Durations to be Used in a Given Emissions Test

The characterization of soak durations described in the preceding section will help identify what needs to be included in an emissions test regarding durations. Three basic approaches for determining the durations to be used are 1) select a set of two or more durations to be used in all tests, 2) randomly generate the durations to be used in each test, and 3) use a combination of 1) and 2).

If the same set of soaks is to be used in all tests, the set can be determined partly on the basis of engineering judgement and partly on the basis of the statistical distribution. Since there is clearly an interest in cold starts, the first soak could be one long enough to allow the engine to reach ambient temperature. If only one other duration is used, the median determined from the database is a reasonable choice. If three others are used, the quartiles (25th, 50th, and 75th percentile values) are reasonable choices. If the number of soaks to be used is more than two, the soaks to be used after the first, long soak can be applied in random order.

In the previous section, a number of possible ways to characterize the statistical distribution of soak durations were discussed. Regardless of the method of characterization, it is possible to randomly generate one or more durations for use in a given test.

Suppose it is decided not to try to describe the database succinctly, but to retain all 12,073 points. It is possible to generate a random duration with the same distribution as the original data points by first generating a random integer i with a uniform distribution between 1 and 12,073. The ith value in the database is the random duration with the desired distribution.

Suppose, on the other hand, the distribution of durations had been described by binning the durations in the database. Suppose further that there are k

bins, and the probability of occurrence of Bin i is p_i. To select a bin, first generate a uniformly distributed random variable x between 0 and 1. Then select Bin 1 if $0 \leq x < p_1$. Select Bin 2 if $p_1 \leq x < p_2$, etc. It is clear that the probability of selecting Bin i, i=1 to k, is in accordance with the distribution of the original data points.

The information about the distribution of the durations <u>within</u> bins is not preserved. It is possible to randomly generate a duration whose distribution is uniform within the limits of the selected bin, however. This should be adequate, since the bins are sufficiently narrow for practical purposes. The upper limit of the highest bin must be assigned somehow; the largest soak duration in the database is one possible choice. The final randomly selected soak duration, then, has approximately the same statistical distribution as the original data points.

In any case, assuming an overnight soak is part of each test, it might be unnecessary to include a second very long soak. Thus, if a soak duration longer than, for example, 3 hours is generated, this duration can be rejected and another generated. The combination of an overnight soak, along with one or more soaks of randomly generated durations restricted to be less than a given value, should be sufficient to represent both long and short soaks and include a random element.

6.3.2 Signal Processing Analysis

Another advanced analysis approach that could be used effectively to understand and simulate driving cycles, is the use of signal processing analysis. In the discussion below, two standard techniques are discussed which could be used jointly to create a tool to analyze the driving patterns in the database and to produce candidate driving cycles for consideration for a new Federal Test Procedure.

6.3.2.1 Conceptual Approach

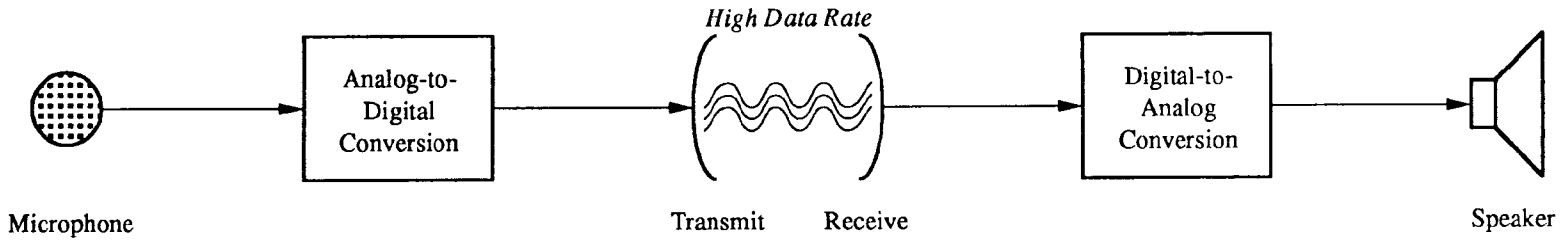
A signal is any measurable quantity in a system that varies in time. Speech waveforms, sonar sound pressure levels, seismic waves, and chemical process concentrations are examples of signals. Because of the long-term interest in these and other application areas, a comprehensive body of signal processing theory and application techniques has been developed.

The driving speed of a vehicle as a function of time is a signal. Other examples of automotive emissions analysis signals include emissions concentrations of various species, engine RPM, manifold pressure, throttle position, lubricant and coolant temperatures, and fuel consumption. In this section, only a single channel speed signal will be considered.

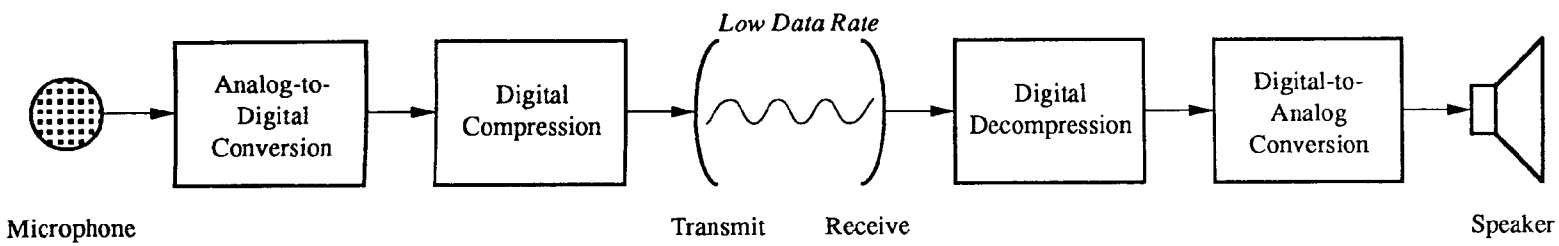
It often helps to use as an analogy a related mature field to suggest useful techniques. In this section, speech compression for telecommunication will be used as a model for analyzing vehicle speed, and a neural network-based music synthesis algorithm will be used as a model for simulating driving patterns. The rest of this section discusses the issues of vehicle speed representation, model parameter estimation, model validation, and vehicle speed simulation.

6.3.2.2 Telecommunications Analogy

The direct way to transmit an audio signal over a digital network (such as the telephone system) is to sample the waveform at a rate based on its bandwidth, transmit these samples, and pass the samples through a digital-to-analog converter at the receiver (Figure 6-47A). This was in fact the process used first at the telephone companies, but they soon discovered that many more lines could be handled with the same equipment if digital compression and decompression were used (Figure 6-47B).



a) Telecommunications without data compression.



b) Telecommunications with data compression.

Figure 6-47. Telecommunications Signal Transmission

The initial compression schemes considered the audio waveforms as abstract signals, and generated compact representations based on allowable tolerances on compression noise levels. This type of compression has been used extensively in digital telecommunications for several decades.

Because of the rapidly increasing capacity requirements and the new wireless communications options with limited spectrum space available, improved compression schemes have been developed. By using a detailed physical model of the speech generation process (voice box) and the auditory system response (ear), the intelligent compression schemes represent only the audio content that can be generated and perceived by humans. By extracting and saving only the essence of the "meaning" of the signal, the most compact representation of the information is obtained. The total compression attained is from 700 kb/s (kilobaud/second), the data rate for a high fidelity audio signal, to about 8 kb/s, the rate for a compressed clearly understandable speech signal.

The message here for the driving pattern analysis is that the model-based approach best captures the essence of the information.

For driving, the raw signal is the speed sampled once a second. There is no insight about the vehicle operation contained in the speed trace itself. But if the speed trace is transformed to a model-based representation, the vehicle behavior is expressed in terms of interpreted quantities (such as accelerating from a stop, cruising on a freeway, slowing for a stop sign, etc.). This is a high-information density form of the speed trace, just as the model-based audio coding is an information-rich version of the speech signal. In the next section, the calculation of model-based speed representations is discussed.

6.3.2.3 Vehicle Speed Representation

Figure 6-48 shows the detail from a segment of sampled speed. The x's on the graph denote the sample values. This is the lowest level of representation of the vehicle speed, and the "meaning" of the vehicle behavior is not explicit. Parameters that define the sampling process are the sampling rate (fast enough to capture rapid speed changes), amplitude resolution (to represent small speed fluctuations), and dynamic range (to cover the full range of possible speeds).

The next level is to represent the speed signal as a sequence of "states". Each state, or driving segment, is described by the type of state and several numerical parameters.

EXAMPLES OF DRIVING STATES	
State	**Parameter**
Engine off	Duration
Idle	Duration
Acceleration	Initial speed, final speed, duration, sigma
Cruise	Initial speed, final speed, duration, sigma
Deceleration	Initial speed, final speed, duration, sigma

The parameter "sigma" is a measure of the variation of the acceleration during the segment. Routines could be easily written to transform any driving cycle to a sequence of such states. The number of states generated would vary, depending on the fidelity requested. Higher fidelity would require more states.

Representing the speed as a sequence of abstract states has several advantages for driving cycle analysis and simulation. The information is compressed, especially when the fidelity requirements are not too stringent. Events related to

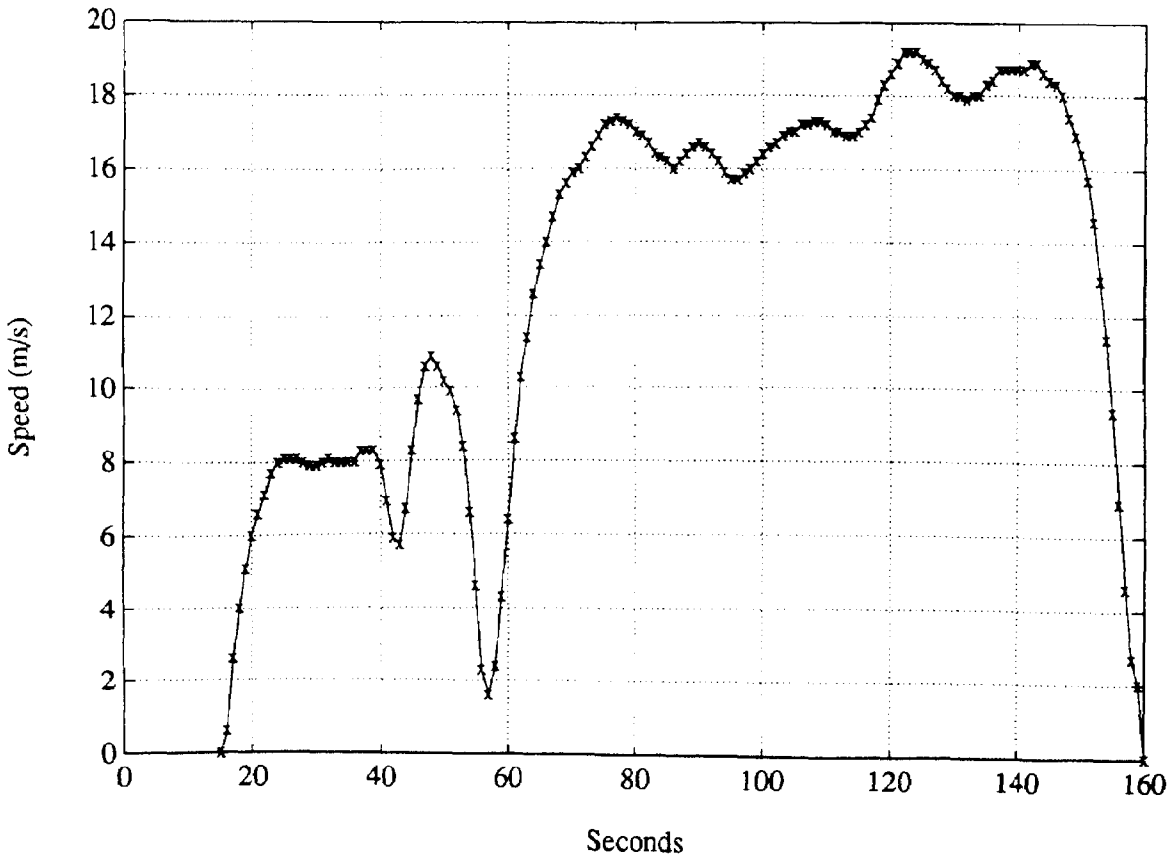


Figure 6-48. Example Driving Segment

emissions, such as engine startup, engine off time, and rapid acceleration, are represented explicitly.

The third level of representation is based on a physical model of driving, including such factors as vehicle types and responses, driver behavior types, road conditions (speed limits, stop signs, hills, etc.), and traffic levels. Just as raw speech signals are transformed into phonemes, sentences, and meaning with automatic speech recognition algorithms, the raw speed signals can be transformed into driving segments and trips by automatic driving recognition algorithms.

The advantage of using a representation based on a deep knowledge of vehicle and driving characteristics is that the information density is especially high and in a form useful for analysis, insight, and simulation. Predicting the effect of changes in vehicle design or traffic laws on the driving pattern is straightforward and accurate. The disadvantage, of course, is the amount of effort required to develop and validate the model-based representation.

6.3.2.4 Neural Network Simulations

Simulation methods, based on either driving theory or measurements, can be used to generate example speed signal traces similar to real-world driving. If the process is well understood, the simulation can be based on a theoretical model. When a large amount of data is available, as is the case with driving, the simulation algorithm can be trained to behave like the example data.

There are several possible reasons for building a simulation of driving. The simulation system will be a source of realistic signals for research and testing. By varying model parameters, the effect of controllable changes to the driving characteristics (such as different traffic laws, new vehicle responses, etc.) can be predicted. And perhaps the most important benefit will be the increased understanding of the driving

process resulting from the development of the simulation and the validation of the results.

Recently developed neural network techniques have been successfully applied to solve complex pattern recognition and control problems. Based loosely on nervous system function, neural networks are most suitable for complex problems for which a large amount of data is available. Generating vehicle speed traces characteristic of a particular type of driver and driving conditions is this class of problem. Neural networks have been trained to solve a similar problem, learning a musical grammar from examples and composing music in the style of the examples. Two neural network approaches to this music problem are described briefly below, along with parallels to the driving modelling problem.

The first paper (20) describes a neural network program that can learn melodic passages and counterpoint style from examples and then generate new passages in the same style. The author trained the network with the three-part Inventions of J. S. Bach and generated music that was "smooth, continuous, and pleasant."

Kohonen listed the main problems in computer music, which all have their analogies in driving models. First, it is difficult to automatically find the start and stop of possible themes. In driving, it is difficult to unambiguously define the start and end of driving segments, such as trips, acceleration sections, cruising, etc. Second, it is difficult to maintain a certain "style" over a passage and switch to a new one at the transition to the next passage. This might correspond to the transition from one style of driving versus another ("easy Sunday drive" vs. "reach the restaurant before closing time" or "freeway" vs. "residential"). Third, special rules are required in the music generator to prevent bad melodic turns, but even with these rules the resulting music still isn't always beautiful. The corollary for driving is that special rules will be needed to prevent unphysical speed traces (e.g., negative speeds, or accelerations beyond the vehicle's limits), but some unrealistic sections will continue to appear periodically.

The heart of Kohonen's approach is to address these difficulties with a "dynamically expanding context". The number of past notes used to determine the next note varies with the location in the piece, and this optimum length of context is determined from examples separately for each note sequence. The grammar is stored as a set of matrix of coefficients that define a set of production rules. The knowledge of the neural network, a form of associative memory, is stored in the weights. The network is trained by applying musical sequences to the inputs (in this case Bach's Inventions), and adjusting the weights to learn the musical patterns.

New, partly random, music sequences are generated by using these stored production rules to compute the notes. Often several different production rules apply in a given situation, and a particular one can be selected randomly to introduce variety in the melody. Musically knowledgeable listeners perceive the resulting music as mechanical but in the style of Bach.

If a similar technique is applied to driving patterns, the variable length of context supports learning about different types of trips with different time scales: backing up in the driveway, traversing city blocks, and extended segments of freeway driving. Musical pieces are described as sequences of notes, of lengths of several hundred to several thousand notes. For training, it is advantageous to transform the speed signal samples to "feature" sequences (such as acceleration, deceleration, cruise, etc.), as discussed above, to reduce the input vector size.

Another neural network for learning musical patterns was trained from the music of George Frederick Handel (21). This author used the ART 3 architecture to design a neural network capable of learning the varying-scale embedded temporal patterns of chords that characterize harmonic syntax. This paper illustrates how carefully designed neural network algorithms, together with large amounts of training data, can recognize and learn the finer detail structure of the input sequence. Since vehicle speeds

also have correlation patterns of varying length, a similar technique could be used to improve the accuracy of driving simulations.

6.3.2.5 A Zeroth Order Signal Processing/Neural Network Driving Pattern Model

Vehicle driving behavior can be visualized in different ways. The traditional way of viewing it is as a series of trips during which the driver accelerates the vehicle to a desired speed and then decelerates when he gets to his destination. The driver accelerates his vehicle away from stop signs and stop lights. The basic concept of this traditional model is that the natural state of the vehicle is at rest with the engine off. Any model that is used must explain why the vehicle is not at rest with the engine off. To do this, reasons must be categorized, explained, or modeled for all accelerations and speeds other than zero.

Any conceptual models can be used to understand and analyze driving pattern behavior, but some of the models may have advantages over others in terms of the simplicity of the mathematics. One that has been attractive to the authors in this study has been based on the concept that the natural or base state of the vehicle is that it is running at a constant and high speed. The rationale for this base state is that the vehicle was manufactured to be driven and that drivers want to go as fast as possible to reach their destination as soon as possible, subject to the driving conditions. The only reason that the vehicle would not be driven at the constant high speed is that the vehicle encounters an "obstacle" for which the driver judiciously causes the vehicle to slow down. After the obstacle has been passed, the speed of the vehicle again increases to its natural high constant speed.

One of the attractive features of this obstacle model is that there are only a few types of obstacles which are needed to explain a decrease in the speed of the vehicle. There are basically five types of obstacles that need to be considered:

- Natural fluctuations in speed;
- Objects to be avoided;
- Curves and turns in the road;
- Traffic controls; and
- The destination.

Even though the driver would like to maintain his vehicle at a constant high speed, because of natural fluctuations in the vehicle power plant operation and small grade changes in the road, there will always be small speed changes. While this type of operation can be maintained on straight, level roads, usually other traffic is in the vicinity and the driver must avoid this other traffic. This causes his vehicle to need to slow down. For safety, the driver must slow down for objects, such as wet pavement or an animal running in front of his vehicle.

In this study, the authors instrumented their own vehicles and kept a written log of where and when the vehicle was driven for each trip. Examination of the speed profile, in comparison with the written log, showed that the speed of the vehicle decreased when the vehicle went around curves in the road or made turns at intersections, even though no traffic controls forced the driver to slow the vehicle down.

If traffic controls are present, these have an obvious effect on the driving pattern of the vehicle. Speed limit signs limit the upper speed of the vehicle to some value. Stop signs cause the driver to slow the vehicle down; in most cases, it is not a stop, but a rolling stop. Stop lights cause vehicles to stop when they are red and usually to slow down when they are green. Finally, reaching the destination, where the vehicle is shut down, is the ultimate obstacle in this model.

It could be that these five categories of obstacles do not describe all events in driving patterns; however, they probably describe a large percentage of them. Another advantage of this obstacle model is that each of the obstacles that cause a reduction in the speed of the vehicle may do so in a characteristic way. Thus, examination of the speed data in the driving pattern database, using appropriate pattern recognition software, may be able to identify, for a large fraction of the obstacles, the nature of the obstacle that was encountered by the driver. A cluster analysis of the obstacle characteristics could be performed.

The speed vs. time profiles for each of the encounters with any obstacle may have similarities that can be described by a relationship between speed and time. Different obstacles would be described by different parameters in the relationship. The result would be that an obstacle model could describe all changes in vehicle speed with one or a few relationships. It would be the parameters that change from obstacle to obstacle.

One such obstacle model that could be used to describe the encounters of a driving vehicle is analogous to a pinball machine. This special pinball machine has rubber bumpers spread throughout its frictionless playing field. The steel ball represents the vehicle. At the beginning of the trip, the ball is shot onto the playing field. It travels for a distance at a high constant speed, until it encounters a rubber bumper. If it hits the rubber bumper head-on, the speed of the steel ball slows rapidly to 0 mph and then accelerates again as it bounces off the rubber bumper. If the ball hits a rubber bumper in a grazing fashion, it does not stop but slows down to a degree, depending on the angle of incidence with the bumper. If the playing field is filled with many rubber bumpers with different softnesses of rubber and with different populations, the speed of the steel ball would produce a very complex-looking speed vs. time profile as it moved through the playing field. The softness of the rubber in the pinball bumpers is analogous to the power/weight ratio for vehicles for accelerations and braking efficiency for decelerations.

In a pinball machine, an understanding of the motion of the ball depends on an understanding of the population distributions of rubber bumpers, their softnesses, and locations. These parameters can be determined on a pinball machine by taking measurements of the speed of pinballs during trips on the playing field. In an analogous manner, the characteristics of obstacles that vehicles encounter on the road that cause them to slow down and speed up can be determined by examining the speed profiles of many vehicles on the road. These measurements have been done in this study. By analyzing these measurements in an intelligent fashion, it should be possible to describe the obstacles in enough detail that simulated driving patterns can be created which have all of the characteristics of the driving patterns measured in this driving pattern study.

Developing such a model may or may not be a simple task; however, through the use of a combination of signal processing analysis and artificial neural networks, it seems that it is possible.

A zeroth order model based on a body (the vehicle) striking a rubber wall (the obstacle) at an angle is described below. The interaction of the body with the rubber wall is modeled using Hooke's Law for the normal component to the wall and the minimum speed attained at the collision to be equal to the speed of the body parallel to the rubber wall. This model produces sines and cosines for the speed profiles for a collision perpendicular to the rubber wall and a more complex equation for speeds striking the wall at an angle. To demonstrate how the signal processing analysis and neural network could be used to learn about driving pattern behavior and then to simulate driving patterns, an example driving segment is presented in Figure 6-49.

In the example driving segment (Figure 6-49), the dashed line is the measured speed and the solid line is the speed predicted by a 17 segment obstacle model fit. The segments are defined by 10 obstacles, which were encountered at the times shown by the arrows. Each segment is defined by three parameters: initial speed, final speed, and duration (Table 6-7). The fourth parameter in the table (k), is computed

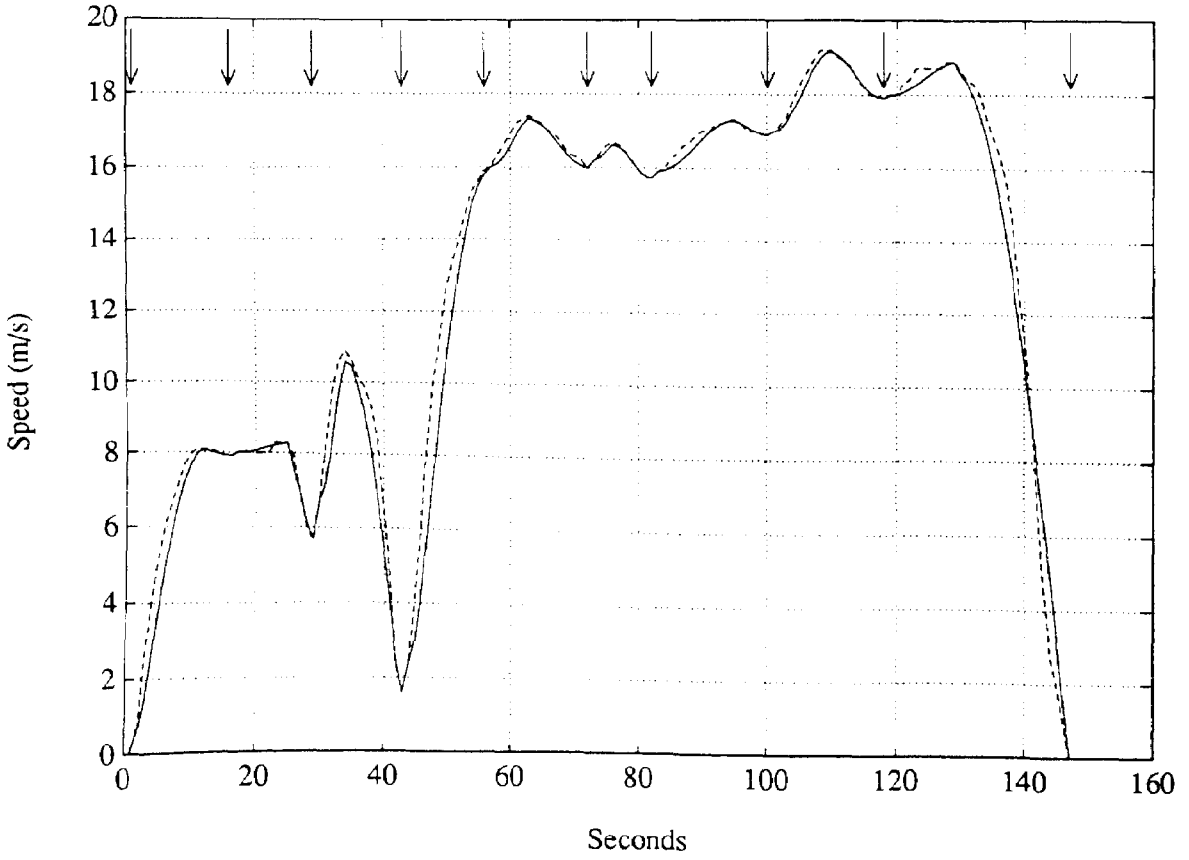


Figure 6-49. Obstacle Model for Example Driving Segment

Table 6-7

Obstacle Description Parameters

Speed Segment	Speed Fitting Parameters			Calculated Collision Softness k
	Beginning Speed (m/s)	Ending Speed (m/s)	Segment Duration (s)	
1	0.6	8.1	10	0.15
2	8.1	7.9	5	0.31
3	8.0	8.3	9	0.17
4	7.9	5.7	4	0.39
5	6.7	10.9	5	0.31
6	10.6	1.6	9	0.17
7	2.4	15.9	13	0.12
8	16.0	17.4	7	0.22
9	17.3	16.0	9	0.39
10	16.2	16.7	4	0.39
11	16.6	15.7	6	0.26
12	15.9	17.3	12	0.13
13	17.3	16.9	6	0.26
14	17.0	19.2	9	0.17
15	19.2	17.9	9	0.17
16	18.0	18.9	11	0.14
17	18.6	0.0	18	0.08

from the other three parameters and is analogous to the spring constant of harmonic motion.

Once the physical modeling parameters are determined for each segment, the parameters for all obstacles in the database are used to train a neural network. This second step in the model has not been done for this example, but conceptually it completes the development of the driving pattern model.

The physical modeling parameters form a condensed representation of the driving information. In the example, the original 147 time samples are represented by 17 segments defined by three parameters each, for a data compression ratio of about 3 to 1. The physical model can be iteratively refined, using large measured driving data sets for testing and validation, to improve the both data compression and model accuracy. The value is not principally in the data compression, but because the parameters capture the essence of the driving information in a compact form. The amount of compression is a measure of the accuracy and generality of the model. Physical models are useful for driving analysis tasks, such as determining the differences between different types of drivers or different vehicle power-weight ratios. The model representation is also useful for comparing driving histories, as would be required, for example, for validating simulated driving cycles.

Physical driving models are especially useful for generating simulated driving cycles. The simulator merely needs to select driving parameters according to the measured statistics of the type of driving desired, and the physical model will accurately fill in the fine detail of the speed vs. time traces. The simulator algorithms could be based on any trainable method, such as neural networks, fuzzy logic, rule-based expert systems, or traditional statistics.

Although the simple obstacle model represents the example data section fairly well, some straightforward model enhancements could improve the model performance significantly.

First, the obstacle model uses the same functional form for acceleration and deceleration segments. But we know that different physical systems (braking and engine power) are involved, and the speed responses would be better represented by a model which incorporates the characteristics of these different systems. The model should also require continuity of the speed and acceleration at the junctions between segments. The obstacle model in the example allows discontinuity of acceleration at these points.

Next, some form of multi-scale analysis should be supported by the model. The user should be able to specify the accuracy required, and the model would adjust the tightness of fit and the number of parameters required accordingly. The few parameters required for a "loose" fit describe the general shape of the speed curve, and the additional parameters added for tighter tolerance requirements describe the detail of speed fluctuations.

By choosing the right mathematical forms for the model, the parameter estimation process can be fully automated. This allows the use of the massive amounts of collected data to test and refine both the functional form and the parameter statistics of the physical models.

6.4 Options for Formulating Driving Cycles

The ultimate goal of this driving pattern study is to evaluate the current certification test procedure, the FTP. These data will be used to determine whether the FTP is adequate, needs to be updated, or needs to be replaced. The current test

procedure specifies the speed of the vehicle versus time, and we anticipate that any new procedure that may replace it would use a similar approach.

6.4.1 Two Possible Bases for a Certification Test Procedure

A new certification test procedure can be developed using one of two bases. The cycles can be representative of today's:

- Driving patterns; or
- Emissions patterns.

Each basis has advantages and disadvantages, as discussed below.

A driving cycle based purely on driving patterns would be representative of the driving pattern of the vehicle population. Emission measurements taken while vehicles are driven in traffic indicates that such a cycle would spend most time testing driving features that produce low emissions and a small amount of time testing high emission driving features. During certain episodes, for example, during cold start operation or during heavy acceleration, HC and CO emissions are high. However, these high emission events occur during a small fraction of the total driving time. This means that a driving cycle representative of vehicle population driving patterns will be inefficient at measuring the performance of the vehicle emission control systems during high emissions episodes, although the cycle is accurately measuring the emissions performance of the vehicle in a cycle representative of real world driving.

Alternatively, a certification test procedure based on the emissions pattern of the vehicle population will reflect the range of driving in the real world but will be weighted by the response of the vehicle emissions to those driving features. Because of this, the emissions-based driving cycle will contain more high emission driving features

and fewer low emission driving features. Thus, the procedure would be efficient at measuring the high emissions behavior of vehicles.

An example will help clarify the important distinction between a driving pattern-based certification test procedure and an emissions pattern-based certification test procedure. Suppose that analysis of the driving pattern data and a separate study of the relationship between emissions and driving indicates that the emissions rate of hydrocarbon can be explained by just two kinds of driving modes: Type A and Type B. Suppose that it is found that vehicles spend 95% of their driving time in Type A driving but generate only 20% of the total fleet hydrocarbon emissions in this mode. Suppose that vehicles spend only 5% of their driving time in Type B driving but generate 80% of the total fleet hydrocarbons in this mode.

The driving based certification test procedure based on this hypothetical information would be a cycle with 95% of the time in the A mode and 5% of the time in the B mode. The emissions-based certification test procedure would be a cycle with 20% of the time in the A mode and 80% of the time in the B mode. This second procedure emphasizes the time spent on high emissions features.

A driving cycle based purely on driving patterns will need to be updated only when the driving patterns of the vehicle population change. Changes may occur relatively slowly over perhaps twenty years. A driving pattern-based test procedure will also continue to representatively measure the emissions of vehicles although the vehicle emission control technology and fuel types may change dramatically in the next several years.

A driving cycle based on emissions patterns depends on the emissions behavior of current vehicles, which in turn depends on the type of fuel and emission control technology used when the current vehicles were being certified. Thus, for example, a new driving procedure developed in the next few years would be based on the

emission characteristics of 1992 vehicles. These vehicles are, of course, creatures of the current Federal Test Procedure, since they have been designed to pass that procedure. As vehicle manufacturers continue to develop more advanced control technologies and as new types of fuels become available in the marketplace, a driving cycle based on emissions behavior of 1992 vehicles may become a poor measure of the emissions behavior of the latest vehicles. Consequently, the new driving cycle may become obsolete in a short time. A continually revised certification test procedure that responds to changes in vehicle technology and fuels, however, will mean that the rules for manufacturing a new vehicle will be continually changing. Manufacturers will find such procedural changes difficult to quickly respond to, given the long lead times needed to integrate a new control system with a future model year vehicle. Also, EPA would need to update the certification test procedure regularly. In addition, there is no guarantee that this circular process would converge toward lower vehicle emissions and a simpler certification test procedure.

Another disadvantage of the emission-based test procedure is that the desired weighting of the high and low emitting driving features may not be the same for HC, CO, and NO_x emissions. Road emissions data indicates that HC and CO emissions increase greatly during cold start operations and heavy accelerations, but the response of NO_x emissions to driving may be different.

The choice of whether to use a driving pattern-based or an emissions pattern-based test procedure is difficult because which will be more effective depends to a large extent on the speed and degree of changes that may occur in emission control systems, fuel composition, and emissions of concern. If changes are slow and small, and if the new procedure can be implemented rapidly, the emissions-based procedure will be more effective for several years. If changes happen quickly and are large, then the emissions-based procedure will remain effective for a shorter time.

6.4.2 Format Options for a New Test Procedure

The final development of the new certification test procedure or updating of the current FTP will depend on the basis of the new procedure and the format that the new procedure might have. As discussed in Section 6.4.1, the certification test procedure may focus on driving patterns or emission patterns. The test procedure could be developed in a straightforward manner as a direct consequence of the advanced statistical analysis techniques or the signal processing data analysis techniques. In the discussion below, options for the revised test procedure are discussed.

Several different certification test procedure formats can be envisioned for an updated or new procedure. These might include procedures based either on driving patterns or emission patterns. The formats include:

- Current FTP;
- Revised FTP (Bag 4);
- New deterministic cycle;
- Multiple deterministic cycles; and
- Multiple stochastic cycles.

After the driving pattern data are fully analyzed, it may be decided that the current FTP is a good representation of today's driving and therefore does not need to be revised. However, the current FTP is believed not to cover the full range of accelerations present in the vehicle population. Since in today's technology vehicles, heavy accelerations are known to produce emissions, the FTP may be underestimating the emission potential of today's new vehicles. One approach to correcting this situation is to add a Bag 4 to the end of the current FTP. This fourth bag would contain the higher accelerations and other emission features that need to be added to the FTP to

make it more representative of actual emission patterns. The driving features that would be included in Bag 4 cannot include all of the driving pattern features that would make the FTP representative of driving patterns in the population. If this is done, most of the driving features in Bag 4 could not contribute significantly to emissions produced by the FTP cycle. Since the features that should be included in Bag 4 are based on emissions, it is imperative that the relationship between emissions and driving be known. This would have to be determined in a separate study or be based on existing information.

If the signal processing approach is used to analyze the data, and if the driving pattern descriptors are evaluated for their contributions to emissions, the current FTP can be evaluated to determine the types of driving features that need to be added to make it more representative of emissions patterns of the vehicle population.

Another approach is to replace the current FTP with a new deterministic cycle (that is, a cast-in-iron cycle). A most likely deterministic cycle could be produced using a simulation based on the advanced analysis of the data. If this new cycle is based on emission patterns, the most likely cycle will emphasize the high emission driving features of the vehicle population. However, if this cycle is based on driving patterns, the most likely cycle will not include very much high emission feature content, since the test procedure would be representative of population driving.

An alternative approach is to use multiple deterministic cycles. Such a battery of cycles could be used to test the vehicles near the extremes of driving behavior measured in the driving pattern study.

Rather than deterministic cycles, which are fixed, multiple stochastic (randomly generated) cycles could be used to certify new vehicles. Such cycles could be generated using a simulation based on the results of the advanced statistical or the signal processing analysis of the driving pattern data.

Randomly generated cycles would have a variety of driving features; the severity of each feature would be randomly selected from the range of severities found in the driving pattern study. For a new vehicle to pass certification, it would have to pass a certain fraction of a certain number of randomly generated driving cycles. A computer program that generates the cycles would be made available to anyone for testing purposes. The fraction of stochastic cycles which must be passed and what determines a pass would have to be decided using statistical and probabilistic techniques.

The advantage of using the stochastic approach to develop a driving pattern based test procedure is that the approach will work regardless of the emission control technology, the fuels being used by the vehicles, or the emissions of concern. In addition, the stochastic approach would be effective because the procedure would encourage manufacturers to develop emission control systems that could pass most randomly generated cycles. EPA's testing of vehicles to be certified might be time-consuming, but the development of an emission control system would not require the testing of numerous stochastic cycles. In the development of a vehicle emission control system, the manufacturer might choose to test the vehicle only for those features where emissions are high. Such a certification test procedure would be good as long as the driving pattern data used to develop the driving pattern descriptors and their distribution of values are good.

7.0 REFERENCES

1. DeFries, T.H. and R.F. Klausmeier, "Evaluation of Driving Pattern Measurement Techniques," Radian Corporation, DCN 91-298-018-01-02, 18 July 1991.

2. "Federal Test Procedures, Part 86 of Title 40." Code of Federal Regulations (40 CFR 86).

3. DeFries, T.H. and S. Kishan, Driving Modes Quality Assurance Project Plan, Revision 1. Radian Corporation, DCN 92-254-036-90-05, 31 January 1992.

4. DeFries, T.H. and G.F. Baker. Instrumented Vehicle Pilot Study of In-Use Driving Behavior in Spokane, Washington. Radian Corporation, DCN 92-245-130-02, 24 January 1992.

5. Horowitz, A.D. "Automobile Usage: A Factbook on Trips and Weekly Travel." GMR-5351, General Motors Research Laboratories, Warren, Michigan, 2 April 1986.

6. Maurin, M. and J. Crauser. "The Kinematic Sequences, an 'Atomistic' Approach to Automobile Travel and the Effects of Travel," Recherche Transports Sécurité. English Issue No. 5, Date unknown.

7. Smith, M. Development of Representative Driving Patterns at Various Average Route Speeds. Scott Research Laboratories, Inc., Report No. EPA-450/3-76-023, February 1974.

8. "Should Europe Adopt a Modified FTP?" Automotive Engineering, V 86, Warrendale, Pennsylvania, 6 June 1978. pp. 50-53.

9. Milkins, E. and H. Watson, "Comparison of Urban Driving Patterns." In: Proceedings of the Motor Vehicle Technology: Progress and Harmony, Second International Pacific Conference on Automotive Engineering. Society of Automotive Engineers (Australasia), Tokyo, Japan, November 1983. pp. 735-745.

10. Watson, H.C. "Influence of Vehicle Driving Patterns on Localized Urban Emissions Sources." In: Proceedings of the Automobile Engineering Meeting. Society of Automotive Engineers, Detroit, Michigan, May 1973.

11. Harkins, J., M. Smith, and M.J. Manos. Vehicle Operations Survey Volume I. Scott Research Laboratories, Inc., SRL-2922-13-1271; CRC-APRAC-CAPE-10-68-9, San Bernardino, California, 17 December 1971.

12. Johnson, T.M., D.L. Formenti, R.F. Gray, and W.C. Peterson. "Measurement of Motor Vehicle Operation Pertinent to Fuel Economy." In: Proceedings of the Automotive Engineering Congress and Exposition. Society of Automotive Engineers, Detroit, Michigan, February 1975.

13. Stivender, D.L. and Y.G. Kim. "Dynamic Computer Techniques for Vehicle Emission Development." In: Proceedings of the Automotive Engineering Congress. Society of Automotive Engineers, Detroit, Michigan, January 1972.

14. Deshpande, G.K. "Development of Driving Schedules for Advanced Vehicle Assessment." In: Proceedings of the International Congress and Exposition. Society of Automotive Engineers, Detroit, Michigan, February 1984.

15. Bullock, K.J. "Driving Cycles." In: Proceedings of the Second Conference on Traffic, Energy, and Emissions. Society of Automotive Engineers (Australasia), Melbourne, Australia, May 1982.

16. André, M. "In Actual Use Car Testing: 70,000 Kilometers and 10,000 Trips by 55 French Cars under Real Conditions." In: Proceedings of the International Congress and Exposition. Society of Automotive Engineers, Detroit, Michigan, February 1991.

17. Williamson, H., T.H. DeFries, R.F. Klausmeier, J. Lange, and L. Collins. Preliminary Analysis of Data Collected in EPA's Operational Characteristics Study. Radian Corporation, DCN 92-298-018-01-05, 2 October 1992.

18. Hartigan, J.A. Clustering Algorithms, Wiley-Interscience, 1975.

19. Gumbel, E.J. Statistics of Extremes, Columbia University Press, 1958.

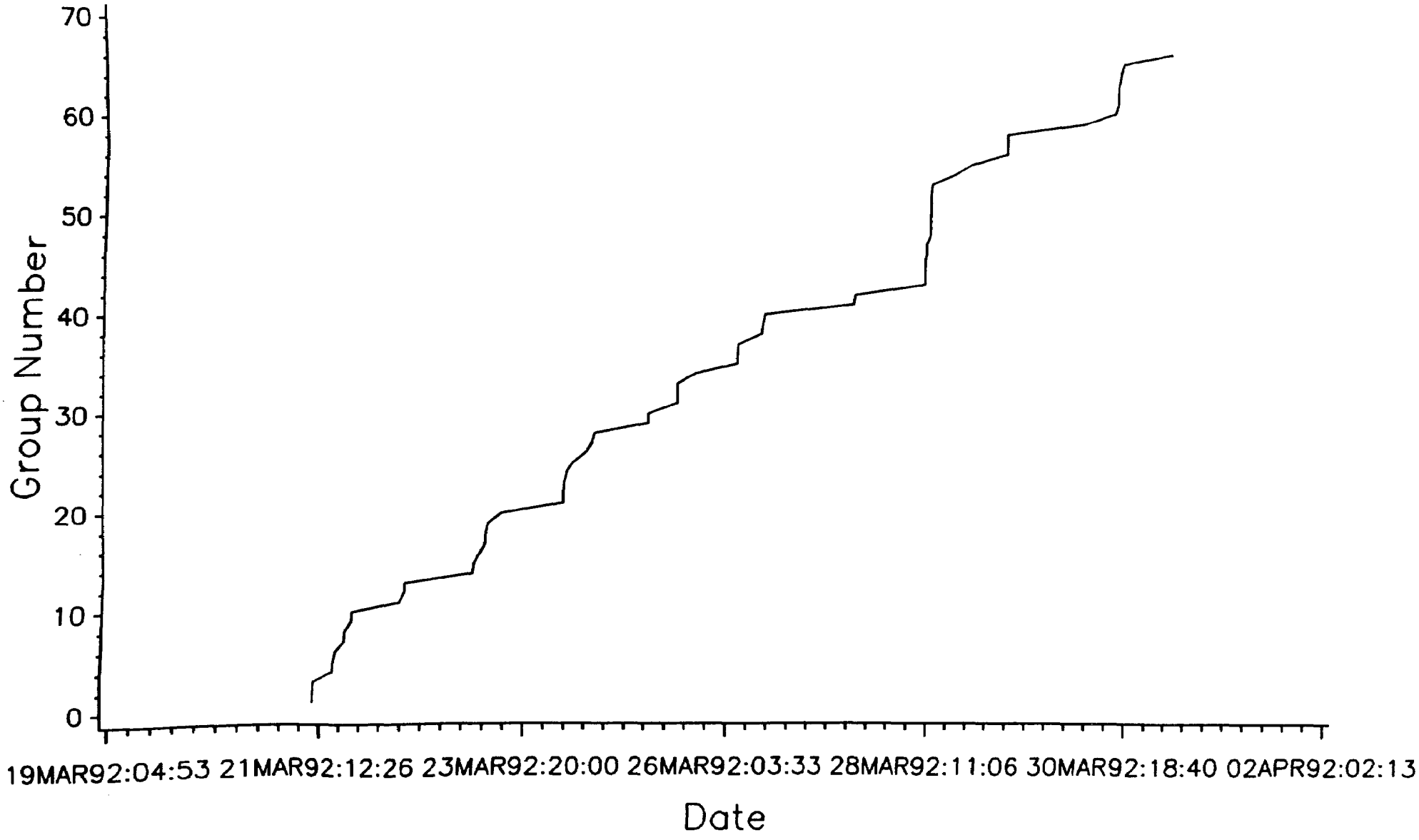
20. Kohonen, T. A Self-Learning Musical Grammar, or "Associative Memory of the Second Kind." In: Proceedings of International Joint Conference on Neural Networks. Washington D.C., June 1989, pages I-1 to I-5.

21. Gjerdingen, R.O. "Learning Syntactically Significant Temporal Patterns of Chords: A Masking Field Embedded in an ART 3 Architecture." Neural Networks. Vol 5, pp 551-564, 1992.

APPENDIX A

SAMPLE QUALITY CHECKING PLOTS

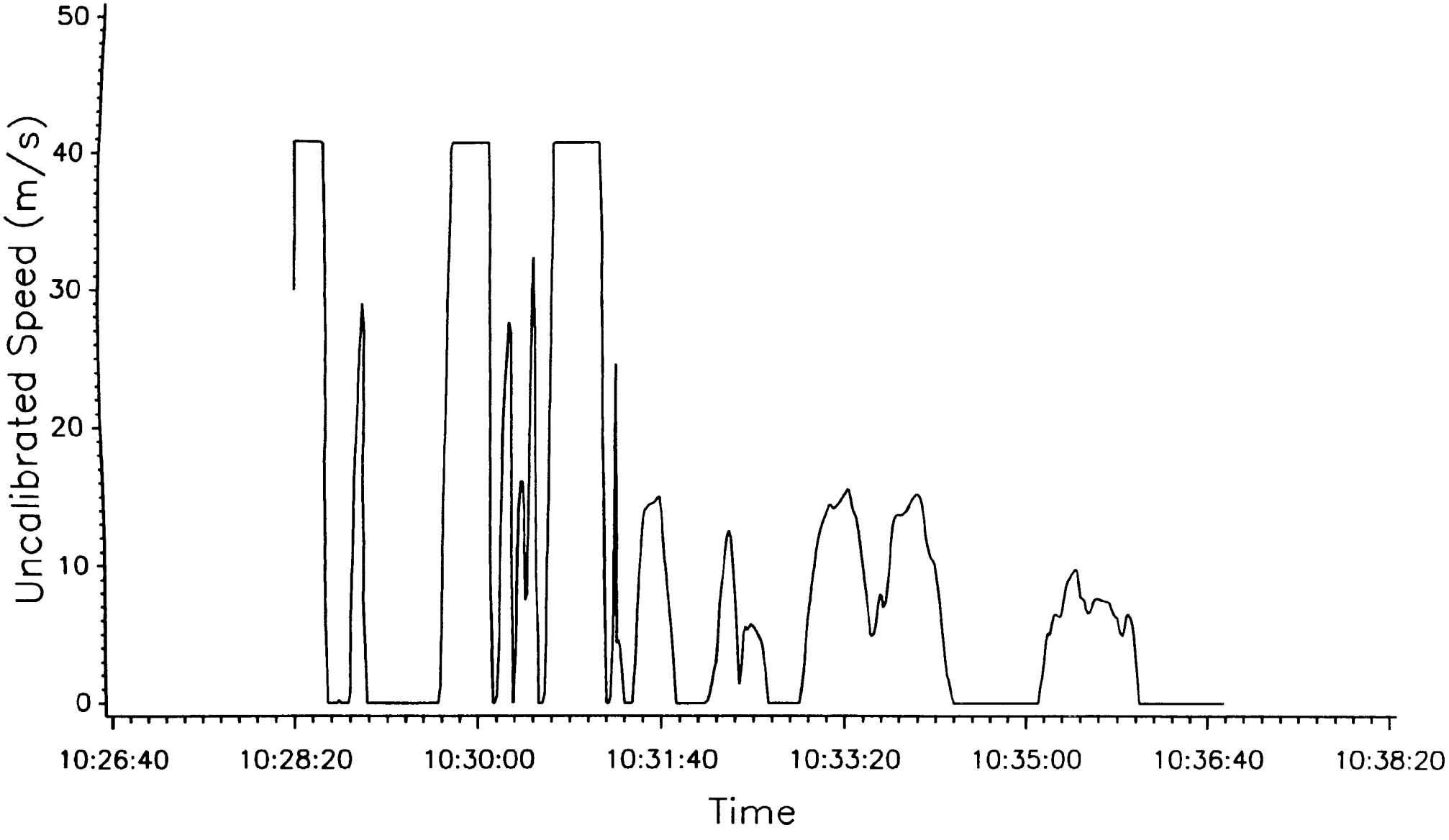
Figure A-1



fu631495.3rd

Figure A-2

DATE=21MAR92



fu631495.3rd

Figure A-3

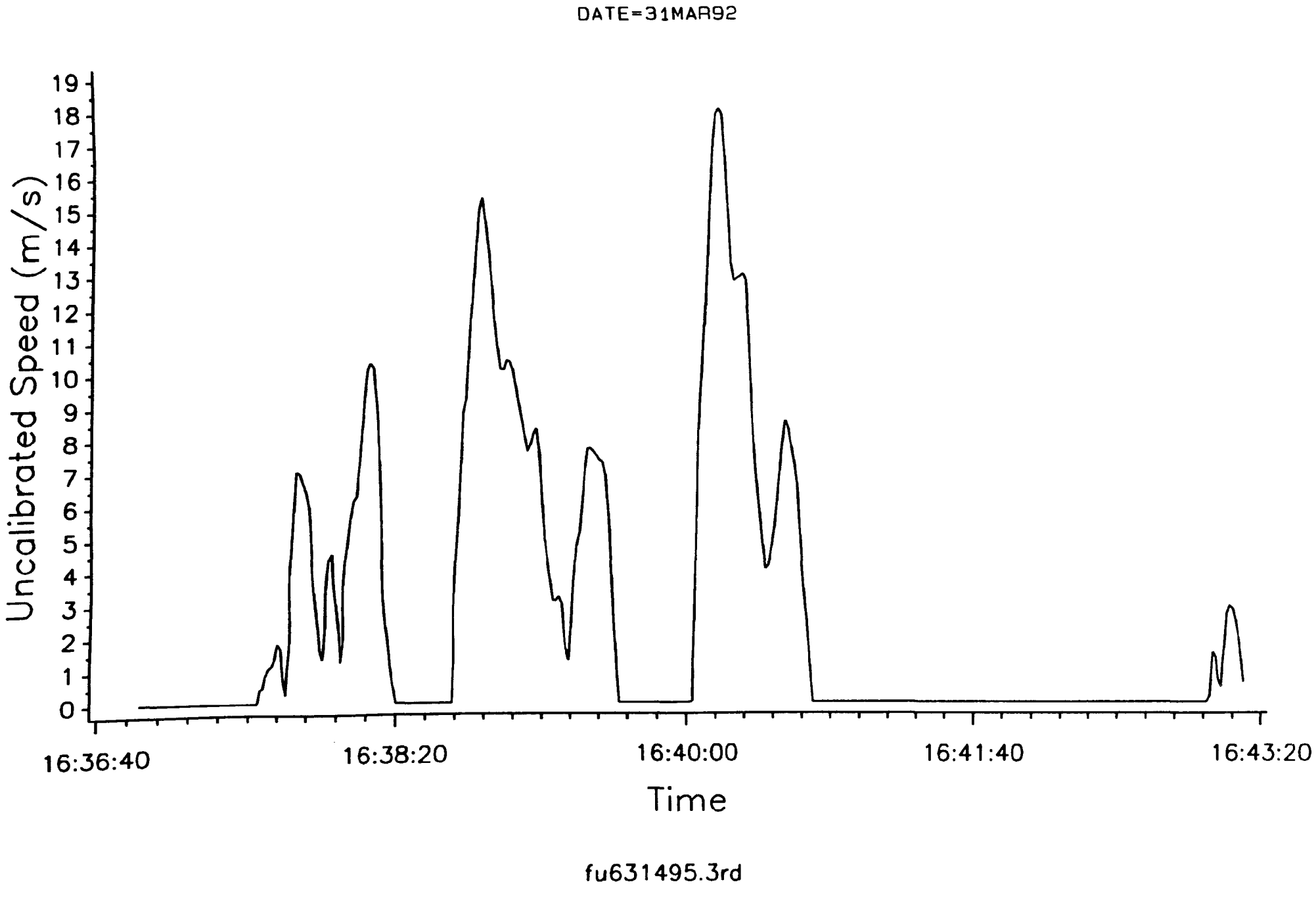
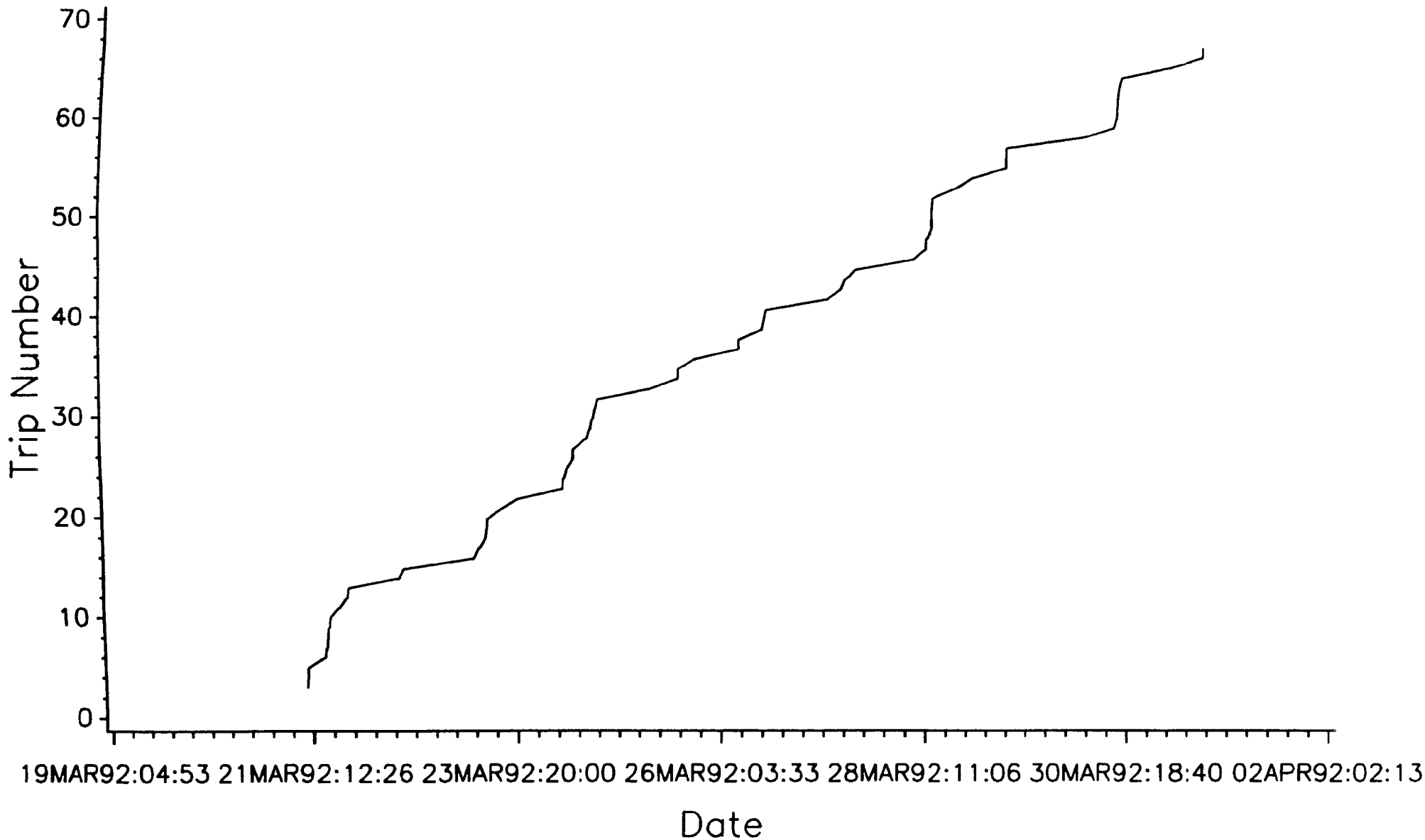
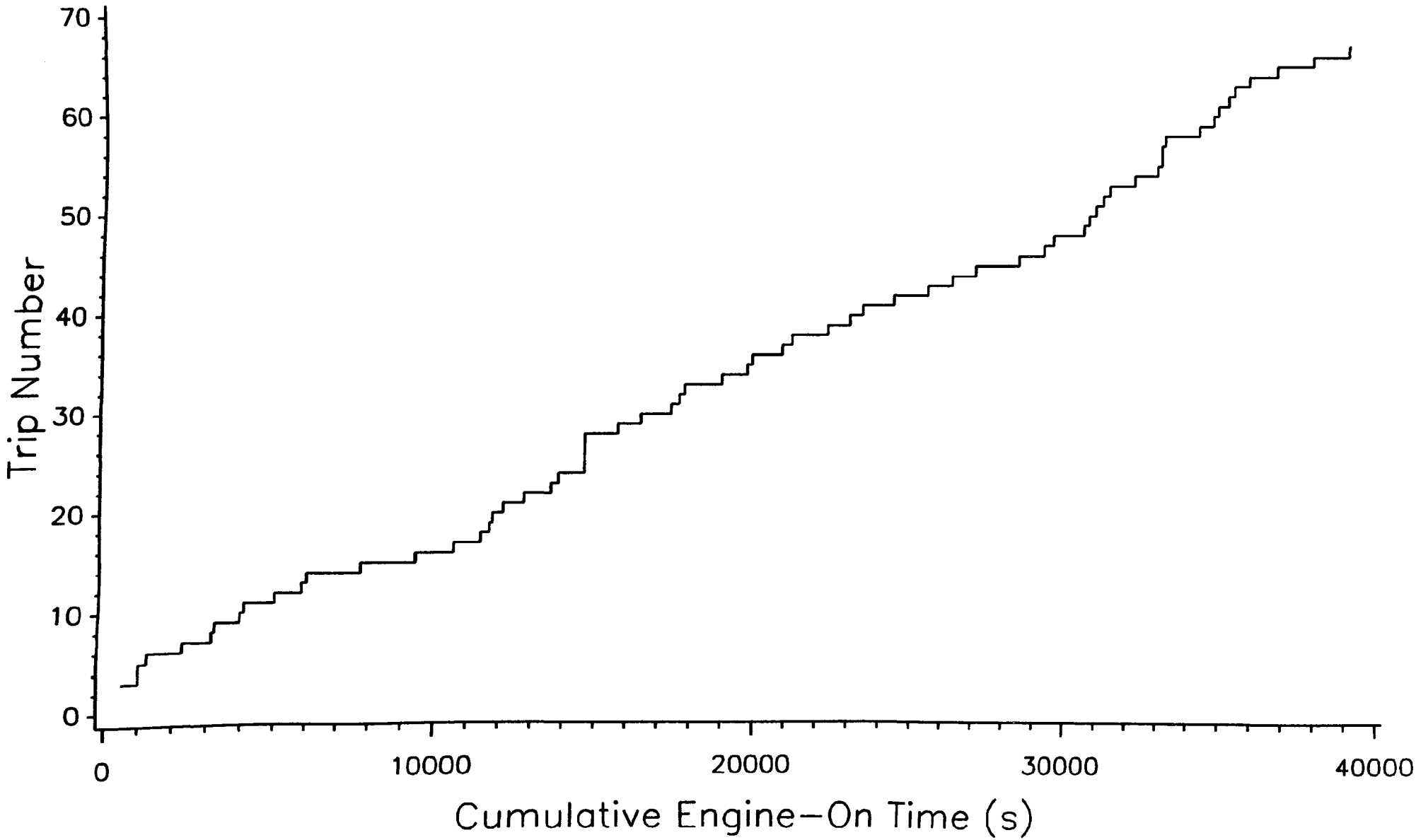

DATE=31MAR92
Uncalibrated Speed (m/s)
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
16:36:40
16:38:20
16:40:00
16:41:40
16:43:20
Time
fu631495.3rd

Figure A-4



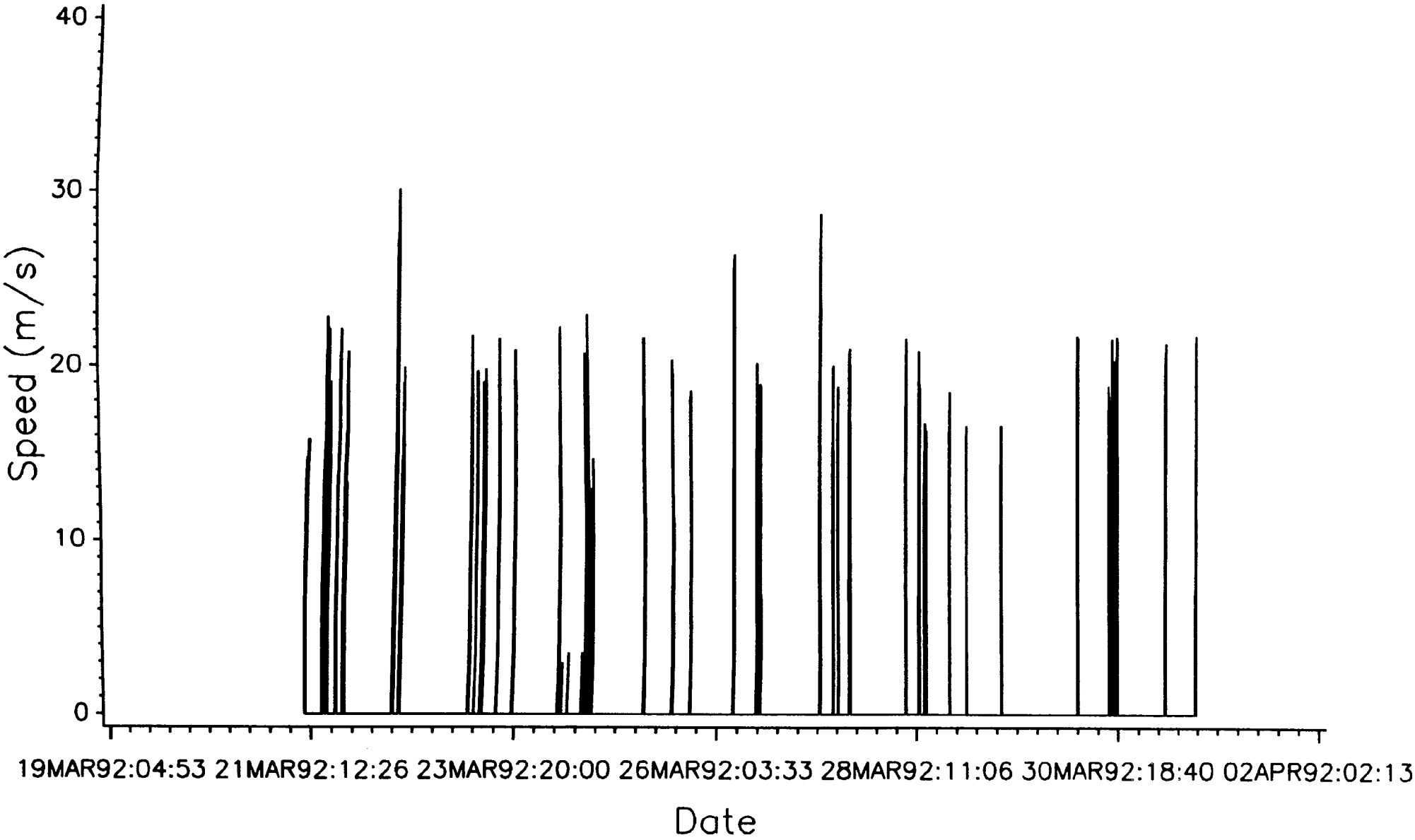
fu631495.3rd

Figure A-5



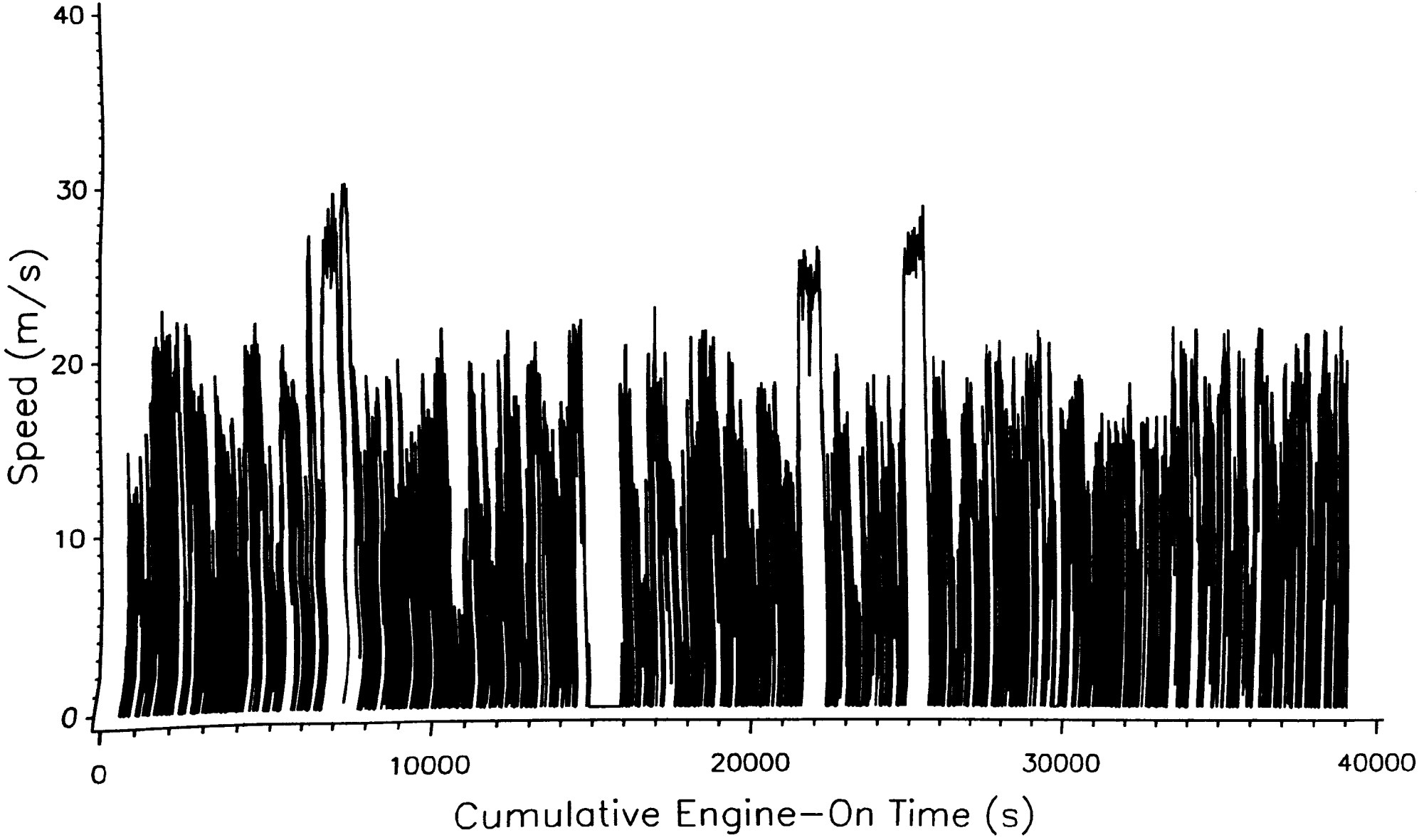
fu631495.3rd

Figure A-6



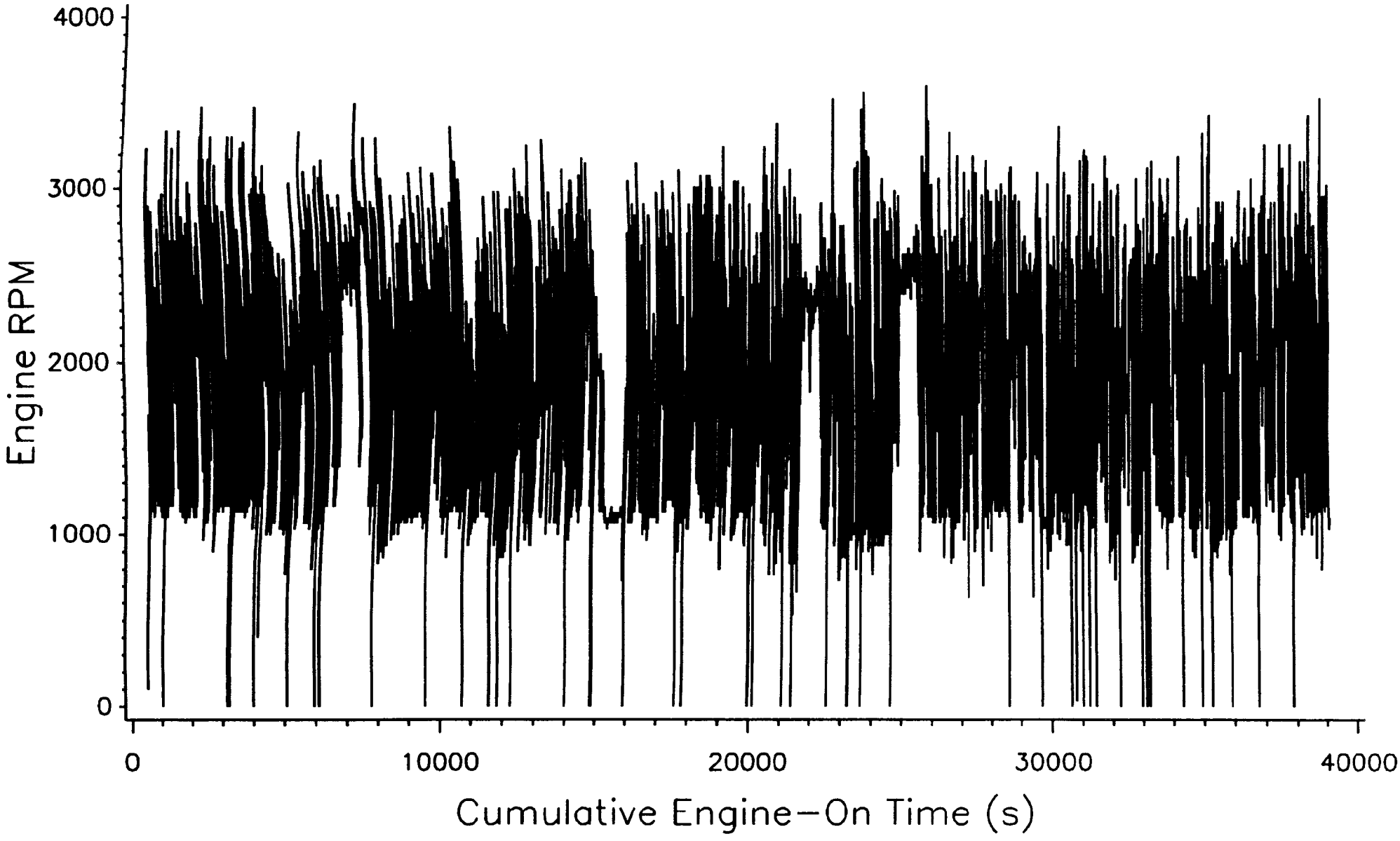
fu631495.3rd

Figure A-7



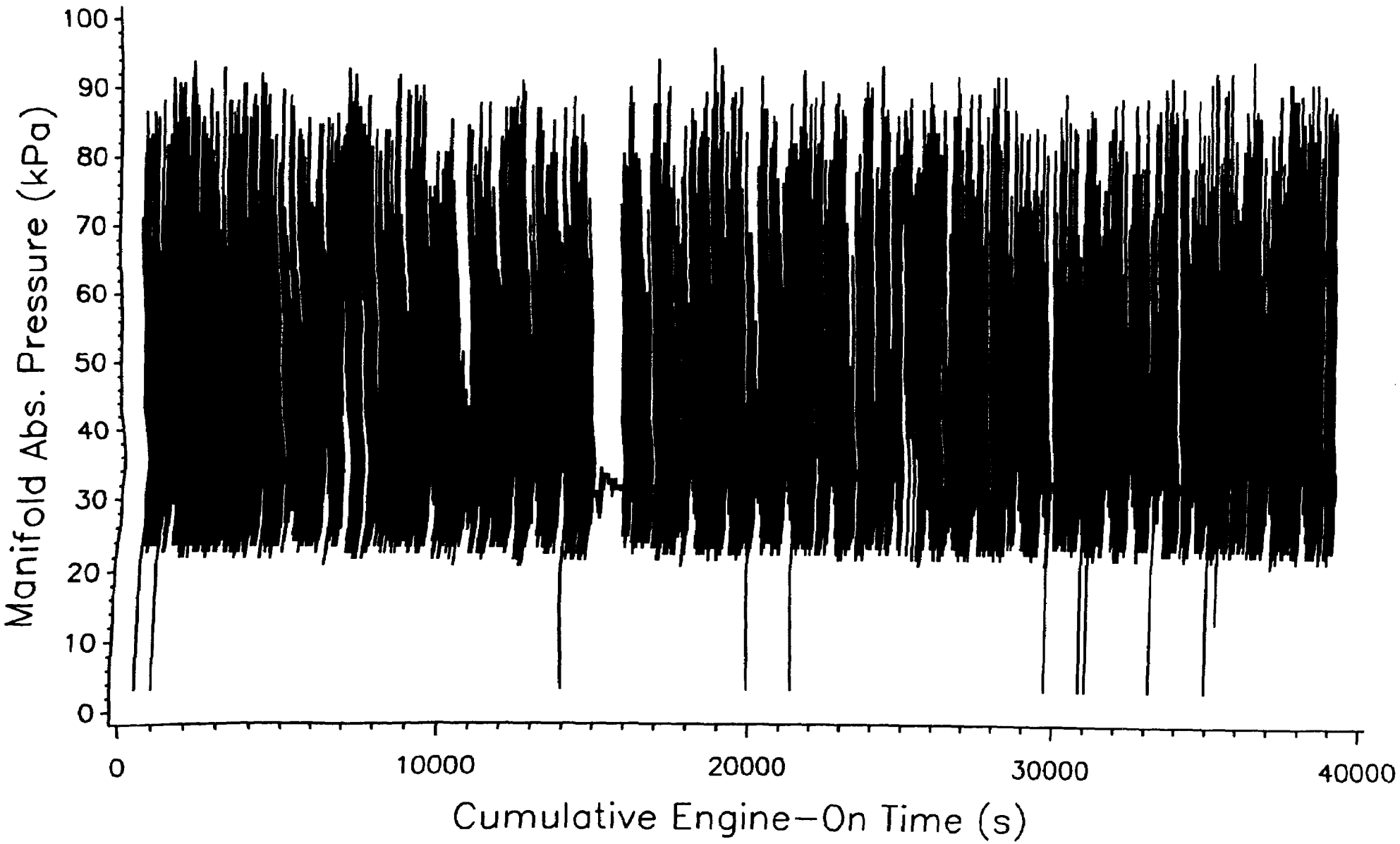
fu631495.3rd

Figure A-8



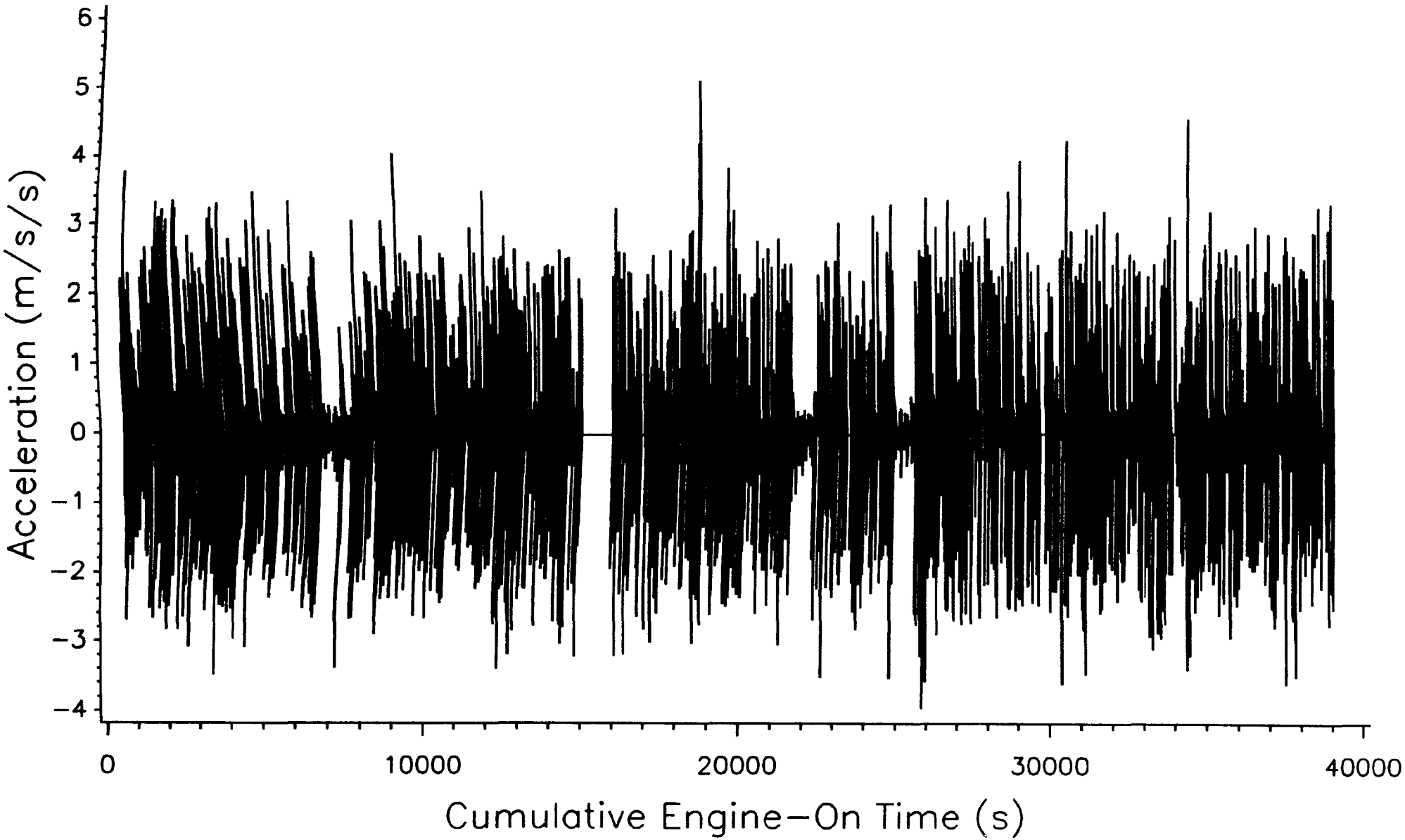
fu631495.3rd

Figure A-9



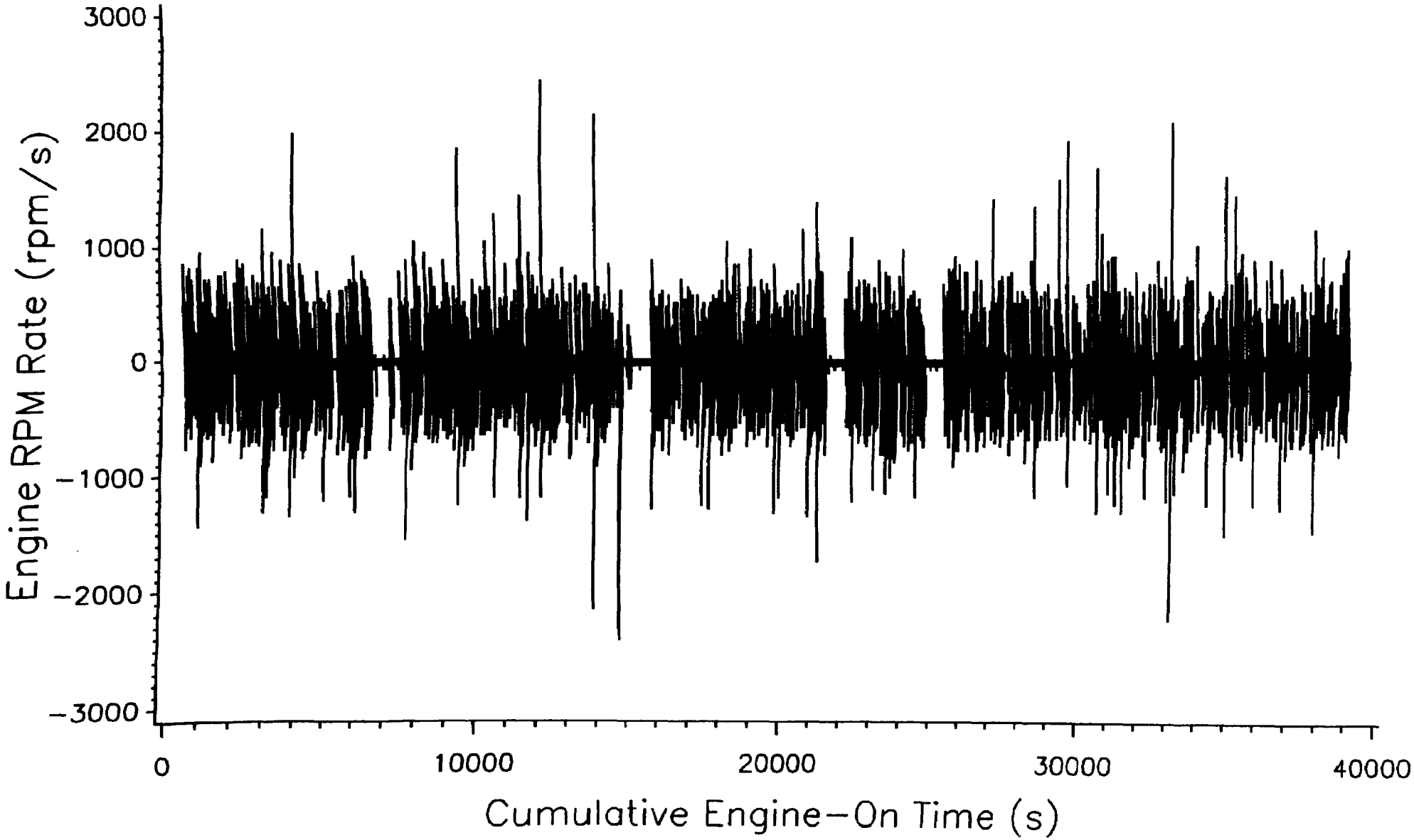
fu631495.3rd

Figure A-10



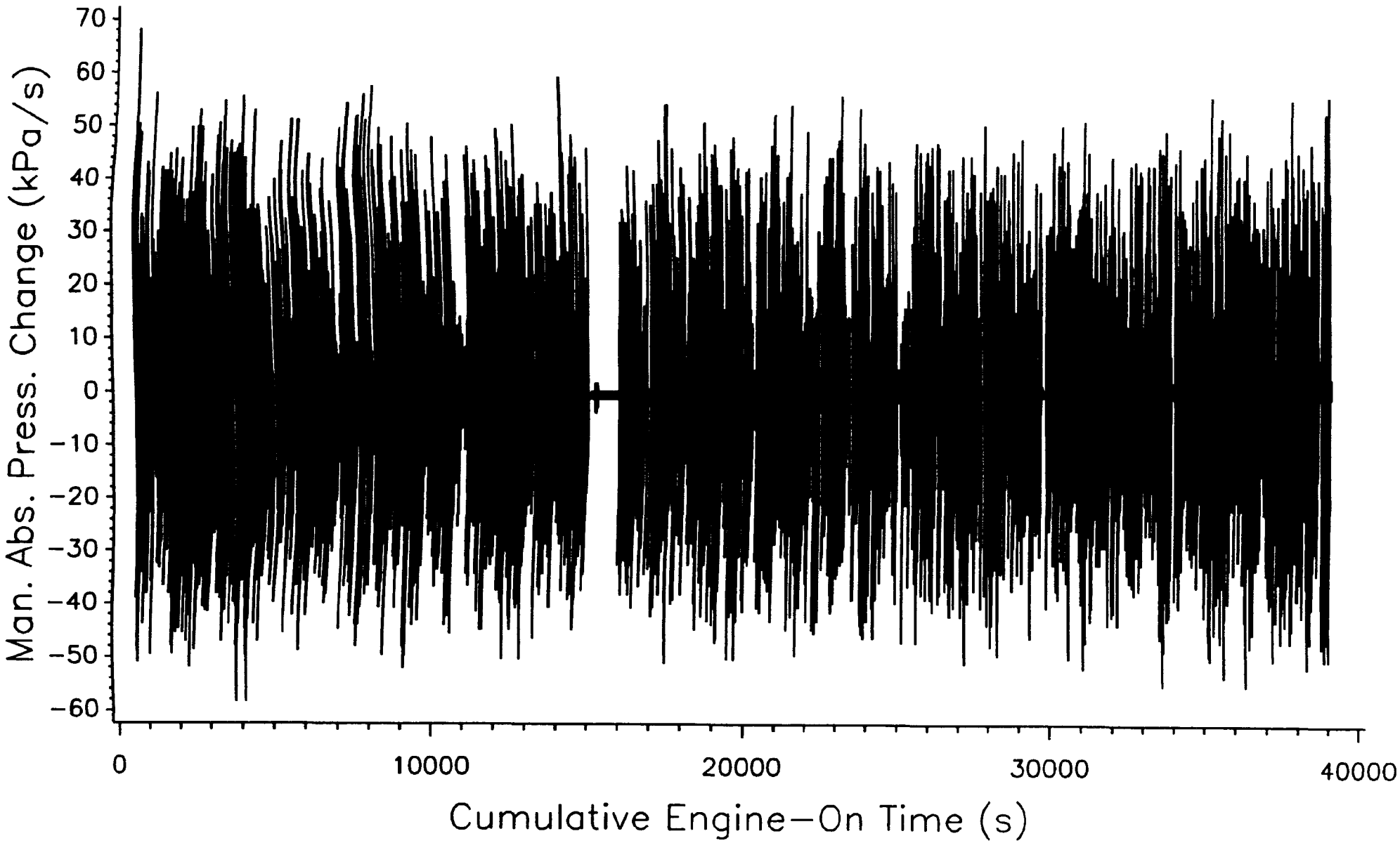
fu631495.3rd

Figure A-11



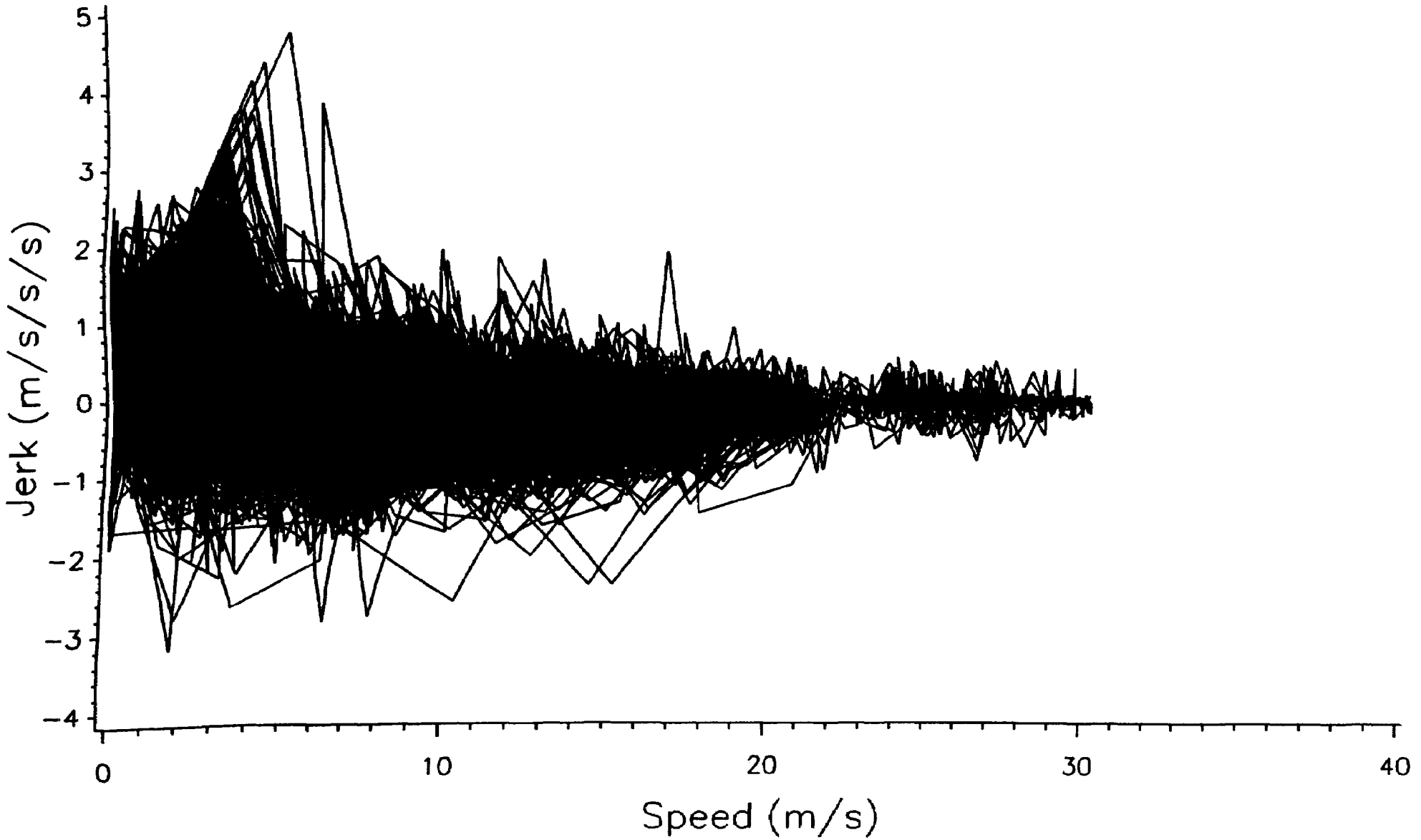
fu631495.3rd

Figure A-12



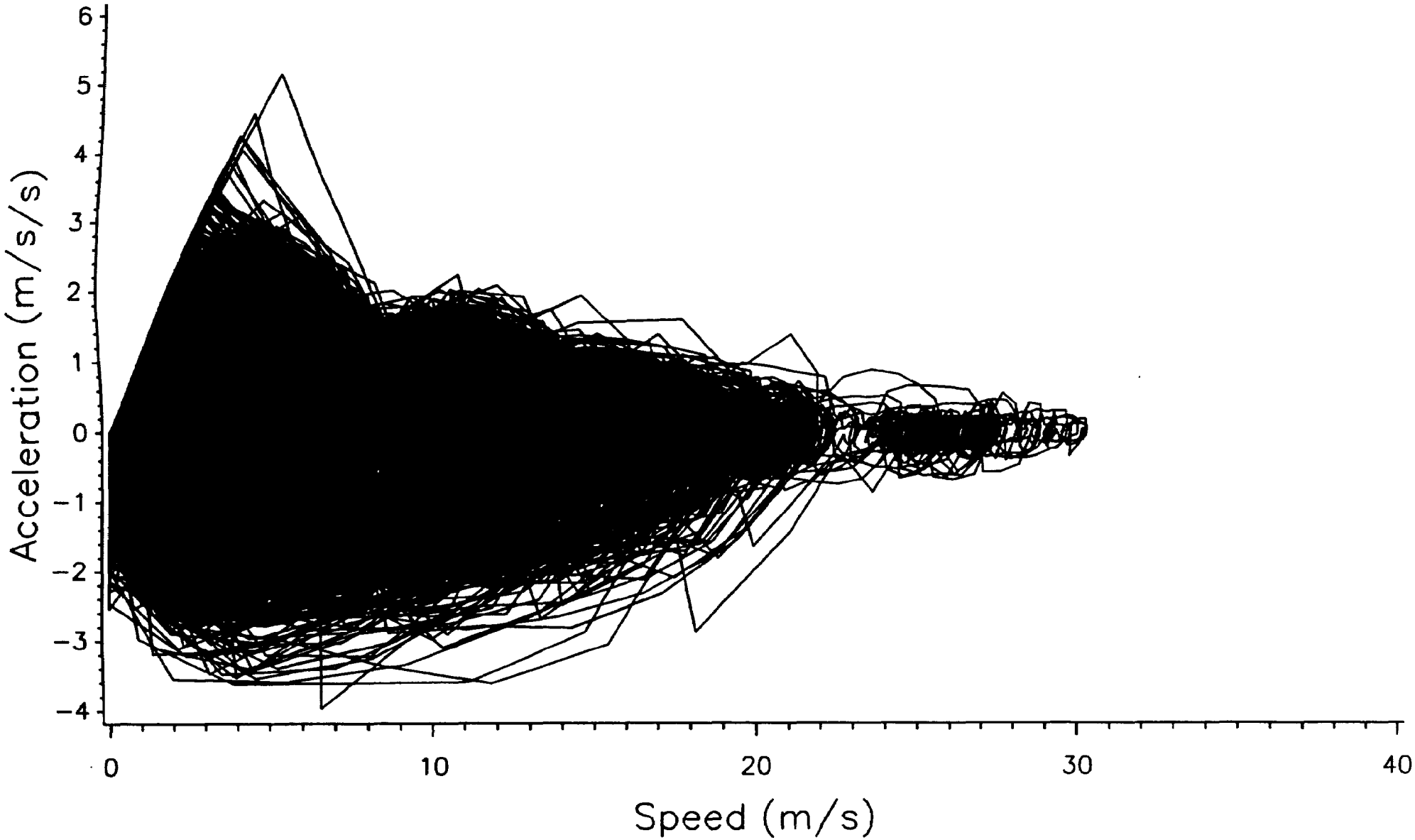
fu631495.3rd

Figure A-13



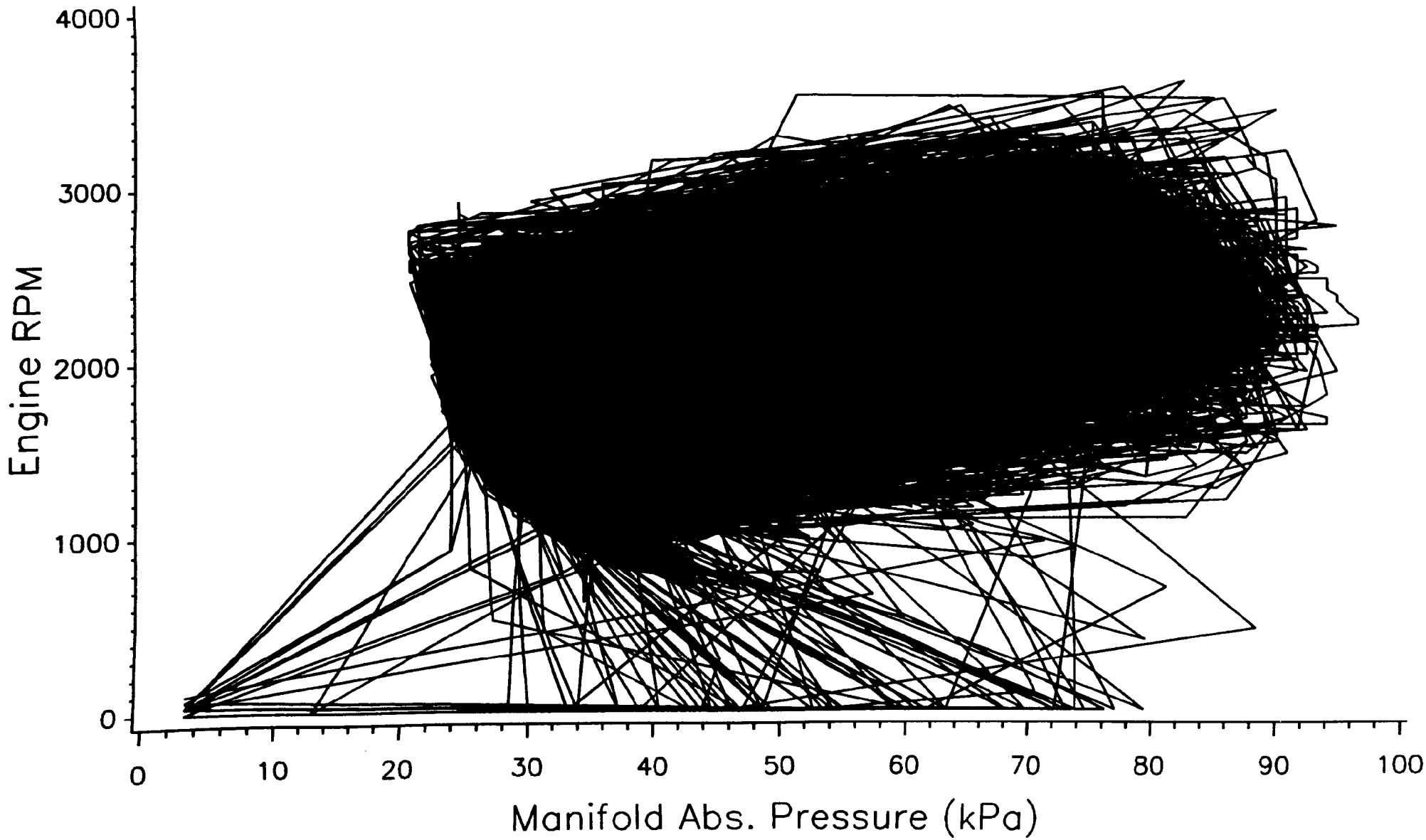
fu631495.3rd

Figure A-14



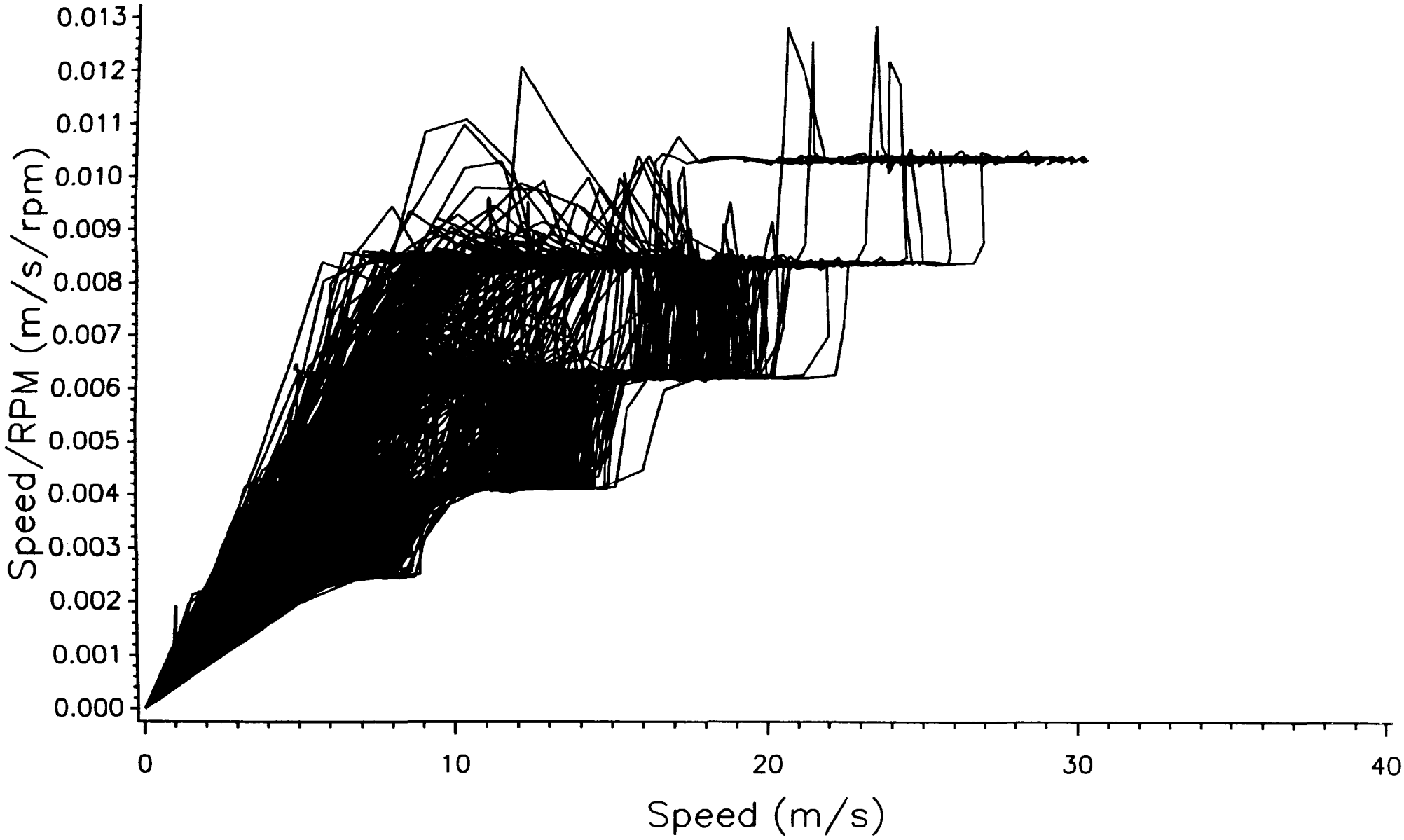
fu631495.3rd

Figure A-15



fu631495.3rd

Figure A-16



fu631495.3rd

APPENDIX B

DATA ANALYSIS PLOTS AND TABLES

Table B-1

OBS	SITE	SAMPLE	VIN	MAKE	MODEL	YEAR	TPL	TPH	TR
1	Balt-Ross	B002	1FTCR10A1MUC48371	ford	ranger	1991	.	.	A
2	Balt-Ross	B005	3B3XA4633MT034156	Dodge	Spirit	1991	30	1913	A
3	Balt-Ross	B008	1G1LT64W8KY218187	Chevrolet	Corsica	1989	0	100	A
4	Balt-Ross	B010	7V1AX885XJ1793960	volvo	240dl	1987	.	.	A
5	Balt-Ross	B011	1B3XG24K5KG180041	Dodge	Daytona	1989	512	2075	A
6	Balt-Ross	B016	1G1FP21S3KL104669	chevrolet	camaro	1989	.	.	A
7	Balt-Ross	B017	YS3AL75L8M7006092	saab	900	1991	.	.	M
8	Balt-Ross	B019	1G1FP21S1JL193186	chevrolet	camaro	1988	.	.	A
9	Balt-Ross	B037	2P4FH413XJR662190	plymouth	voyager	1988	.	.	A
10	Balt-Ross	B039	1P3BK46D2KC469869	plymouth	reliantk	1989	.	.	A
11	Balt-Ross	B042	1G6AD69B3D9266654	cadillac	sedandeville	1983	.	.	A
12	Balt-Ross	B044	1G2HZ54C2KW215880	Pontiac	Bonneville	1989	0	100	A
13	Balt-Ross	B050	1GCEG25HXC7125742	chevrolet	c20van	1982	.	.	A
14	Balt-Ross	B052	1HGCB7661MA049561	handa	accord	1991	.	.	A
15	Balt-Ross	B053	1G3NT14DXKM255041	Oldsmobile	Calais	1989	0	100	A
16	Balt-Ross	B055	JM1GD2224L1810193	Mazda	626	1990	250	2173	M
17	Balt-Ross	B058	1G2AB2705E7332521	pontiac	2000	1984	.	.	A
18	Balt-Ross	B059	1G1JF11W2K7180967	chevrolet	cAvelierz24	1989	.	.	A
19	Balt-Ross	B062	1FAPP14J2MW269094	Ford	Escort	1991	.	.	M
20	Balt-Ross	B066	1YVGD31B5M5138706	MAZDA	mx-6	1991	.	.	M
21	Balt-Ross	B072	1FTCR10A10UK81004	ford	ranger	1989	.	.	M
22	Balt-Ross	B074	1MEPM6042LH679380	Mercury	Cougar	1990	426	2316	A
23	Balt-Ross	B081	1G1JC1113KJ171405	chevrolet	cavalier	1989	.	.	A
24	Balt-Ross	B084	1G2AB2707E7250564	PONTIAC	SUNBIRD	1984	.	.	A
25	Balt-Ross	B086	1FAPP36X9KK201666	ford	tempo	1989	.	.	A
26	Balt-Ross	B088	1GCDC14Z8KZ211565	chevrolet	silverado	1989	.	.	A
27	Balt-Ross	B098	1GTBS14R2GS533452	gmc	s15	1986	.	.	A
28	Balt-Ross	B099	1G3HY14C3KW311671	Oldsmobile	88	1989	0	100	A
29	Balt-Ross	B105	JT4RN50R7G0173173	toyota	pickup	1987	.	.	M
30	Balt-Ross	B113	1N4GB2253KC735159	Nissan	Sentra	1989	665	4298	M
31	Balt-Ross	B119	1G1JF14T4M7133492	Chevrolet	Cavalier	1991	0	100	A
32	Balt-Ross	B123	TE725009680	toyota	corollawagon	1980	.	.	M
33	Balt-Ross	B124	1B3BP48D5KN589752	dodge	shadow	1989	.	.	A
34	Balt-Ross	B130	1FABP44E2KF117098	ford	mustanglx	1989	.	.	A
35	Balt-Ross	B139	1G4AL1937FG463396	buick	century	1985	.	.	A
36	Balt-Ross	B140	1MEPM36X2KK620959	Mercury	Topaz	1989	364	2163	A
37	Balt-Ross	B143	JT2RA44C6B0001018	toyota	celica	1981	.	.	M
38	Balt-Ross	B144	JE3CU36X6KU035123	Eagle	Summit	1989	262	2512	A
39	Balt-Ross	B150	1B3YA44K6JG448546	dodge	daytona	1988	.	.	A
40	Balt-Ross	B153	1GNCT18Z3K0152538	chevrolet	blazer	1989	.	.	A

Table B-1 (Continued)

OBS	SITE	SAMPLE	VIN	MAKE	MODEL	YEAR	TPL	TPH	TR
41	Balt-Ross	B156	1GCFC24H1KE115676	chevrolet	silverado2500	1989	.	.	A
42	Balt-Ross	B163	JHMCA5386JC052224	honda	accordlxi	1988	.	.	M
43	Balt-Ross	B164	1B3BD31D6FG241191	CHRYSLER	ARIESK	1984	.	.	A
44	Balt-Ross	B165	2B4GK55R7MR201092	Dodge	Caravan	1991	413	1955	A
45	Balt-Ross	B167	1YVGD22B0M5125967	Mazda	626	1991	246	2159	A
46	Balt-Ross	B169	1G4XB69R0FW454358	buick	skylark	1985	.	.	A
47	Balt-Ross	B178	JH4DA3458KS013350	accura	integra	1989	.	.	A
48	Balt-Ross	B184	1G4AH51R1HT438622	buick	century	1987	.	.	A
49	Balt-Ross	B190	JT2EL43B2M0027569	toyota	tercel	1991	.	.	A
50	Balt-Ross	B191	1GCDC14H3ME100424	chevrolet	1500	1991	.	.	A
51	Balt-Ross	B193	1GCDC14Z6KE135013	chevrolet	scotsdale1500	1989	.	.	A
52	Balt-Ross	B195	JHMBA7431GC066566	honda	accord	1986	.	.	A
53	Balt-Ross	B206	2MEBM75F1KX665883	MERCURY	GRANDMARQUIS	1989	.	.	A
54	Balt-Ross	B208	JM1FC3312G0121078	MAZDA	RX-7	1986	.	.	M
55	Balt-Ross	B210	JF1AC42B2KC210379	subaru	dl	1989	.	.	A
56	Balt-Ross	B233	JN1GB21SXKU537381	NISSAN	SENTRA	1989	.	.	A
57	Balt-Ross	B236	1W19J9B567918	CHEVROLET	MALIBU	1979	.	.	A
58	Balt-Ross	B243	YV1AX8852H1723847	VOLVO	240DL	1987	.	.	M
59	Balt-Ross	B247	2B4FK5131JR676116	DODGE	CARAVAN	1988	.	.	A
60	Balt-Ross	B255	1C3BC59KXHF330954	CHRYSLER	TOWNANDCOUNTRY	1988	.	.	A
61	Balt-Exet	B268	1G1AW35K5CR225618	chevrolet	Malibu_Classic	1982	.	.	A
62	Balt-Exet	B273	1FTCR11T1JUE26260	ford	Ranger	1988	.	.	A
63	Balt-Exet	B275	JT2AL31G7E0225492	TOYOTA	TERCEL	1984	.	.	M
64	Balt-Exet	B286	CRN1498264964	CHEVROLET	LUV	1979	.	.	M
65	Balt-Exet	B287	1237J9B412061	CHEVROLET	MONTECARLO	1979	.	.	A
66	Balt-Exet	B297	1MEBP9237GH654018	MERCURY	COUGAR	1986	.	.	A
67	Balt-Exet	B302	1G1LT54T2LY160319	Chevrolet	Corsica	1990	0	100	A
68	Balt-Exet	B314	1G3CX69B9G4332506	OLDSMOBILE	98	1988	.	.	A
69	Balt-Exet	B315	1FTEX15H2GKA94158	FORD	F150	1986	.	.	A
70	Balt-Exet	B317	8G87H169118	FORD	THUNDERBIRD	1978	.	.	A
71	Balt-Exet	B319	1FABP259XHW11G408	FORD	ESCORT	1987	.	.	A
72	Balt-Exet	B329	1G1GZ11G2HP118178	CHEVROLET	MONTECARLO	1987	.	.	A
73	Balt-Exet	B337	JT2MX62EX80014430	toyota	cressida	1981	.	.	A
74	Balt-Exet	B338	1G6AD478XC9150406	CADILLAC	COUPDEVILLE	1982	.	.	A
75	Balt-Exet	B344	1Y1SK5167LZ072182	GEO	PRIZM	1990	.	.	A
76	Balt-Exet	B351	1G4AJ47A8EH477206	buick	rega	1984	.	.	A
77	Balt-Exet	B354	1FAPP36X0KK176575	Ford	Tempo	1989	473	700	A
78	Balt-Exet	B358	1G1AW51W8K6151308	Chevrolet	Celebrity	1989	0	100	A
79	Balt-Exet	B361	JT2AE92W6J3076220	TOYATA	COROLLAWAGON	1988	.	.	A
80	Balt-Exet	B363	1G1JF14T2M7136097	Chevrolet	Cavalier	1991	0	100	A

Table B-1 (Continued)

OBS	SITE	SAMPLE	VIN	MAKE	MODEL	YEAR	TPL	TPH	TR
81	Balt-Exet	B365	JT2AE83E4G3279918	TOYOTA	CAROLLA	1986	.	.	M
82	Balt-Exet	B367	1G2JB6903G7538623	PONTIAC	SUNBIRD	1986	.	.	A
83	Balt-Exet	B368	KMHLF31J3JU420717	HYUNDAI	EXCEL	1988	.	.	A
84	Balt-Exet	B369	JE2AE72SXD2040392	TOYOTA	CAROLLA	1983	.	.	M
85	Balt-Exet	B370	JN1HJ01P7KT248360	Nissan	Maxima	1989	502	3977	A
86	Balt-Exet	B371	1N6ND0650EC332168	nissan	pickup	1984	.	.	A
87	Balt-Exet	B375	2G1AW35X3G1114186	chevrolet	celebritygl	1986	.	.	A
88	Balt-Exet	B376	JN1HB1155CU006220	NISSAN	SENTRA	1982	.	.	M
89	Balt-Exet	B381	1G3H73735G1874913	OLDSMOBILE	88	1986	.	.	A
90	Balt-Exet	B386	JE2AE82E1G3308647	TOYOTA	COROLLA	1986	.	.	A
91	Balt-Exet	B389	JT2TE72W2C5109018	TOYOTA	COROLLA	1982	.	.	A
92	Balt-Exet	B392	2G4WB54T1M1805808	Buick	Regal	1991	0	100	A
93	Balt-Exet	B395	JN1PB1254FU631495	NISSAN	SENTRA	1985	.	.	M
94	Balt-Exet	B406	1G2NE27L1FC748917	PONTIAC	GRANDAM	1985	.	.	A
95	Balt-Exet	B410	JM2UF1135J0369027	MAZDA	b2000	1988	.	.	M
96	Balt-Exet	B413	4J47AAG110524	BUICK	REGAL	1980	.	.	A
97	Balt-Exet	B419	4J47WAG128222	BUICK	REGAL	1980	.	.	A
98	Balt-Exet	B420	1AB08C3DY262608	Chevrolet	Chevette	1983	.	.	A
99	Balt-Exet	B435	JB3CU14XXKU025841	Dodge	Colt	1989	317	2508	M
100	Balt-Exet	B436	4P3CS34TXME109053	PLYMOUTH	LASER	1991	.	.	M
101	Balt-Exet	B438	JT2EL31G0H0069950	TOYOTA	TERCEL	1987	.	.	M
102	Balt-Exet	B441	1G1AB08C5EA125860	CHEVROLET	CHEVET	1984	.	.	A
103	Balt-Exet	B445	JT4YR29G5V5007140	TOYOTA	VAN	1986	.	.	M
104	Balt-Exet	B447	1G4AM69A7CH145805	BUICK	REGAL	1982	.	.	A
105	Balt-Exet	B451	1P3BP36K4HF153374	PLYMOUTH	RELIANTK	1987	.	.	A
106	Balt-Exet	B454	2G4WD14W3K1400883	Buick	Regal	1989	0	100	A
107	Balt-Exet	B460	1FABP46F6D4168830	FORD	THUNDERBIRD	1983	.	.	A
108	Balt-Exet	B467	1HGBA743XGA063308	HONDA	ACCORD	1986	.	.	A
109	Balt-Exet	B468	JT2EL31D5H0075958	toyota	tercel	1987	.	.	M
110	Balt-Exet	B472	1P3BM18C6ED304919	PLYMOUTH	HORIZON	1984	.	.	M
111	Spokane	S002	1GCGK24M8GJ162254	CHEVROLET	SILVERADO20	1986	.	.	A
112	Spokane	S003	JN1HJ01P8LT366371	Nissan	Maxima	1990	533	3977	A
113	Spokane	S004	KMHLA31J8HU121264	hyundai	excelgs	1987	.	.	M
114	Spokane	S006	1G2AF54T9L6235376	Pontiac	6000 LE	1990	0	100	A
115	Spokane	S008	1FAPP36X7JK162901	ford	tempogl	1988	.	.	A
116	Spokane	S011	1G3NT69U9GM372803	olds	calais	1986	.	.	A
117	Spokane	S014	3G4AL54N3LS605881	Buick	Century	1990	0	100	A
118	Spokane	S015	HL41G8B367586	plymouth	volare	1978	.	.	A
119	Spokane	S018	GCFBAD246990	ford	fiesta	1980	.	.	M
120	Spokane	S019	JM1BG2265L0111262	Mazda	Protege	1990	268	1937	A

Table B-1 (Continued)

OBS	SITE	SAMPLE	VIN	MAKE	MODEL	YEAR	TPL	TPH	TR
121	Spokane	S024	JF2KA83A2JD727208	SUBARU	JUSTY4WD	1988	.	.	M
122	Spokane	S027	39128622	cadillac	coupedeville	1969	.	.	A
123	Spokane	S028	1G2HX54C9L1241876	PONTIAC	Bonneville	1990	0	100	A
124	Spokane	S036	JT3FJ62G5J0087906	toyota	landcruiser	1988	.	.	A
125	Spokane	S038	1G4AT27P2EK537437	buick	skylark	1984	.	.	A
126	Spokane	S040	1G3AM54N2L6363462	Oldsmobile	Cutlass	1990	0	100	A
127	Spokane	S041	JT2AE92W1J3141485	toyota	corolla	1988	.	.	M
128	Spokane	S045	1YVGD22B9L5241604	Mazda	626	1990	248	2181	A
129	Spokane	S046	2FTEF14N6GCA49786	ford	f150	1986	.	.	M
130	Spokane	S047	1B3XA463GLF914826	Dodge	Spirit	1990	376	1931	A
131	Spokane	S048	AA0BE8S328524	plymouth	trailduster	1978	.	.	A
132	Spokane	S050	1MEBP89C9EG646134	mercury	marquis	1984	.	.	A
133	Spokane	S051	JM1GD222XL1822669	Mazda	626	1990	246	2185	M
134	Spokane	S053	1FACP52U5LG167445	Ford	Taurus	1990	355	2137	A
135	Spokane	S054	1B7HW14T0GS016645	dodge	rampu	1986	.	.	A
136	Spokane	S055	1J089AA196188	chevrolet	chevet	1980	.	.	M
137	Spokane	S061	JM1BF2227G0145368	mazda	323	1986	.	.	A
138	Spokane	S063	JT2SV21E2L0336391	Toyota	Camry	1990	0	100	A
139	Spokane	S067	1C3BH58E1GN168729	chrysler	labaron	1986	.	.	A
140	Spokane	S069	JM1BF2327J0116975	mazda	323	1988	.	.	M
141	Spokane	S070	JA3CR46V8LZ036160	Mitsubishi	Galant	1990	397	2487	A
142	Spokane	S072	2G2AK37H5E2268581	pontiac	grandprix	1984	.	.	A
143	Spokane	S073	JF2AN55B4GD439011	subaru	gl10	1986	.	.	M
144	Spokane	S078	1C3BA54E0EG237812	chrysler	laser	1984	.	.	A
145	Spokane	S088	JT2AE92E6J3034861	toyota	corolla	1988	.	.	A
146	Spokane	S089	1B4FK44R0LX295520	Dodge	Caravan	1990	338	1927	A
147	Spokane	S090	1GNDL1526LB143279	chevrolet	astro	1990	.	.	A
148	Spokane	S092	1P3XA46K8LF815124	Plymouth	Acclaim	1990	378	1852	A
149	Spokane	S093	2G1WN54T4L9218037	Chevrolet	Lumina	1990	0	100	A
150	Spokane	S094	1G2WK14W3JF252210	pontiac	grandprixle	1988	.	.	A
151	Spokane	S097	2B4FK4530LR632793	Dodge	Caravan	1990	414	1918	A
152	Spokane	S098	1G4CW54C8L1624667	Buick	Park Avenue	1990	0	100	A
153	Spokane	S100	1G1AW19R0G6112876	chevrolet	celebrity	1986	.	.	A
154	Spokane	S103	1G1LV14W9JE673479	chevrolet	beretta	1988	.	.	A
155	Spokane	S105	1FABP0521CW107600	ford	escort	1982	.	.	M
156	Spokane	S107	1B3XA4639LF838812	Dodge	Spirit	1990	395	1904	A
157	Spokane	S109	JT2SV24E2L3411553	Toyota	Camry	1990	0	100	A
158	Spokane	S112	1YVGD31BXL5201264	MAZDA	mx6	1990	.	.	A
159	Spokane	S114	KMHLF21J9HU104162	hyundai	xl	1987	.	.	M
160	Spokane	S117	JT2AE94A4L3346545	toyota	corolla	1990	.	.	A

Table B-1 (Continued)

OBS	SITE	SAMPLE	VIN	MAKE	MODEL	YEAR	TPL	TPH	TR
161	Spokane	S118	1G8CT1881E0141922	chevrolet	blazer	1984	.	.	A
162	Spokane	S119	1N4GB22B6LC764253	Nissan	Sentra	1990	456	4280	M
163	Spokane	S120	JT2SV22E0L3407469	toyota	camry	1990	.	.	A
164	Spokane	S126	1Y15K5467LZ153033	geo	prizm	1990	.	.	A
165	Spokane	S128	1NXAE82G3J2543668	toyota	corolla	1986	.	.	M
166	Spokane	S129	1YVGD22B6LS224064	Mazda	626	1990	245	2175	A
167	Spokane	S131	1MECM5344LG630501	Mercury	Sable	1990	417	2026	A
168	Spokane	S133	1G2NE54D1LC373895	Pontiac	Grand Am	1990	0	100	A
169	Spokane	S134	1HGCA554XJA105600	honda	accord	1988	.	.	M
170	Spokane	S135	JB71M55E2JP049855	dodge	ram50	1988	.	.	M
171	Spokane	S137	1G2PG9793GP263091	pontiac	fiero	1986	.	.	A
172	Spokane	S138	3M69FAR476562	oldsmobile	cutlasbrougham	1980	.	.	A
173	Spokane	S143	JM1BF2321J0174161	MAZDA	323	1988	.	.	M
174	Spokane	S144	1FA8P28A4DF128103	ford	mustang	1984	.	.	M
175	Spokane	S147	JM2VF1133J0354042	mazda	b2200pickup	1988	.	.	M
176	Spokane	S148	2G1WL54T8L1197259	Chevrolet	Lumina	1990	0	100	A
177	Spokane	S156	1ZVPT20C1L5138646	ford	probe	1990	.	.	A
178	Spokane	S158	1B3BA64E3EG128750	dodge	daytona	1984	.	.	A
179	Spokane	S163	1GCEK14L5EJ110666	chevrolet	c10pickup	1984	.	.	A
180	Spokane	S164	1G3HY54C9LH309730	Oldsmobile	88	1990	0	100	A
181	Spokane	S165	1N4GB22B9LC742425	nissan	sentra	1990	.	.	M
182	Spokane	S167	1GCBS14C3G2140458	chevrolet	s10pickup	1990	.	.	A
183	Spokane	S169	JF1AX94241G316659	subaru	xt6	1988	.	.	M
184	Spokane	S172	2B4FK41K2JR589231	dodge	caravan	1988	.	.	A
185	Spokane	S175	JN1P52654EW633444	nissan	200sx	1984	.	.	M
186	Spokane	S176	256690C110112	pontiac	executive	1970	.	.	A
187	Spokane	S177	1G1LW14T8LE150508	Chevrolet	Beretta	1990	0	100	M
188	Spokane	S178	JF1AC43B1JC230491	subaru	gl	1988	.	.	A
189	Spokane	S179	1GCBS14E5G2149162	chevrolet	s10pickup	1986	.	.	M
190	Spokane	S180	JM2UC2217C0554694	mazda	b2000	1982	.	.	M
191	Spokane	S181	3G4A454N7LS609966	Buick	Century	1990	0	100	A
192	Spokane	S184	RA42061277	TOYOTA	CELICA	1978	.	.	A
193	Spokane	S187	1G8CT18R5G8134828	chevrolet	s10blazer	1986	.	.	M
194	Spokane	S194	JM2UF2111G0523195	mazda	b2000	1986	.	.	M
195	Spokane	S197	RN47029466	toyota	sr5pickup	1980	.	.	M
196	Spokane	S200	X1X115A6114134	chevrolet	citation	1980	.	.	M
197	Spokane	S201	1G3HY54C9L1816555	Oldsmobile	88	1990	0	100	A
198	Spokane	S203	1FABP3497GW162154	ford	escort	1986	.	.	M
199	Spokane	S205	JM2UF1119G0634121	mazda	b2000	1986	.	.	M
200	Spokane	S209	17A0987815	volkswagon	rabbit	1980	.	.	M

Table B-1 (Continued)

OBS	SITE	SAMPLE	VIN	MAKE	MODEL	YEAR	TPL	TPH	TR
201	Spokane	S211	JM1BF2228G0153432	mazda	323dx	1986	.	.	M
202	Spokane	S212	1M07VA7159960	chevrolet	monza	1980	.	.	A
203	Spokane	S214	1N6HD114XJC317900	nissan	pickup	1988	.	.	M
204	Spokane	S217	1G2WJ54T3LF263419	Pontiac	Grand Prix	1990	0	100	A
205	Spokane	S218	SMK2089776	honda	accord	1980	.	.	M
206	Spokane	S219	1W27M8K407920	chevrolet	malibuclassic	1978	.	.	A
207	Spokane	S221	1G1AD35P5EJ104025	chevrolet	cavalier	1984	.	.	A
208	Spokane	S222	JMV2F1136K0765114	mazda	b2200	1989	.	.	M
209	Spokane	S224	1FABP64T8JH140673	FORD	THUNDERBIRD	1988	.	.	M
210	Spokane	S227	1FABP40A4JF228320	ford	mustanglx	1988	.	.	M
211	Spokane	S229	JM2VC1218E0824500	mazda	b2000	1984	.	.	M
212	Spokane	S235	2G2AF51R0H9223691	pontiac	6000	1987	.	.	A
213	Spokane	S236	1G1LV14T1LE144679	Chevrolet	Beretta	1990	0	100	A
214	Spokane	S239	1G1JF77W1GJ208794	chevrolet	z24	1986	.	.	M
215	Spokane	S241	1FMDJ1541ELA53608	ford	bronco	1984	.	.	M
216	Spokane	S243	2G1WN54T9L9201394	Chevrolet	Lumina	1990	0	100	A

TABLE OF SP5 BY AC1

SP5 AC1

Percent	-33	-31	-28	-26	-25	-22	-20	-19	-18	-16	-15	-14	-13	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.35
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.15
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.50
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.97
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.17
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.94
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.18
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.38
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.50
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.56
Total	1	1	1	1	1	1	1	1	1	1	2	8	16	6915785
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

(Continued)

TABLE OF SP5 BY AC1

SP5 AC1

Percent	-33	-31	-28	-26	-25	-22	-20	-19	-18	-16	-15	-14	-13	Total
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.96
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.95
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.21
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.51
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	1	1	1	1	1	1	1	1	1	1	2	8	16	6915785
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

(Continued)

TABLE OF SP5 BY AC1

SP5 AC1

Percent	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.12	0.23	0.39	18.54	19.35
5	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.12	0.31	0.54	0.86	1.44	6.15
10	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.12	0.24	0.40	0.50	0.64	1.04	5.50
15	0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.13	0.27	0.43	0.48	0.59	0.98	5.97
20	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.11	0.24	0.41	0.48	0.59	1.00	6.17
25	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.16	0.33	0.45	0.70	1.52	6.94
30	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.08	0.21	0.37	0.87	2.99	9.18
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.10	0.21	0.81	4.72	11.38
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.06	0.10	0.51	3.68	8.50
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.29	1.95	4.56
Total	40	85	174	449	1569	4578	12959	37489	84196	167796	241242	494090	3180831	6915785
	0.00	0.00	0.00	0.01	0.02	0.07	0.19	0.54	1.22	2.43	3.49	7.14	45.99	100.00

(Continued)

TABLE OF SP5 BY AC1

SP5 AC1

Percent	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	Total
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.19	1.30	2.96
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.17	1.41	2.95
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.18	2.18	4.21
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	1.87	3.51
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.98	1.85
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.33	0.66
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.14
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	40	85	174	449	1569	4578	12959	37489	84196	167796	241242	494090	3180831	6915785
	0.00	0.00	0.00	0.01	0.02	0.07	0.19	0.54	1.22	2.43	3.49	7.14	45.99	100.00

(Continued)

TABLE OF SP5 BY AC1

SP5 AC1

Percent	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.35
5	1.73	0.53	0.29	0.18	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.15
10	0.82	0.53	0.39	0.30	0.19	0.13	0.06	0.03	0.02	0.01	0.00	0.00	0.00	5.50
15	0.94	0.76	0.58	0.40	0.20	0.09	0.03	0.01	0.00	0.00	0.01	0.00	0.00	5.97
20	1.01	0.93	0.75	0.41	0.13	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	6.17
25	1.49	1.03	0.69	0.34	0.09	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.94
30	2.75	1.15	0.46	0.19	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	9.18
35	4.19	0.94	0.26	0.07	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.38
40	3.40	0.56	0.11	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.50
45	1.87	0.30	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.56
Total	1698887	514091	251894	136891	51915	22347	7907	3499	1556	628	366	136	57	6915785
	24.57	7.43	3.64	1.98	0.75	0.32	0.11	0.05	0.02	0.01	0.01	0.00	0.00	100.00

(Continued)

TABLE OF SP5 BY AC1

SP5 AC1

Percent	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
50	1.23	0.17	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.96
55	1.20	0.13	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.95
60	1.71	0.11	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.21
65	1.33	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.51
70	0.68	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85
75	0.18	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66
80	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	1698887	514091	251894	136891	51915	22347	7907	3499	1556	628	366	136	57	6915785
	24.57	7.43	3.64	1.98	0.75	0.32	0.11	0.05	0.02	0.01	0.01	0.00	0.00	100.00

(Continued)

TABLE OF SP5 BY AC1

SP5 AC1

Percent	14	15	16	17	18	19	20	26	27	31	32	33	34	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.35
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.15
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.50
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.97
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.17
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.94
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.18
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.38
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.50
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.56
Total	26	16	12	5	6	2	4	1	1	1	1	1	1	6915785
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

(Continued)

TABLE OF SP5 BY AC1

SP5 AC1

Percent	14	15	16	17	18	19	20	26	27	31	32	33	34	Total
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.96
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.95
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.21
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.51
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	26	16	12	5	6	2	4	1	1	1	1	1	1	6915785
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

Frequency Missing = 24626

Table B-3 Speed Frequency Distribution

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	0	0	1348267	19.4634	19.46	80.54
2	0	5	426249	6.1533	25.61	74.39
3	5	10	380510	5.4930	31.10	68.90
4	10	15	412799	5.9591	37.06	62.94
5	15	20	426868	6.1622	43.22	56.78
6	20	25	479650	6.9241	50.14	49.86
7	25	30	635168	9.1692	59.31	40.69
8	30	35	787139	11.3630	70.67	29.33
9	35	40	588185	8.4909	79.16	20.84
10	40	45	315393	4.5530	83.71	16.29
11	45	50	204782	2.9562	86.67	13.33
12	50	55	204206	2.9479	89.62	10.38
13	55	60	291118	4.2025	93.82	6.18
14	60	65	242497	3.5006	97.32	2.68
15	65	70	127742	1.8441	99.16	0.84
16	70	75	45645	0.6589	99.82	0.18
17	75	80	9674	0.1397	99.96	0.04
18	80	85	1175	0.0170	99.98	0.02
19	85	90	128	0.0018	99.98	0.02
20	90	95	11	0.0002	99.98	0.02

Table B-4 Acceleration Frequency Distribution

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	-34	-33	1	0.0000	0.00	100.00
2	-32	-31	1	0.0000	0.00	100.00
3	-29	-28	1	0.0000	0.00	100.00
4	-27	-26	1	0.0000	0.00	100.00
5	-26	-25	1	0.0000	0.00	100.00
6	-23	-22	1	0.0000	0.00	100.00
7	-21	-20	1	0.0000	0.00	100.00
8	-20	-19	1	0.0000	0.00	100.00
9	-19	-18	1	0.0000	0.00	100.00
10	-17	-16	1	0.0000	0.00	100.00
11	-16	-15	2	0.0000	0.00	100.00
12	-15	-14	8	0.0001	0.00	100.00
13	-14	-13	16	0.0002	0.00	100.00
14	-13	-12	40	0.0006	0.00	100.00
15	-12	-11	85	0.0012	0.00	100.00
16	-11	-10	174	0.0025	0.00	100.00
17	-10	-9	449	0.0065	0.01	99.99
18	-9	-8	1569	0.0227	0.03	99.97
19	-8	-7	4578	0.0662	0.10	99.90
20	-7	-6	12959	0.1874	0.29	99.71
21	-6	-5	37489	0.5421	0.83	99.17
22	-5	-4	84196	1.2174	2.05	97.95
23	-4	-3	167796	2.4263	4.48	95.52
24	-3	-2	241242	3.4883	7.97	92.03
25	-2	-1	494090	7.1444	15.11	84.89
26	-1	0	3180831	45.9938	61.10	38.90
27	0	1	1698887	24.5654	85.67	14.33
28	1	2	514091	7.4336	93.10	6.90
29	2	3	251894	3.6423	96.74	3.26
30	3	4	136891	1.9794	98.72	1.28
31	4	5	51915	0.7507	99.47	0.53
32	5	6	22347	0.3231	99.79	0.21
33	6	7	7907	0.1143	99.90	0.10
34	7	8	3499	0.0506	99.95	0.05
35	8	9	1556	0.0225	99.97	0.03
36	9	10	628	0.0091	99.98	0.02
37	10	11	366	0.0053	99.99	0.01
38	11	12	136	0.0020	99.99	0.01
39	12	13	57	0.0008	99.99	0.01
40	13	14	26	0.0004	99.99	0.01

Table B-4 (Continued) Acceleration Frequency Distribution

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
41	14	15	16	.00023135	99.99	0.01
42	15	16	12	.00017352	99.99	0.01
43	16	17	5	.00007230	99.99	0.01
44	17	18	6	.00008676	99.99	0.01
45	18	19	2	.00002892	99.99	0.01
46	19	20	4	.00005784	99.99	0.01
47	25	26	1	.00001446	99.99	0.01
48	26	27	1	.00001446	99.99	0.01
49	30	31	1	.00001446	99.99	0.01
50	31	32	1	.00001446	99.99	0.01
51	32	33	1	.00001446	99.99	0.01
52	33	34	1	.00001446	99.99	0.01

Table B-5 Power Frequency Distribution

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	0	20	914113	33.9787	33.98	66.02
2	20	40	549123	20.4116	54.39	45.61
3	40	60	400522	14.8879	69.28	30.72
4	60	80	291349	10.8298	80.11	19.89
5	80	100	190744	7.0902	87.20	12.80
6	100	120	125479	4.6642	91.86	8.14
7	120	140	80238	2.9825	94.84	5.16
8	140	160	48698	1.8102	96.65	3.35
9	160	180	27911	1.0375	97.69	2.31
10	180	200	17295	0.6429	98.33	1.67
11	200	220	14588	0.5423	98.87	1.13
12	220	240	13465	0.5005	99.37	0.63
13	240	260	6413	0.2384	99.61	0.39
14	260	280	4461	0.1658	99.78	0.22
15	280	300	1954	0.0726	99.85	0.15
16	300	320	1033	0.0384	99.89	0.11
17	320	340	850	0.0316	99.92	0.08
18	340	360	588	0.0219	99.94	0.06
19	360	380	393	0.0146	99.95	0.05
20	380	400	307	0.0114	99.96	0.04
21	400	420	156	0.0058	99.97	0.03
22	420	440	104	0.0039	99.97	0.03
23	440	460	176	0.0065	99.98	0.02
24	460	480	114	0.0042	99.98	0.02
25	480	500	56	0.0021	99.98	0.02
26	500	520	48	0.0018	99.98	0.02
27	520	540	22	0.0008	99.98	0.02
28	540	560	15	0.0006	99.98	0.02
29	560	580	6	0.0002	99.98	0.02
30	580	600	10	0.0004	99.98	0.02
31	600	620	7	0.0003	99.98	0.02
32	620	640	4	0.0001	99.98	0.02
33	640	660	1	0.0000	99.98	0.02
34	660	680	1	0.0000	99.98	0.02
35	700	720	1	0.0000	99.98	0.02
36	880	900	1	0.0000	99.98	0.02
37	1420	1440	1	0.0000	99.98	0.02
38	1580	1600	1	0.0000	99.98	0.02
39	2700	2720	1	0.0000	99.98	0.02
40	2720	2740	1	0.0000	99.98	0.02

Table B-5 (Continued) Power Frequency Distribution

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
41	2860	2880	1	.000037171	99.98	0.02

Figure B-6

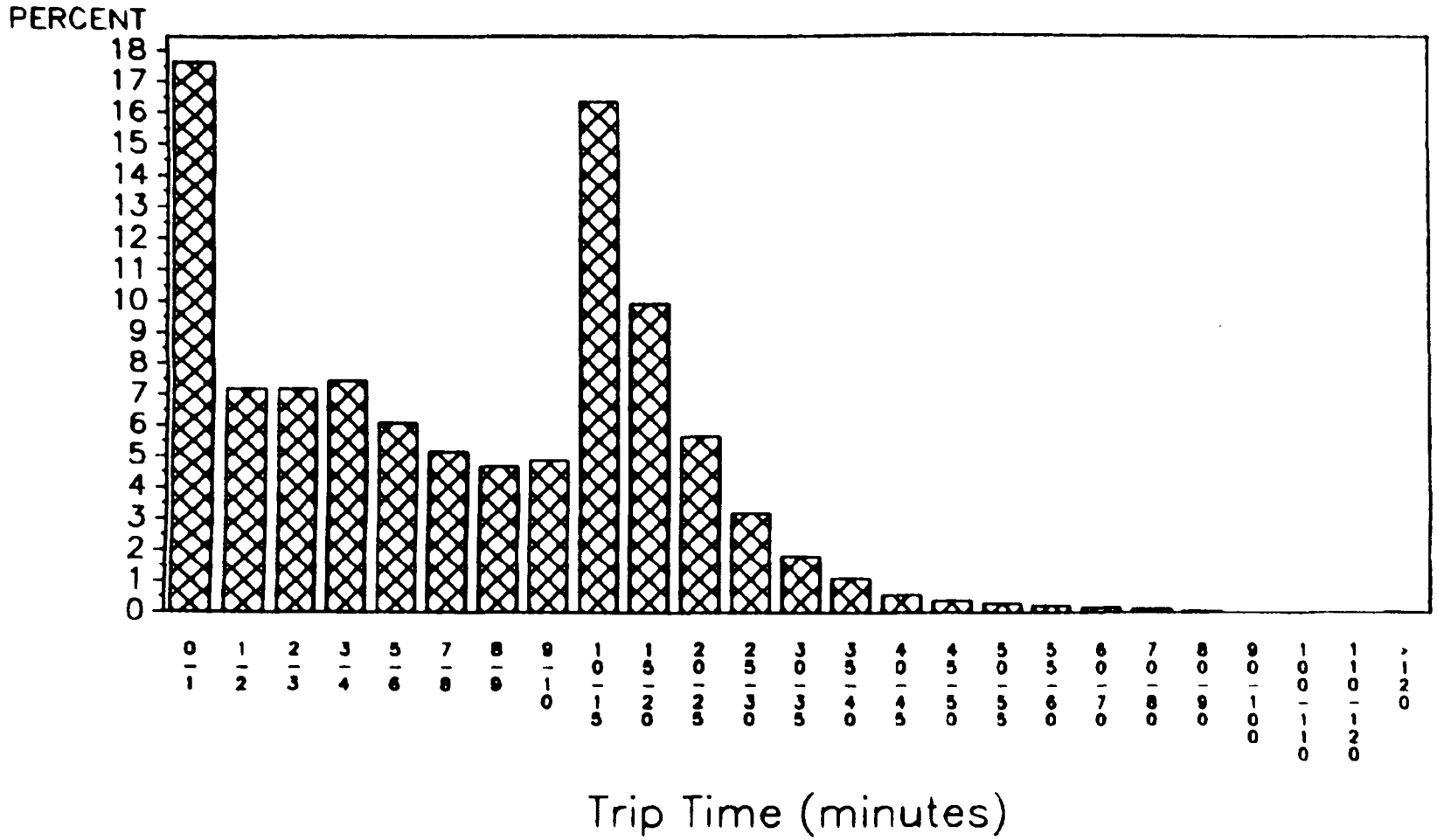

PERCENT
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0-1
1-2
2-3
3-4
5-6
7-8
8-9
9-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-70
70-80
80-90
90-100
100-110
110-120
>120
Trip Time (minutes)

Table B-7 Distribution of Trip Time

CTTLIN	Frequency	Percent	Cumulative Frequency	Cumulative Percent	Decumulative Percent
0-1	1879	15.6	1879	15.6%	84.4%
1-2	766	6.3	2645	21.9%	78.1%
2-3	764	6.3	3409	28.2%	71.8%
3-4	794	6.6	4203	34.8%	65.2%
4-5	769	6.4	4972	41.2%	58.8%
5-6	648	5.4	5620	46.6%	53.4%
6-7	634	5.3	6254	51.8%	48.2%
7-8	550	4.6	6804	56.4%	43.6%
8-9	497	4.1	7301	60.5%	39.5%
9-10	519	4.3	7820	64.8%	35.2%
10-15	1742	14.4	9562	79.2%	20.8%
15-20	1056	8.7	10618	87.9%	12.1%
20-25	602	5	11220	92.9%	7.1%
25-30	339	2.8	11559	95.7%	4.3%
30-35	192	1.6	11751	97.3%	2.7%
35-40	116	1	11867	98.3%	1.7%
40-45	58	0.5	11925	98.8%	1.2%
45-50	40	0.3	11965	99.1%	0.9%
50-55	30	0.2	11995	99.4%	0.6%
55-60	24	0.2	12019	99.6%	0.4%
60-70	18	0.1	12037	99.7%	0.3%
70-80	14	0.1	12051	99.8%	0.2%
80-90	7	0.1	12058	99.9%	0.1%
90-100	3	0	12061	99.9%	0.1%
100-110	2	0	12063	99.9%	0.1%
110-120	4	0	12067	100.0%	0.0%
>120	6	0	12073	100.0%	0.0%

Table B-8 Trip Time Classes (Minutes)

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	0.200	0.252	1230	10.1880	10.19	89.81
2	0.252	0.317	61	0.5053	10.70	89.30
3	0.317	0.399	58	0.4804	11.18	88.82
4	0.399	0.502	113	0.9360	12.12	87.88
5	0.502	0.632	114	0.9443	13.06	86.94
6	0.632	0.796	136	1.1265	14.19	85.81
7	0.796	1.002	167	1.3833	15.57	84.43
8	1.002	1.262	191	1.5820	17.15	82.85
9	1.262	1.589	239	1.9796	19.13	80.87
10	1.589	2.000	336	2.7831	21.91	78.09
11	2.000	2.518	387	3.2055	25.12	74.88
12	2.518	3.170	525	4.3485	29.47	70.53
13	3.170	3.991	635	5.2597	34.73	65.27
14	3.991	5.024	786	6.5104	41.24	58.76
15	5.024	6.325	853	7.0654	48.31	51.69
16	6.325	7.962	951	7.8771	56.19	43.81
17	7.962	10.024	1044	8.6474	64.84	35.16
18	10.024	12.619	1036	8.5811	73.42	26.58
19	12.619	15.887	929	7.6949	81.11	18.89
20	15.887	20.000	827	6.8500	87.96	12.04
21	20.000	25.179	613	5.0774	93.04	6.96
22	25.179	31.698	405	3.3546	96.39	3.61
23	31.698	39.905	230	1.9051	98.30	1.70
24	39.905	50.238	101	0.8366	99.14	0.86
25	50.238	63.246	58	0.4804	99.62	0.38
26	63.246	79.621	26	0.2154	99.84	0.16
27	79.621	100.237	10	0.0828	99.92	0.08
28	100.237	126.191	7	0.0580	99.98	0.02
29	126.191	158.866	3	0.0248	100.00	0.00
30	158.866	200.000	2	0.0166	100.02	-0.02

Figure B-9

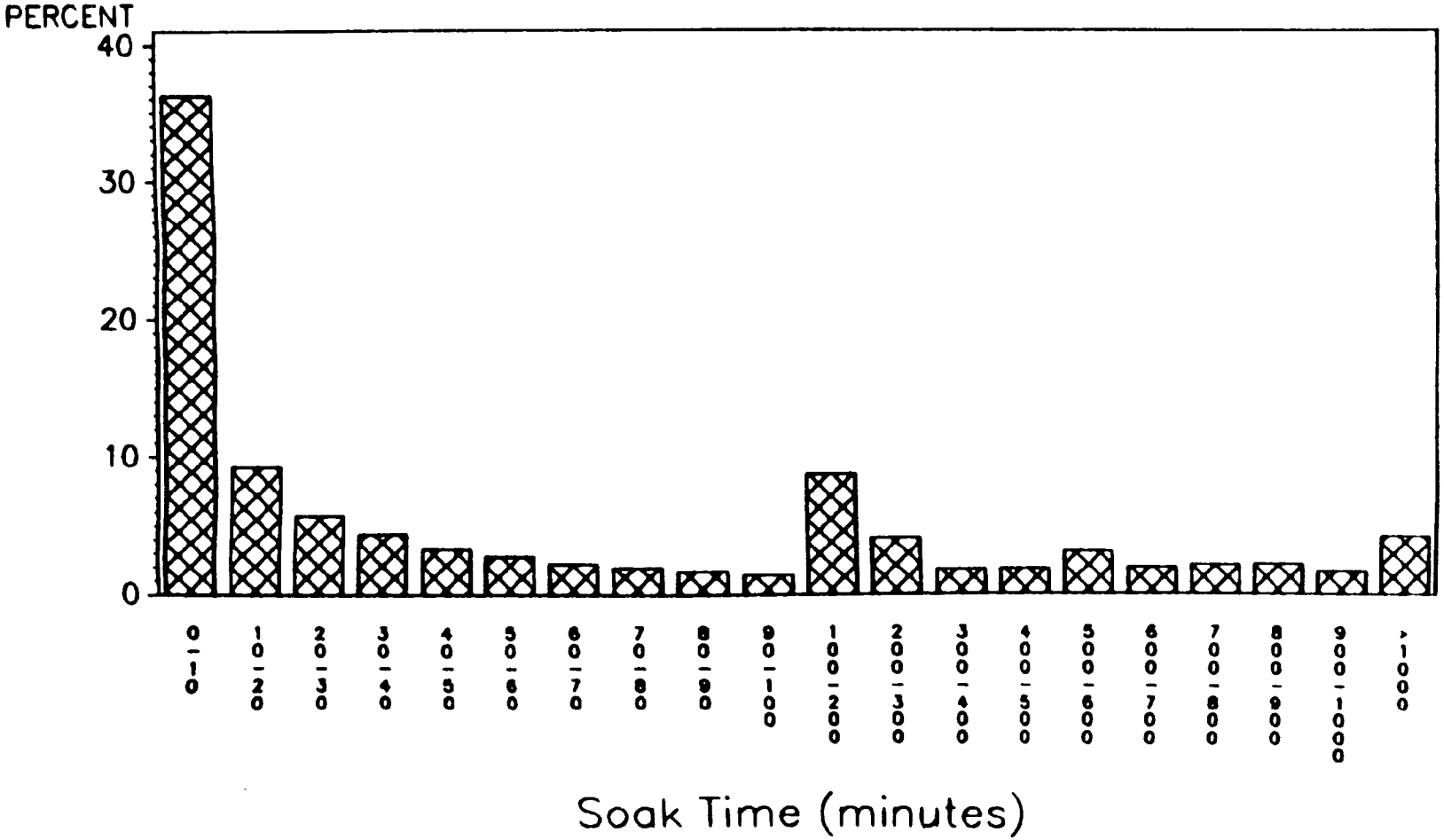

PERCENT
40
30
20
10
0
0-10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90-100
100-200
200-300
300-400
400-500
500-600
600-700
700-800
800-900
900-1000
>1000
Soak Time (minutes)

Table B-10 *Distribution of Soak Time*

CSTLIN	Frequency	Percent	Cumulative Frequency	Cumulative Percent	Decumulative Percent
0-10	4294	35.6	4294	36.2%	63.8%
10-20	1093	9.1	5387	45.4%	54.6%
20-30	677	5.6	6064	51.1%	48.9%
30-40	518	4.3	6582	55.5%	44.5%
40-50	385	3.2	6967	58.8%	41.2%
50-60	321	2.7	7288	61.5%	38.5%
60-70	259	2.1	7547	63.7%	36.3%
70-80	224	1.9	7771	65.5%	34.5%
80-90	189	1.6	7960	67.1%	32.9%
90-100	159	1.3	8119	68.5%	31.5%
100-200	1033	8.6	9152	77.2%	22.8%
200-300	484	4	9636	81.3%	18.7%
300-400	207	1.7	9843	83.0%	17.0%
400-500	212	1.8	10055	84.8%	15.2%
500-600	364	3	10419	87.9%	12.1%
600-700	228	1.9	10647	89.8%	10.2%
700-800	252	2.1	10899	91.9%	8.1%
800-900	256	2.1	11155	94.1%	5.9%
900-1000	195	1.6	11350	95.7%	4.3%
>1000	507	4.2	11857	100.0%	0.0%

Table B-11 Soak time (Minutes) Classes

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	0.10	0.16	708	5.97116	5.97	94.03
2	0.16	0.25	47	0.39639	6.37	93.63
3	0.25	0.40	570	4.80729	11.18	88.82
4	0.40	0.63	58	0.48916	11.67	88.33
5	0.63	1.00	101	0.85182	12.52	87.48
6	1.00	1.59	231	1.94822	14.47	85.53
7	1.59	2.51	440	3.71089	18.18	81.82
8	2.51	3.98	683	5.76031	23.94	76.06
9	3.98	6.31	694	5.85308	29.79	70.21
10	6.31	10.00	762	6.42658	36.22	63.78
11	10.00	15.85	724	6.10610	42.33	57.67
12	15.85	25.12	769	6.48562	48.82	51.18
13	25.12	39.81	780	6.57839	55.40	44.60
14	39.81	63.10	801	6.75550	62.16	37.84
15	63.10	100.00	751	6.33381	68.49	31.51
16	100.00	158.49	702	5.92055	74.41	25.59
17	158.49	251.19	609	5.13621	79.55	20.45
18	251.19	398.11	410	3.45787	83.01	16.99
19	398.11	630.96	659	5.55790	88.57	11.43
20	630.96	1000.00	851	7.17719	95.75	4.25
21	1000.00	1584.89	393	3.31450	99.06	0.94
22	1584.89	2511.89	56	0.47229	99.53	0.47
23	2511.89	3981.07	44	0.37109	99.90	0.10
24	3981.07	6309.57	13	0.10964	100.01	-0.01
25	6309.57	10000.00	1	0.00843	100.02	-0.02

Figure B-12

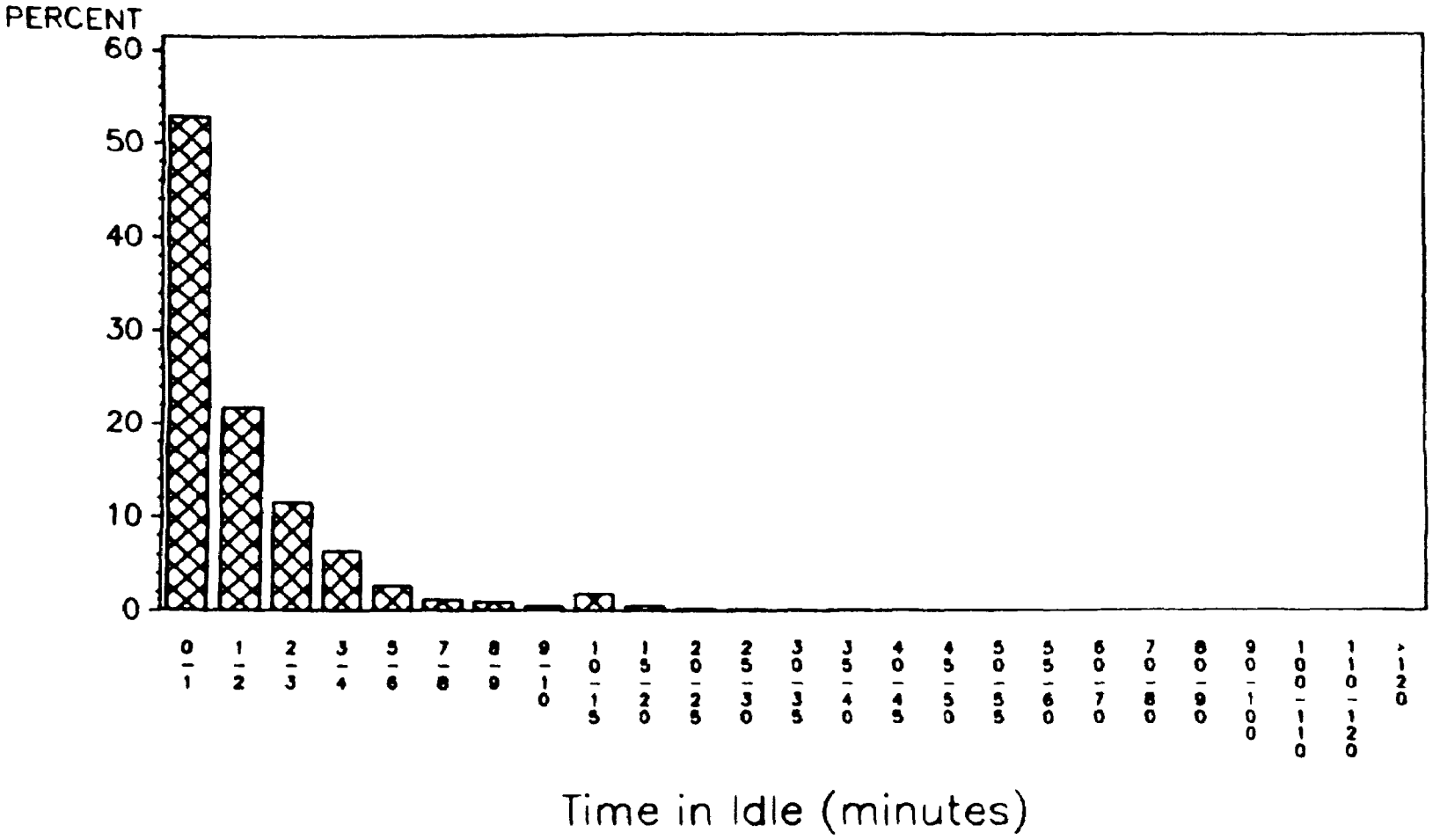

PERCENT
60
50
40
30
20
10
0
0-1
1-2
2-3
3-4
5-6
7-8
8-9
9-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-70
70-80
80-90
90-100
100-110
110-120
>120
Time in Idle (minutes)

Table B-13 Distribution of Idle Time

CITLIN	Frequency	Percent	Cumulative Frequency	Cumulative Percent	Decumulative Percent
0	47	0.4	47	0.4%	99.6%
0-1	5741	47.6	5788	50.2%	49.8%
1-2	2361	19.6	8149	70.7%	29.3%
2-3	1246	10.3	9395	81.5%	18.5%
3-4	692	5.7	10087	87.5%	12.5%
4-5	425	3.5	10512	91.2%	8.8%
5-6	291	2.4	10803	93.7%	6.3%
6-7	176	1.5	10979	95.2%	4.8%
7-8	122	1	11101	96.3%	3.7%
8-9	98	0.8	11199	97.1%	2.9%
9-10	54	0.4	11253	97.6%	2.4%
10-15	192	1.6	11445	99.2%	0.8%
15-20	52	0.4	11497	99.7%	0.3%
20-25	14	0.1	11511	99.8%	0.2%
25-30	7	0.1	11518	99.9%	0.1%
30-35	2	0	11520	99.9%	0.1%
35-40	5	0	11525	99.9%	0.1%
40-45	1	0	11526	99.9%	0.1%
45-50	1	0	11527	100.0%	0.0%
50-55	1	0	11528	100.0%	0.0%
>55	4	0	11532	100.0%	0.0%

Table B-14 Time in Idle (Minutes) Classes

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	0.040	0.050	848	7.38354	7.38	92.62
2	0.050	0.063	.	0.00000	7.38	92.62
3	0.063	0.080	116	1.01001	8.39	91.61
4	0.080	0.100	402	3.50022	11.89	88.11
5	0.100	0.126	145	1.26252	13.15	86.85
6	0.126	0.159	255	2.22029	15.37	84.63
7	0.159	0.200	374	3.25642	18.63	81.37
8	0.200	0.252	314	2.73400	21.36	78.64
9	0.252	0.318	407	3.54375	24.90	75.10
10	0.318	0.400	466	4.05747	28.96	71.04
11	0.400	0.504	477	4.15324	33.11	66.89
12	0.504	0.634	579	5.04136	38.15	61.85
13	0.634	0.798	606	5.27645	43.43	56.57
14	0.798	1.005	754	6.56508	50.00	50.00
15	1.005	1.265	790	6.87854	56.88	43.12
16	1.265	1.592	751	6.53896	63.42	36.58
17	1.592	2.005	820	7.13975	70.56	29.44
18	2.005	2.524	749	6.52155	77.08	22.92
19	2.524	3.177	651	5.66826	82.75	17.25
20	3.177	4.000	539	4.69308	87.44	12.56
21	4.000	5.036	434	3.77884	91.22	8.78
22	5.036	6.340	346	3.01263	94.23	5.77
23	6.340	7.981	234	2.03744	96.27	3.73
24	7.981	10.048	156	1.35829	97.63	2.37
25	10.048	12.649	130	1.13191	98.76	1.24
26	12.649	15.924	69	0.60078	99.36	0.64
27	15.924	20.047	42	0.36569	99.73	0.27
28	20.047	25.238	14	0.12190	99.85	0.15
29	25.238	31.773	7	0.06095	99.91	0.09
30	31.773	40.000	10	0.08707	100.00	0.00

Figure B-15

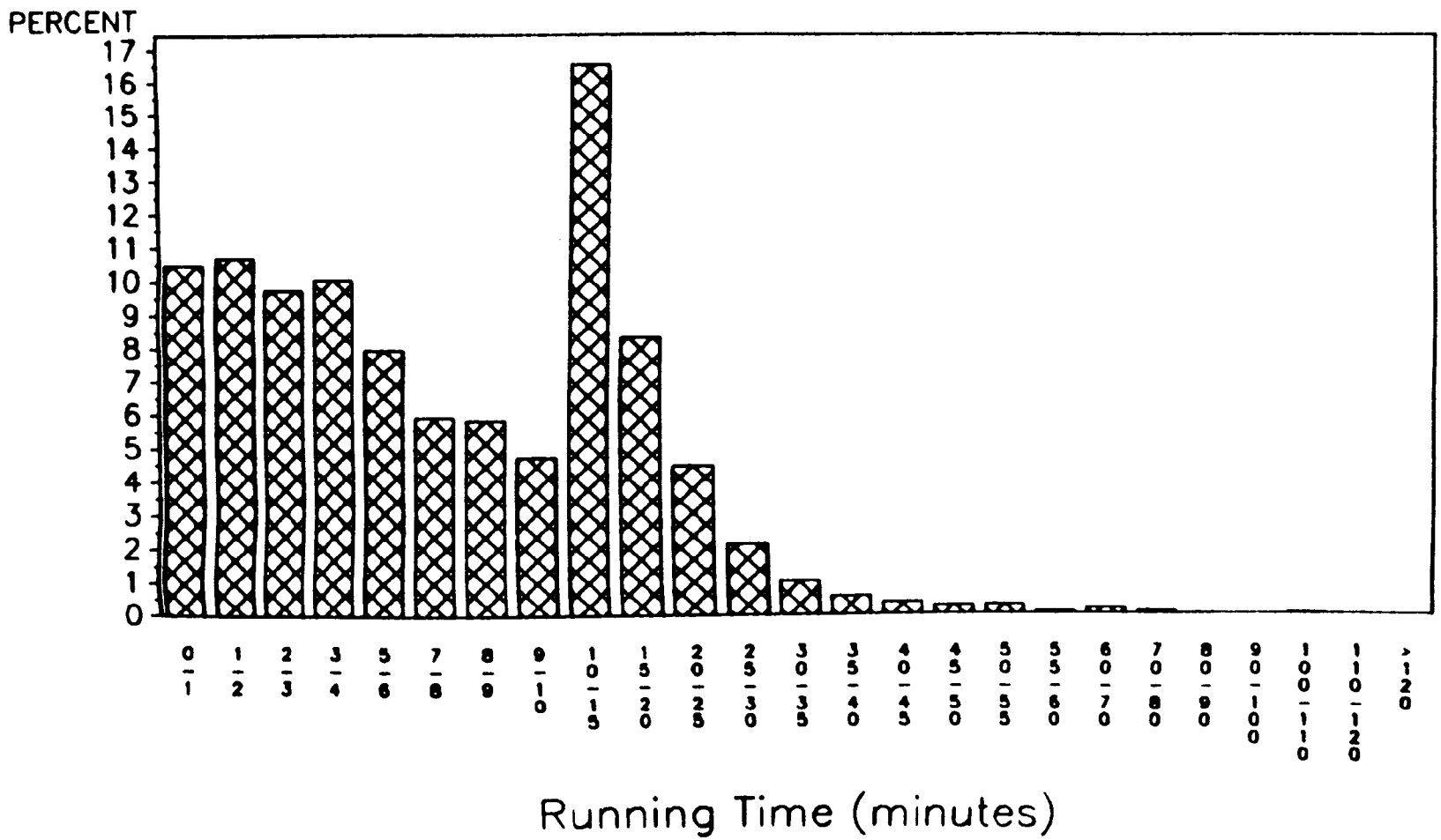

PERCENT
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0-1
1-2
2-3
3-4
5-6
7-8
8-9
9-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-70
70-80
80-90
90-100
100-110
110-120
>120
Running Time (minutes)

Table B-16 Distribution of Running Time

CRTLIN	Frequency	Percent	Cumulative Frequency	Cumulative Percent	Decumulative Percent
0	715	5.9	715	6.2%	93.8%
0-1	983	8.1	1698	14.7%	85.3%
1-2	1004	8.3	2702	23.4%	76.6%
2-3	917	7.6	3619	31.4%	68.6%
3-4	945	7.8	4564	39.6%	60.4%
4-5	775	6.4	5339	46.3%	53.7%
5-6	750	6.2	6089	52.8%	47.2%
6-7	643	5.3	6732	58.4%	41.6%
7-8	560	4.6	7292	63.3%	36.7%
8-9	551	4.6	7843	68.0%	32.0%
9-10	447	3.7	8290	71.9%	28.1%
10-15	1551	12.9	9841	85.4%	14.6%
15-20	784	6.5	10625	92.2%	7.8%
20-25	423	3.5	11048	95.8%	4.2%
25-30	203	1.7	11251	97.6%	2.4%
30-35	96	0.8	11347	98.4%	1.6%
35-40	52	0.4	11399	98.9%	1.1%
40-45	34	0.3	11433	99.2%	0.8%
45-50	24	0.2	11457	99.4%	0.6%
50-55	26	0.2	11483	99.6%	0.4%
55-60	7	0.1	11490	99.7%	0.3%
60-70	18	0.1	11508	99.8%	0.2%
70-80	9	0.1	11517	99.9%	0.1%
80-90	3	0	11520	99.9%	0.1%
90-100	1	0	11521	99.9%	0.1%
100-110	5	0	11526	100.0%	0.0%
110-120	2	0	11528	100.0%	0.0%

Table B-17 Time in Running (Minutes) Classes

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	0.200	0.252	329	3.04151	3.04	96.96
2	0.252	0.317	71	0.65637	3.70	96.30
3	0.317	0.399	70	0.64713	4.35	95.65
4	0.399	0.502	122	1.12785	5.48	94.52
5	0.502	0.632	109	1.00767	6.49	93.51
6	0.632	0.796	125	1.15559	7.65	92.35
7	0.796	1.002	157	1.45142	9.10	90.90
8	1.002	1.262	240	2.21873	11.32	88.68
9	1.262	1.589	339	3.13396	14.45	85.55
10	1.589	2.000	425	3.92900	18.38	81.62
11	2.000	2.518	481	4.44670	22.83	77.17
12	2.518	3.170	585	5.40815	28.24	71.76
13	3.170	3.991	777	7.18314	35.42	64.58
14	3.991	5.024	807	7.46048	42.88	57.12
15	5.024	6.325	951	8.79172	51.67	48.33
16	6.325	7.962	963	8.90265	60.57	39.43
17	7.962	10.024	1030	9.52205	70.09	29.91
18	10.024	12.619	932	8.61607	78.71	21.29
19	12.619	15.887	789	7.29407	86.00	14.00
20	15.887	20.000	608	5.62078	91.62	8.38
21	20.000	25.179	432	3.99371	95.61	4.39
22	25.179	31.698	239	2.20949	97.82	2.18
23	31.698	39.905	102	0.94296	98.76	1.24
24	39.905	50.238	60	0.55468	99.31	0.69
25	50.238	63.246	39	0.36054	99.67	0.33
26	63.246	79.621	20	0.18489	99.85	0.15
27	79.621	100.237	4	0.03698	99.89	0.11
28	100.237	126.191	7	0.06471	99.95	0.05
29	126.191	158.866	2	0.01849	99.97	0.03
30	158.866	200.000	2	0.01849	99.99	0.01

Figure B-18

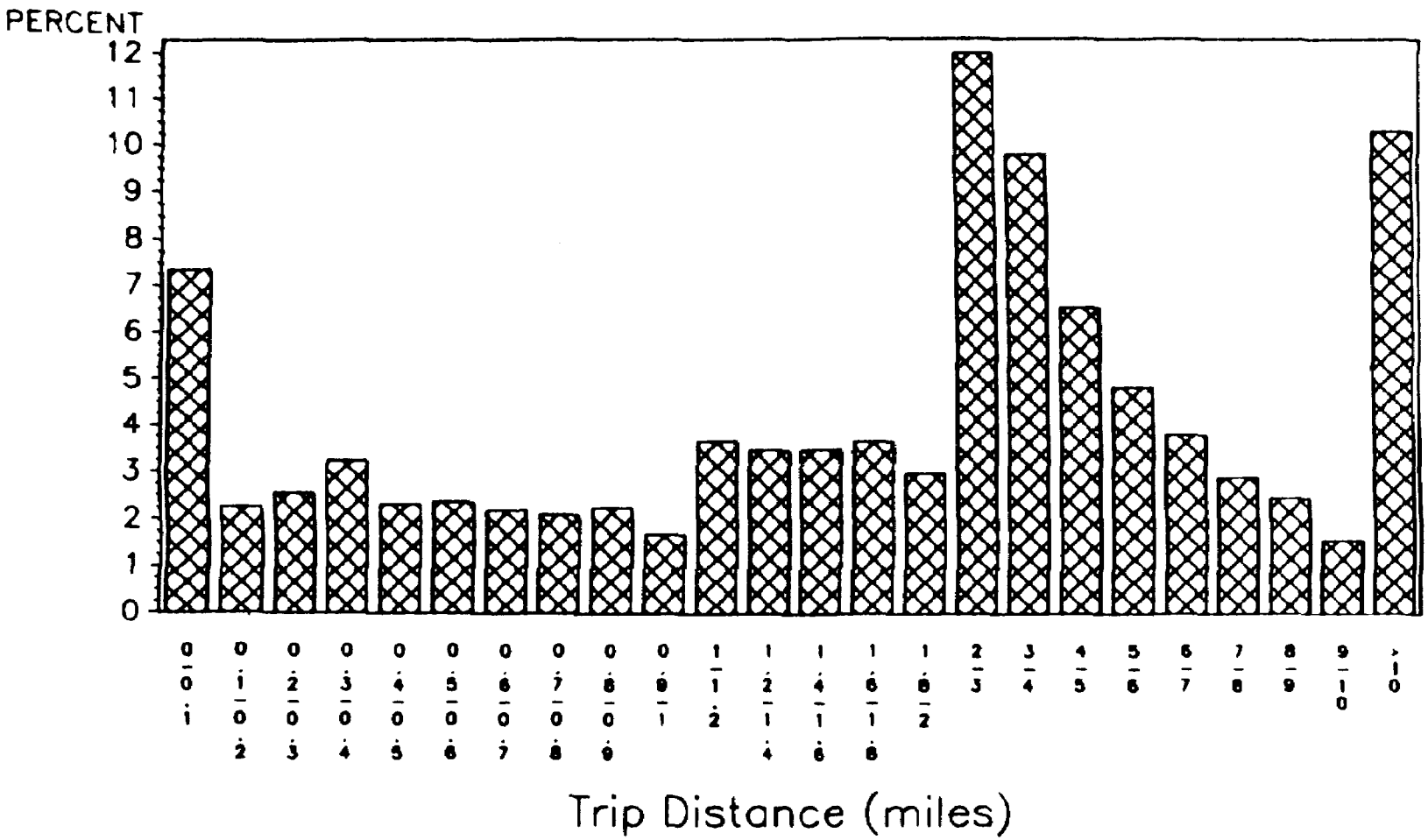

PERCENT
12
11
10
9
8
7
6
5
4
3
2
1
0
0-.01
.01-.02
.02-.03
.03-.04
.04-.05
.05-.06
.06-.07
.07-.08
.08-.09
.09-.1
.1-.2
.2-.4
.4-.6
.6-.8
.8-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10
>10
Trip Distance (miles)

Table B-19 Distribution of Trip Distance

CDSLIN	Frequency	Percent	Cumulative Frequency	Cumulative Percent	Decumulative Percent
0	1256	10.4	1256	10.4%	89.6%
0-0.1	794	6.6	2050	17.0%	83.0%
0.1-0.2	246	2	2296	19.0%	81.0%
0.2-0.3	277	2.3	2573	21.3%	78.7%
0.3-0.4	351	2.9	2924	24.2%	75.8%
0.4-0.5	253	2.1	3177	26.3%	73.7%
0.5-0.6	258	2.1	3435	28.5%	71.5%
0.6-0.7	239	2	3674	30.4%	69.6%
0.7-0.8	229	1.9	3903	32.3%	67.7%
0.8-0.9	246	2	4149	34.4%	65.6%
0.9-1	184	1.5	4333	35.9%	64.1%
1-1.2	397	3.3	4730	39.2%	60.8%
1.2-1.4	378	3.1	5108	42.3%	57.7%
1.4-1.6	379	3.1	5487	45.4%	54.6%
1.6-1.8	397	3.3	5884	48.7%	51.3%
1.8-2	325	2.7	6209	51.4%	48.6%
2-3	1296	10.7	7505	62.2%	37.8%
3-4	1058	8.8	8563	70.9%	29.1%
4-5	707	5.9	9270	76.8%	23.2%
5-6	523	4.3	9793	81.1%	18.9%
6-7	413	3.4	10206	84.5%	15.5%
7-8	315	2.6	10521	87.1%	12.9%
8-9	268	2.2	10789	89.4%	10.6%
9-10	171	1.4	10960	90.8%	9.2%
>10	1113	9.2	12073	100.0%	0.0%

Table B-20 Trip Distance (miles) Classes

00:15 Tuesday, August 11, 1992 1118

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	0.010	0.013	312	2.88435	2.88	97.12
2	0.013	0.016	35	0.32356	3.20	96.80
3	0.016	0.020	51	0.47148	3.67	96.33
4	0.020	0.025	34	0.31432	3.98	96.02
5	0.025	0.032	57	0.52695	4.51	95.49
6	0.032	0.040	59	0.54544	5.06	94.94
7	0.040	0.050	60	0.55468	5.61	94.39
8	0.050	0.063	58	0.53619	6.15	93.85
9	0.063	0.079	65	0.60091	6.75	93.25
10	0.079	0.100	63	0.58242	7.33	92.67
11	0.100	0.126	88	0.81353	8.14	91.86
12	0.126	0.158	67	0.61940	8.76	91.24
13	0.158	0.200	88	0.81353	9.57	90.43
14	0.200	0.251	140	1.29426	10.86	89.14
15	0.251	0.316	199	1.83970	12.70	87.30
16	0.316	0.398	287	2.65323	15.35	84.65
17	0.398	0.501	261	2.41287	17.76	82.24
18	0.501	0.631	332	3.06924	20.83	79.17
19	0.631	0.794	376	3.47601	24.31	75.69
20	0.794	1.000	445	4.11389	28.42	71.58
21	1.000	1.259	498	4.60386	33.02	66.98
22	1.259	1.585	628	5.80568	38.83	61.17
23	1.585	1.995	736	6.80410	45.63	54.37
24	1.995	2.512	696	6.43432	52.06	47.94
25	2.512	3.162	823	7.60839	59.67	40.33
26	3.162	3.981	828	7.65462	67.32	32.68
27	3.981	5.012	734	6.78562	74.11	25.89
28	5.012	6.310	662	6.12000	80.23	19.77
29	6.310	7.943	567	5.24175	85.47	14.53
30	7.943	10.000	455	4.20634	89.68	10.32
31	10.000	12.589	368	3.40205	93.08	6.92
32	12.589	15.849	288	2.66248	95.74	4.26
33	15.849	19.953	145	1.34048	97.08	2.92
34	19.953	25.119	144	1.33124	98.41	1.59
35	25.119	31.623	60	0.55468	98.96	1.04
36	31.623	39.811	32	0.29583	99.26	0.74
37	39.811	50.119	35	0.32356	99.58	0.42
38	50.119	63.096	15	0.13867	99.72	0.28
39	63.096	79.433	13	0.12018	99.84	0.16
40	79.433	100.000	13	0.12018	99.96	0.04

Figure B-21

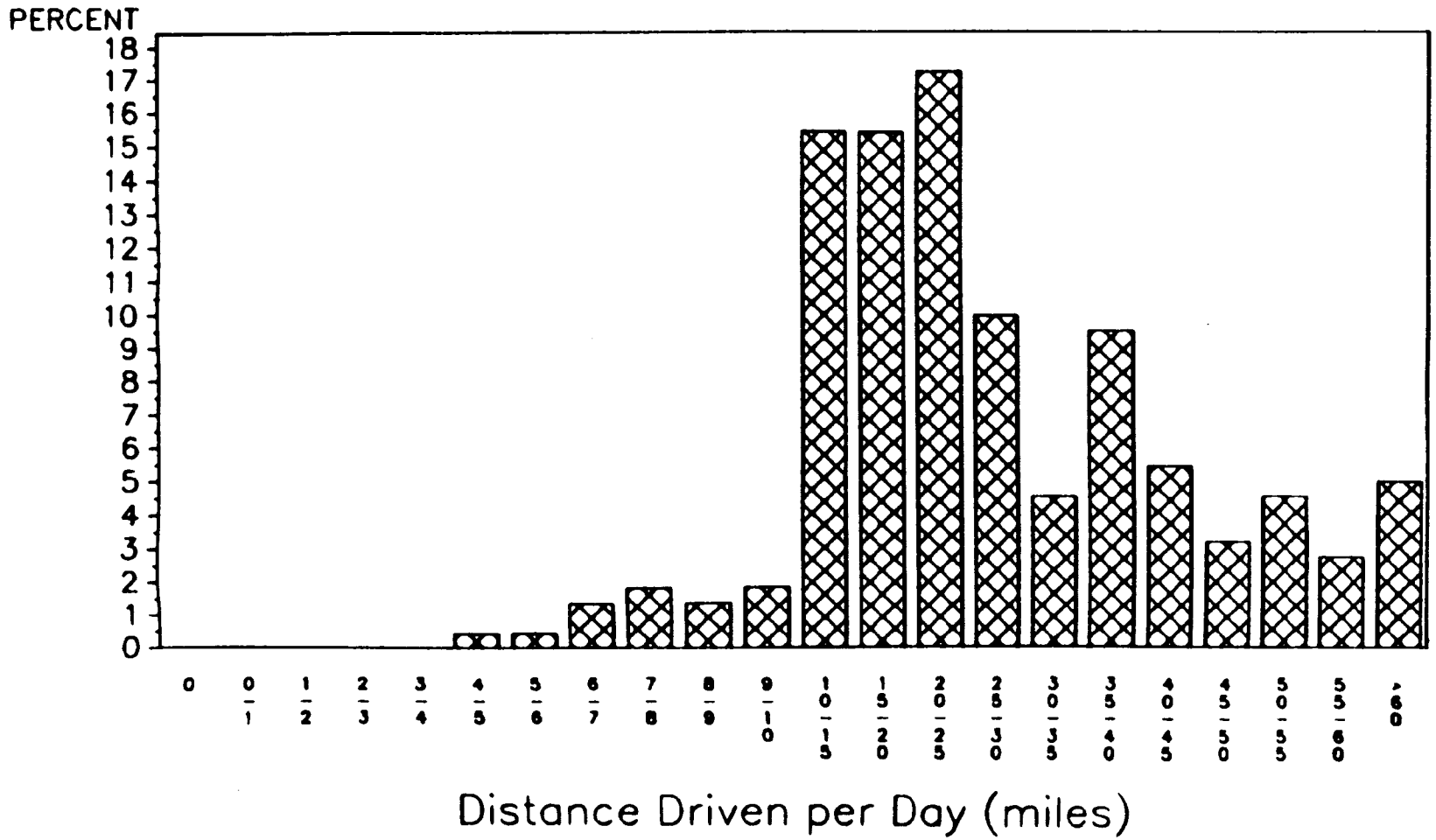

PERCENT
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
0-1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
>60
Distance Driven per Day (miles)

Table B-22 Distance Driven per Day (miles)

CTDLIN	Frequency	Percent	Cumulative Frequency	Cumulative Percent	Decumulative Percent
4-5	1	0.5	1	0.5%	99.5%
5-6	1	0.5	2	0.9%	99.1%
6-7	3	1.4	5	2.3%	97.7%
7-8	4	1.9	9	4.2%	95.8%
8-9	3	1.4	12	5.6%	94.4%
9-10	4	1.9	16	7.4%	92.6%
10-15	34	15.7	50	23.1%	76.9%
15-20	34	15.7	84	38.9%	61.1%
20-25	38	17.6	122	56.5%	43.5%
25-30	21	9.7	143	66.2%	33.8%
30-35	10	4.6	153	70.8%	29.2%
35-40	21	9.7	174	80.6%	19.4%
40-45	11	5.1	185	85.6%	14.4%
45-50	7	3.2	192	88.9%	11.1%
50-55	10	4.6	202	93.5%	6.5%
55-60	6	2.8	208	96.3%	3.7%
>60	8	3.7	216	100.0%	0.0%

Table B-23 Distance Driven per Day (miles)

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	0.100	0.126	.	0.0000	0.00	100.00
2	0.126	0.158	.	0.0000	0.00	100.00
3	0.158	0.200	.	0.0000	0.00	100.00
4	0.200	0.251	.	0.0000	0.00	100.00
5	0.251	0.316	.	0.0000	0.00	100.00
6	0.316	0.398	.	0.0000	0.00	100.00
7	0.398	0.501	.	0.0000	0.00	100.00
8	0.501	0.631	.	0.0000	0.00	100.00
9	0.631	0.794	.	0.0000	0.00	100.00
10	0.794	1.000	.	0.0000	0.00	100.00
11	1.000	1.259	.	0.0000	0.00	100.00
12	1.259	1.585	.	0.0000	0.00	100.00
13	1.585	1.995	.	0.0000	0.00	100.00
14	1.995	2.512	.	0.0000	0.00	100.00
15	2.512	3.162	.	0.0000	0.00	100.00
16	3.162	3.981	.	0.0000	0.00	100.00
17	3.981	5.012	1	0.4630	0.46	99.54
18	5.012	6.310	1	0.4630	0.92	99.08
19	6.310	7.943	7	3.2407	4.16	95.84
20	7.943	10.000	7	3.2407	7.40	92.60
21	10.000	12.589	18	8.3333	15.73	84.27
22	12.589	15.849	23	10.6481	26.38	73.62
23	15.849	19.953	27	12.5000	38.88	61.12
24	19.953	25.119	40	18.5185	57.40	42.60
25	25.119	31.623	20	9.2593	66.66	33.34
26	31.623	39.811	29	13.4259	80.09	19.91
27	39.811	50.119	19	8.7963	88.89	11.11
28	50.119	63.096	16	7.4074	96.30	3.70
29	63.096	79.433	4	1.8519	98.15	1.85
30	79.433	100.000	4	1.8519	100.00	0.00

Table B-24 Vehicle Operation (minutes per day)

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	0	0	.	0.0000	0.00	100.00
2	0	10	.	0.0000	0.00	100.00
3	10	20	4	1.8519	1.85	98.15
4	20	30	15	6.9444	8.79	91.21
5	30	40	19	8.7963	17.59	82.41
6	40	50	22	10.1852	27.78	72.22
7	50	60	28	12.9630	40.74	59.26
8	60	70	40	18.5185	59.26	40.74
9	70	80	26	12.0370	71.30	28.70
10	80	90	18	8.3333	79.63	20.37
11	90	100	15	6.9444	86.57	13.43
12	100	110	6	2.7778	89.35	10.65
13	110	120	11	5.0926	94.44	5.56
14	120	130	3	1.3889	95.83	4.17
15	130	140	4	1.8519	97.68	2.32
16	140	150	1	0.4630	98.14	1.86
17	150	160	.	0.0000	98.14	1.86
18	160	170	1	0.4630	98.60	1.40
19	170	180	2	0.9259	99.53	0.47
20	180	190	.	0.0000	99.53	0.47
21	190	200	1	0.4630	99.99	0.01
22	200	210	.	0.0000	99.99	0.01
23	210	220	.	0.0000	99.99	0.01
24	220	230	.	0.0000	99.99	0.01
25	230	240	.	0.0000	99.99	0.01
26	240	250	.	0.0000	99.99	0.01
27	250	260	.	0.0000	99.99	0.01
28	260	270	.	0.0000	99.99	0.01
29	270	280	.	0.0000	99.99	0.01
30	280	290	.	0.0000	99.99	0.01
31	290	300	.	0.0000	99.99	0.01

Table B-25 Number of Trips per day

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	0	0	.	0.0000	0.00	100.00
2	0	1	.	0.0000	0.00	100.00
3	1	2	.	0.0000	0.00	100.00
4	2	3	9	4.1667	4.17	95.83
5	3	4	17	7.8704	12.04	87.96
6	4	5	35	16.2037	28.24	71.76
7	5	6	33	15.2778	43.52	56.48
8	6	7	24	11.1111	54.63	45.37
9	7	8	30	13.8889	68.52	31.48
10	8	9	27	12.5000	81.02	18.98
11	9	10	15	6.9444	87.96	12.04
12	10	11	8	3.7037	91.66	8.34
13	11	12	9	4.1667	95.83	4.17
14	12	13	2	0.9259	96.76	3.24
15	13	14	2	0.9259	97.69	2.31
16	14	15	1	0.4630	98.15	1.85
17	15	16	1	0.4630	98.61	1.39
18	16	17	1	0.4630	99.07	0.93
19	17	18	.	0.0000	99.07	0.93
20	18	19	1	0.4630	99.53	0.47
21	19	20	1	0.4630	99.99	0.01

Table B-26 Number of Stops per hour

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	0	0	.	0.0000	0.00	100.00
2	0	2	.	0.0000	0.00	100.00
3	2	4	.	0.0000	0.00	100.00
4	4	6	.	0.0000	0.00	100.00
5	6	8	.	0.0000	0.00	100.00
6	8	10	.	0.0000	0.00	100.00
7	10	12	.	0.0000	0.00	100.00
8	12	14	2	0.9259	0.93	99.07
9	14	16	1	0.4630	1.39	98.61
10	16	18	1	0.4630	1.85	98.15
11	18	20	3	1.3889	3.24	96.76
12	20	22	4	1.8519	5.09	94.91
13	22	24	6	2.7778	7.87	92.13
14	24	26	6	2.7778	10.65	89.35
15	26	28	10	4.6296	15.28	84.72
16	28	30	13	6.0185	21.30	78.70
17	30	32	8	3.7037	25.00	75.00
18	32	34	11	5.0926	30.09	69.91
19	34	36	19	8.7963	38.89	61.11
20	36	38	22	10.1852	49.08	50.92
21	38	40	23	10.6481	59.73	40.27
22	40	42	25	11.5741	71.30	28.70
23	42	44	12	5.5556	76.86	23.14
24	44	46	17	7.8704	84.73	15.27
25	46	48	10	4.6296	89.36	10.64
26	48	50	6	2.7778	92.14	7.86
27	50	52	6	2.7778	94.92	5.08
28	52	54	2	0.9259	95.85	4.15
29	54	56	4	1.8519	97.70	2.30
30	56	58	1	0.4630	98.16	1.84
31	58	60	4	1.8519	100.01	-0.01

Table B-27 Speed Frequency Distribution

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	0	0	357	19.0502	19.05	80.95
2	0	5	90	4.8026	23.85	76.15
3	5	10	90	4.8026	28.65	71.35
4	10	15	97	5.1761	33.83	66.17
5	15	20	168	8.9648	42.79	57.21
6	20	25	318	16.9691	59.76	40.24
7	25	30	298	15.9018	75.66	24.34
8	30	35	150	8.0043	83.66	16.34
9	35	40	84	4.4824	88.14	11.86
10	40	45	16	0.8538	88.99	11.01
11	45	50	54	2.8815	91.87	8.13
12	50	55	104	5.5496	97.42	2.58
13	55	60	48	2.5614	99.98	0.02

Table B-28 FTP Acceleration Frequency Distribution

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	-4	-3	104	5.5556	5.56	94.44
2	-3	-2	79	4.2201	9.78	90.22
3	-2	-1	117	6.2500	16.03	83.97
4	-1	0	833	44.4979	60.53	39.47
5	0	1	430	22.9701	83.50	16.50
6	1	2	157	8.3868	91.89	8.11
7	2	3	71	3.7927	95.68	4.32
8	3	4	81	4.3269	100.01	-0.01

Table B-29 FTP Power Frequency Distribution

OBS	LOWER	UPPER	COUNT	PERCENT	CUM	DECUM
1	0	20	233	31.5291	31.53	68.47
2	20	40	203	27.4696	59.00	41.00
3	40	60	134	18.1326	77.13	22.87
4	60	80	72	9.7429	86.87	13.13
5	80	100	48	6.4953	93.37	6.63
6	100	120	21	2.8417	96.21	3.79
7	120	140	10	1.3532	97.56	2.44
8	140	160	10	1.3532	98.91	1.09
9	160	180	2	0.2706	99.18	0.82
10	180	200	6	0.8119	99.99	0.01