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Truck Driving Pattern and Use Survey Phase II Final Report Part II Los Angeles

by

Leroy Higdon
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Standards Development and Support Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air and Waste Management
U.S. Environmental Protection Agency

Forward

This report presents the data collection procedures used in Phase II Part II of the CAPE-21, Truck Driving Pattern and Use Survey. It covers only the data collection in Los Angeles, and describes collection processes, equipment, personnel, sample plans and resultant data base.

No attempts are made to show conclusions as to the validity of the data since this topic will be covered in a separate report to be released at a later date.

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I. Introduction

A. Background

Phase II Part II of the CAPE-21, Truck Driving Pattern and Use Survey is the continuation of a two city survey consisting of New York and Los Angeles.

This report deals only with Part II of the CAPE-21 program, and covers the Los Angeles survey. The New York portion of the CAPE-21 program was conducted by Wilbur Smith and Associates and is covered in a final report under the heading Phase II Part 1, Truck Driving Pattern and Use Survey.

The selection of the two cities which make up the study was made jointly by a panel of representatives from the U.S. Environmental Protection Agency (EPA) and the Coordinating Research Council (CRC). It was based on the need for in-use heavy-duty truck data which, when analyzed, would indicate typical truck operation in urban areas of the United States.

To test a statistically acceptable number of vehicles in each urban area in the United States for the purpose of determining how heavy-duty vehicles are operated in normal service in each case, would have involved the expenditure of vast amounts of manpower and finances and would have taken a significant amount of time to complete. To overcome these restrictions the CAPE-21 panel decided to select two cities which, when combined statistically, represented the extremes in driving conditions under which heavy-duty vehicles must operate.

The city of New York was chosen as representative of one extreme, because it is an old city having a dense population in a relatively small area, with narrow streets, limited numbers of expressways, and numerous restrictions to automotive traffic movement in the form of traffic control devices (stop lights and signs). The choice of Los Angeles for the second city in the survey was made because it represents just the opposite in extremes from New York. The rationale for the selection of the two cities has been shown to be correct in an earlier study conducted by Wilbur Smith and Associates of Columbia, South Carolina.[1,2]

The program objective was to collect engine and vehicle operational data on a number of in-use heavy-duty trucks and buses, which would, when analyzed, describe the way these vehicles are operated in regular use by their owners. The data collected during the survey were intended for use in the development of representative driving cycles for use in the testing of heavy-duty trucks and/or truck engines for compliance with emission standards for the control of air pollution. From the standpoint of emission testing for air quality control, the optimum in any test cycle is reached when a single representative cycle can be used which is representative of the way vehicles are operated in the control area of interest as a whole. To acheive this, the data base used in the development of such a cycle must be representative of types of vehicles predominantly used in areas which, when combined, represent the mean in operational characteristics within the control area.

The CAPE-21 program, through careful design of its sample plan, is a comprehensive study which will supply a data base that is statistically representative of heavy-duty truck operations in two localities. When combined, this data base should reasonably represent the mean in truck operation within the continental United States (the control area of interest).

Phase II of the CAPE-21 program was conducted at a cost of just over $250,000.00, excluding salaries, and an expenditure in manpower of approximately 19,000 manhours. The Los Angeles survey was started in January, 1975, and ran to May 1975. This report deals only with the statistical sample plan, data collection operations, and instrumentation used in the Los Angeles portion of the survey. Analysis of the data is the subject of a separate project and will be reported on under separate cover.

B. Conclusion

In-use data collection of the type sought in the CAPE-21 Truck Driving Pattern and Use Survey is, in the authors opinion, bordering on the upper extremes of state of the art for in-use motor vehicle data collection. This condition is aggravated by the fact that the owners involved in studies of this type are commercial operators depending on these vehicles for profit revenue, a condition which strongly influences every facet of the study. Participation by owners in in-use programs of this type is greatly dependent on their awareness of problems of air pollution, and the need for its control. In addition to this, the willingness to participate extends only to the point where economics are not a factor.

During the performance of the Los Angeles portion of the CAPE-21 study, every effort was made to inform the participants of the EPA's need for conducting the study. Wherever possible the cost to owners caused by the use of his vehicle in the survey was absorbed by EPA. The results of this effort was an exceptional response on behalf of the participants to aid in the success of the study.

With the completion of the Los Angeles Study, EPA has established the formation of the most in-depth data base of in-use heavy-duty truck operation ever assembled. The data describe, in explicit detail, the operational characteristics of heavy-duty vehicles in actual use by the operators. It is free from the outside influences or restrictions inherent in studies of this type when conducted entirely by skilled test drivers and technicians. It depicts the movement of heavy-duty vehicles in normal traffic over unpredicted routes in terms of road speed, and the engine operational characteristics (RPM and power) from which this road speed is derived.

There can be little question as to the representativeness of the data collected in the Los Angeles survey, in that every precaution was taken to insure that the operators were not influenced in any way by the survey team or the on board equipment, in the performance of their normal duties.

The data base resulting from the CAPE-21 study is applicable to a wide variety of investigative endeavors and should prove to be unparalleled in its usefulness for some time to come. It is not, however, unlimited in its ability to answer or satisfy all possible questions concerning the movement of heavy-duty vehicle operation in urban areas of the United States, and when used should be considered with the same degree of technical understanding afforded any other data base for its original intent.

II. Program Structure

A. Purpose

The CAPE-21 program was designed, and conducted to provide a data base from which heavy-duty engine and chassis emission test cycles might be developed which are representative of operation in the real world. The data then have the ability to represent the mean operational characteristics in the sample area from which it came.

B. Sample Plan

When planning to undertake a program like CAPE-21, one must first decide on the area to be sampled and having done so identify the parameters to be sampled within the area. If the data to be collected are to be used to represent the mean of the measured parameters within the area, or if the area under consideration is assumed to be represented by the data as being the norm or average characteristics as a function of the area, then some method must be devised to measure the extremes which can then be used to predict the means. When considering the extremes of the sample area, it is necessary to consider the kind of data needed and identify those parameters, within the sample area of interest, which most greatly influence these parameters.

The sample area, in this case, is the United States, and the mean can be derived if the extremes of the area are known. The total area of the selected extremes can further be reduced in size when consideration is given to the fact that, the EPA is primarily concerned with urban areas in its efforts to control air quality. The test means (sample size) can now be confined to vehicle operation within these extremes. Because the study is concerned with traffic flow within the selected portions of the extremes, the controlling factors in the types of data that will result from the testing of vehicles within the recognized confines of the sample area are directly relatable to the means in the types of restrictions to traffic flow.

With the above considerations in mind, the city of New York was considered as meeting one extreme because it is an old city having narrow roadways, few limited access roads (freeways), a traffic control system which consists of stop lights and stop signs requiring frequent stop and start type operation, and external interference to traffic flow, in the form of pedestrian crossing, in high volume at peak traffic hours. Additionally, New York's major industries have been distinctly located in specific sections of a city of relatively small area compared to Los Angeles, the second city used in the survey. It was felt that Los Angeles represents the opposite in every category mentioned above. These two cities then were considered the area extremes for the CAPE-21 Truck Driving Pattern and Use Survey.

To satisfy the requirement for data which can be used for engine and/or chassis cycle development, the parameters of major concern are 1) engine RPM, 2) engine horsepower and, 3) vehicle road speed. Sample area parameters which most greatly effect these operational parameters are, 1) topography, 2) degree of congestion which attributes restrictions to traffic flow, 3) traffic control systems, and 4) uncontrollable and periodic interference to traffic flow (i.e., pedestrian movement).

In order to select the survey sample configuration, a Heavy-Duty Vehicle Driving Pattern and Use Survey was conducted by Wilbur Smith and Associates (WSA)[1,2] under joint contract from EPA and CRC (Coordinating Research Council). This survey (referred to as CAPE-21 Phase I Parts 1 and 2 for New York and Los Angeles respectively) was conducted in order to acquire information pertaining to the composition, function, and travel behavior of urban truck travel in the two cities. From Part 2 of these data, a sample plan, which for economical reasons was restricted to fifty (50) vehicles, was designed by WSA which, statistically, was representative of the truck population in the Los Angeles Basin. (See figure 1.)

After reviewing the Phase I Part 2 data and the resultant sample plan submitted by WSA, several changes were made to better facilitate the engineering and economical considerations of the data collection program. The final sample plan used in the Phase II Part 2 Los Angeles survey (see figure 2) called for a total of fifty (50) vehicles to be tested from five (5) geographical areas in the greater Los Angeles basin. Each vehicle was required to have a gross vehicle weight (GVW) of not less than ten (10) thousand pounds and would be tested for from two (2) to five (5) days of normal in-service operation. A day of operation was defined as any twenty-four (24) hour calendar period during which a vehicle left its normal storage location, for one hour or more duration, to perform a task or number of tasks, the length of which was immaterial.

In addition to the fifty (50) vehicles originally scheduled to be tested in the CAPE-21 program, five city busses were added to the study in both New York and Los Angeles. These vehicles were to be tested both as inter-city as well as intra-city vehicles and were acquired from the major transportation agencies in each location.

As an afterthought, and because the opportunity presented itself favorably. Two trucks, one two axle tractor trailer, gas, and one two axle single unit, gas, were instrumented and driven over the road between Los Angeles and San Francisco, California, and between Los Angeles, California and Ann Arbor, Michigan. Similarly, a Trailways over-the-road bus was tested between Los Angeles, California and Denver, Colorado.

Vehicles were divided into four (4) groups by axle configuration. Two axle single unit (2A), three axle single unit (3A), two axle tractor trailer (2TT) and three axle tractor trailer (3TT), busses were considered as a separate category. The sample was further divided into two fuel classes, gasoline and diesel. In order to qualify as being representative of operation in a given geographical area, a vehicle had to

FIGURE 1
SAMPLE PLAN FOR LOS ANGELES

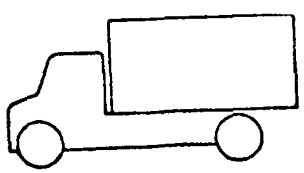
	Strata	Number of Trucks	Number of Days	Truck Days of Data
1.	6-10,000, 2 Axle, RC	10	4	40
2.	6-10,000, 2 Axle, BE	8	4	32
3.	10-15,000, 2 Axle, RC	2	4	8
4.	10-15,000, 2 Axle, BE	1	4	4
5.	15-20,000, 2 Axle, RC	0	-	-
6.	15-20,000, 2 Axle, BE	0	-	-
7.	6-10,000, 3 Axle, RC	0	-	-
8.	6-10,000, 3 Axle, BE	1	4	4
9.	10-15,000, 3 Axle, RC	1	5	5
10.	10-15,000, 3 Axle, BE	3	5	15
11.	15-20,000, 3 Axle, RC	1	3	3
12.	15-20,000, 3 Axle, BE	1	4	4
13.	20-25,000, 3 Axle, RC	0	-	-
14.	20-25,000, 3 Axle, BE	0	-	-
15.	6-10,000, 4 Axle, RC	0	-	-
16.	6-10,000, 4 Axle, BE	0	-	-
17.	10-15,000, 4 Axle, RC	0	-	-
18.	10-15,000, 4 Axle, BE	0	-	-
19.	15-20,000, 4 Axle, RC	1	4	4
20.	15-20,000, 4 Axle, BE	1	3	3
21.	20-25,000, 4 Axle, RC	2	3	6
22.	20-25,000, 4 Axle, BE	4	4	16
23.	25-30,000, 4 Axle, RC	1	2	2
24.	25-30,000, 4 Axle, BE	8	2	16
25.	30-35,000, 4 Axle, RC	1	2	2
26.	30-35,000, 4 Axle, BE	3	2	6
27.	+35,000, 4 Axle, BE	1	2	2
	TOTAL	50		172

RC - Regular Commercial; BE - California Board of Equalization
Column 2 indicates the number of days truck is to be tested.

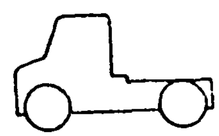
FIGURE 2

GEOGRAPHIC SAMPLING PLAN FOR
LOS ANGELES COUNTY
(CAPE-21)

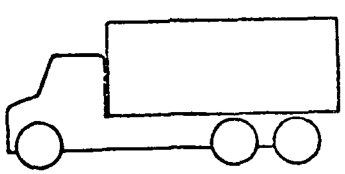
Truck Type		All Areas		Los Angeles		Inglewood		Van Nuys/ Pasadena		Whittier/ Long Beach		Alhambra		Totals
		Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel	
2A	No. Trucks	20	3	8	1	3	0	3	0	4	1	2	1	23
	No. Truck Days	80	8	32	4	12	0	12	0	16	2	8	2	88
3A	No. Trucks	3	4	1	1	1	0	0	1	0	1	1	1	7
	No. Truck Days	12	20	4	5	4	0	0	5	0	5	4	5	32
2TT	No. Trucks	5	5	2	2	1	1	1	0	1	2	0	0	10
	No. Truck Days	16	10	4	4	4	2	4	0	4	4	0	0	26
3TT	No. Trucks	2	8	1	3	0	1	0	1	1	2	0	1	10
	No. Trucks Days	8	18	4	6	0	3	0	3	4	4	0	2	26



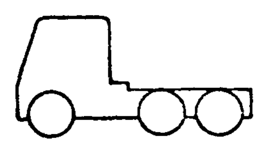
2A



2TT



3A



3TT

have originated its daily operation in that area.

C. Vehicle Acquisition

Olson Laboratories Inc. (OLI) of Anaheim, California, under contract to EPA to support the survey team, was supplied with listings of commercially registered vehicles of the truck classes sought, by the Department of Motor Vehicles for the state of California. The listing, a copy of which is seen in figure 3, consisted of information regarding type of truck, number of axles, weight, fuel type, and registered owner's name and address. Using the listing OLI personnel contacted 480 owners by phone in an attempt to locate the required vehicle in the required operating locale. Two hundred twelve (212) owners meeting both truck type and location requirements were contacted, of which sixty-two (62) agreed to participate in the study. The difficulties experienced in finding willing participants lie primarily in the information source employed. As can be seen in figure 3, only the registered name and address of owners are listed, this information does not indicate if the vehicle is based at that location. During the survey it was found that, in fact, some vehicles were not even based in the state of California. Vehicles were finally obtained by starting with registered owners and tracing the truck whereabouts by phone until a definite answer could be obtained from the operator as to his willingness and ability to participate.

In addition to difficulties experienced in locating the required vehicles, it was found that owners were reluctant to participate in the program when it was learned that the study was being conducted by a government agency. This problem stemmed from the fact that not only was the truck to be instrumented, but that an on-board observer working for the government would ride with the equipment. The thought was expressed by owners that more was being monitored than vehicle operation. To overcome this distrust, personal visits were made to prospective participants to explain the intent of the survey and answer any questions, this reduced declines to acceptable levels in California. Table 1 shows the statistics for truck acquisition, and the resultant sample population.

Once the required vehicle was found the owner was required to sign a written agreement authorizing the installation of the instrumentation, and describing the legal obligations and limitations. The vehicle was then delivered to one of two dynamometer facilities for installation and calibration.

D. Vehicle Instrumentation Installation Scheduling

Once a participation agreement was secured, a vehicle was entered into the scheduling process. This process consisted of obtaining a signed agreement with the owner of the vehicle (figure 4), inspection of the vehicle prior to instrumentation installation, and scheduling of the vehicle for installation.

FIGURE 3

DEPARTMENT OF MOTOR VEHICLES, STATE OF CALIFORNIA
REGISTRATION LISTINGS

Axle Group	Weight Group	Year	Model	Truck Type	Cab Loc.	Fuel	Wheels		State Weight	Name	Address 1	Address 2
							Tot.	Dr.				
3	15-20K	65	PTB	TAN	U	D	9	9	060	Douglas Oil Co.	816 West 5th St.	Los Angeles, CA 90017
3	15-20K	73	KEN	TRA	U	D	9	9	054	Seven Flags Co-Op	12420 Bloom-field Av.	Sante Fe Springs, CA 90670
3	15-20K	69	MCK	TRA	U	D	9	9	057	Dresser In-dustries Inc.	10960 Wil-shire Bl.	Los Angeles, CA 90024
3	15-20K	71	WST	FLA	U	D	9	9	060	Sun Lumber Co.	3435 Wil-shire Bl.	Los Angeles, CA 90010
3	15-20K	69	KEN	TRA	U	D	9	9	050	Selectruk, Inc.	5030 Gif-ford Av.	Los Angeles, CA 90058
3	15-20K	69	KEN	TAN	U	D	9	9	060	Southern Tank Lines	16613 Minn-esota Av.	Paramount, CA 90723
3	15-20K	66	WHI	TRA	U	D	9	9	050	Mr. Donald W. Smith	12004 S. Louis Av.	Whittier, CA 90605
3	15-20K	64	KEN	TRA	U	D	9	9	050	Davidson C. L. Truck-ing, Inc.	420 Camino De Encnt.	Redondo Beach, CA 90277
3	15-20K	67	PTB	TRA	U	D	9	9	050	Mr. Clifford J. Turner	10919 S. Van Ness Av.	Inglewood, CA 90303

FIGURE 3--Continued

Axle Group	Weight Group	Year	Model	Truck Type	Cab Loc.	Fuel	Wheels Tot.	Wheels Dr.	State Weight	Name	Address 1	Address 2
3	15-20K	65	PTB	DUM	U	D	9	9	057	Mr. David C. Delacruz	10342 Rio Hondo Pkwy.	El Monte, CA 91733
3	15-20K	64	KEN	TRA	U	D	9	9	050	Wilennis, Inc.	1136 E. 58th Dr.	Los Angeles, CA 90001
3	15-20K	72	KEN	TRA	U	D	9	9	054	Mr. Richard F. Millar	3308 N. Lamer St.	Burbank, CA 91504
3	15-20K	67	PTB	TRA	U	D	9	9	054	Mr. Walter C. Welty	15002 Kingsbury St.	San Fernando, CA 91340
3	15-20K	64	KEN	TRA	U	D	9	9	054	Mr. Anthony G. Rosales	247 N. Sandalwood Av.	La Puente, CA 91744
3	15-20K	65	PTB	TAN	U	D	9	9	057	Colbro Corp.	14011 S. Central Av.	Los Angeles, CA 90059
3	15-20K	68	KEN	TRA	U	D	9	9	050	Berkeley Investments, Ltd.	355 S. Flower St.	Los Angeles, CA 90017
3	15-20K	67	KEN	TRA	U	D	9	9	054	Mr. James B. Hicks	2356 S. Sepulveda Bl.	Los Angeles, CA 90064
3	15-20K	67	WHI	TRA	U	D	9	9	050	Mr. Essix Harris	2820 Century Bl.	Lynwood, CA 90262
3	15-20K	68	PTB	TRA	U	D	9	9	050	Gray Trk. Co.	4280 Bandini Bl.	Los Angeles, CA 90023

FIGURE 3--Continued

Axle Group	Weight Group	Year	Model	Truck Type	Cab Loc.	Fuel	Wheels Tot.	Wheels Dr.	State Weight	Name	Address 1	Address 2
3	15-20K	67	KEN	TRA	U	D	9	9	054	Ball Son Transfer	1136 Clint-wood Av.	La Puente, CA 91744
3	15-20K	69	FOR	TMX	U	D	9	9	050	Greenes Ready Mixed	19030 S. Normandie Av.	Torrance, CA 90502
3	15-20K	66	AUT	TRA	N	D	9	9	050	Griffith Co.	3650 Cherry Av.	Long Beach, CA 90807
3	15-20K	71	KEN	TRA	U	D	9	9	050	J. V. Trucking	510 W. 6th St.	Los Angeles, CA 90014
3	15-20K	72	KEN	TRA	U	D	9	9	050	Jersey Maid Milk Prod.	1040 W. Slauson Av.	Los Angeles, CA 90044
3	15-20K	69	WHI	DUM	U	D	9	9	060	Alusa West-ern, Inc.	Box 575	Azusa, CA 91702
3	15-20K	72	WFT	TRA	C	D	9	9	050	Ameron	400 S. Atlantic Bl.	Monterey Park, CA 91754
3	15-20K	70	WFT	TRA	C	D	9	9	054	Atlantic Richfield Co.	515 S. Flower St.	Los Angeles, CA 90017

TABLE 1
TRUCK ACQUISITION RESPONSE SUMMARY

No longer own or not in service	20
Lease truck-owner not willing	12
No room in cab for observer	21
Too busy (too much trouble)	40
Don't want to be bothered	10
Unqualified refusal	9
Other reasons for refusal	3
Security problems	2
No longer business	4
Several contacts and call backs with no response or decision	12
Not listed in telephone directory or unlisted number	2
Legal problems	5
Insurance problems	7
Union problems	3
TOTAL	150

Total sample available for testing out of 212 possible--62.

FIGURE 4

AGREEMENT

This agreement is between whose address is and who is the owner or operator of a motor vehicle bearing the license and hereafter referred to as owner, and Olson Laboratories Incorporated, a corporation in the State of Minnesota, whose home office is 421 East Cerritos Avenue, Anaheim, California, and hereafter referred to as the consultant.

The purpose of the agreement between the two parties is to describe the participation of the owner in certain experiments to be conducted by the consultant under a study sponsored by the U.S. Environmental Protection Agency. The experiment involves the instrumentation of the owner's vehicle described above by the Environmental Protection Agency and the placing of a consultant's observer on the vehicle as a passenger during normal operations of the owner's vehicles, during days between and , hereinafter referred to as the experiment period.

The owner agrees to deliver at his expense and using his driver, the said vehicle to the consultant's facility at , on between the hours of and for the purpose of installation and calibration of equipment to automatically monitor that vehicle's engine speed, vehicle speed, engine load factor and other vehicle parameters by equipment and means provided by the Environmental Protection Agency and the consultant.

The Environmental Protection Agency and the consultant agree to perform this installation in a manner and location so as to not interfere with the normal function or operation of the said vehicle.

The consultant will provide an observer during the experiment period to ride on said vehicle during its normal operation and to make such observations and enter into the consultant's log such data that might be observed by him during the experiment period. The consultant agrees that the observer will not engage in any other function than his observation activity and the owner will not require the observer to engage in any such activity other than that described.

The consultant will be responsible for all damages and liabilities resulting from the installation, data recording and removal of equipment on the owner's vehicle, and all actions of the consultant's employees, the consultant's subcontractor's employees, and other agents acting for the consultant. The consultant will hold the owner free from personal and property damages and other liabilities related to said equipment and the actions of the consultant's employees.

FIGURE 4--Continued

The owner will hold the consultant free from any liabilities or responsibilities for any act or damages caused by or to the owner's vehicle and employees, including delays, accidents, or other incidences related to all normal functions, operations and use of the said vehicle.

The rights in the data collected shall be vested in the consultant and assignees for the purposes of the study, except however, the consultant agrees not to identify or otherwise relate the owner or his employees to the data so collected without specific written permission of the owner or the employee so involved.

To compensate the owner for all expenses involved in the participation in the experiment and all conditions related thereto, the consultant agrees to pay to the owner the sum of   within 30 days of the conclusion of said experiment.

This agreement is accepted by both parties, this day   ,
19   , and is executed in   , in the county of
and the State of   .

Witnesseth:

For the Owner	For the Consultant
________________________	OLSON LABORATORIES, INC.
By______________________	By______________________
Title____________________	Title____________________

Vehicle inspection prior to installation, although planned to take place two days before installation, was difficult to achieve in most cases because it involved holding a vehicle out of service for one or more hours while the inspection was performed. Owners who chose to participate in the program did so somewhat reluctantly when told that the vehicle would be out of service for from three to five hours on the day of instrumentation installation. When asked to hold a vehicle out of service for an additional period of time for an inspection, refusals were quite common. In addition to owner reluctance, vehicle pre-inspection was discontinued in Los Angeles because in those instances where it was performed and defects found that would influence the test if not repaired, owners were not agreeable to making such repairs unless it effected the normal work the vehicle was to do. For example, worn tires that might blow during dyno testing but were considered acceptable for normal driving would not be replaced, broken speedometer cables or related parts were of no importance to owners from an operation standpoint, but were vital to the survey needs. Whenever possible, items in need of repair or replacement were put in operating condition by the survey team at their expense, in order to prevent losing the use of the vehicle. Obviously, this did not apply to high cost items such as tires. When repairs were considered unreasonable and the owner could not be persuaded to perform them, the vehicle was rejected and a replacement vehicle located.

Calibration and installation of instrumentation was performed at two (2) locations in Los Angeles. Each installation was equipped with a Clayton tandom water brake chassis dynamometer. These dynamometers were owned and operated by the 1) State of California Vehicle Maintenance Department of the California Department of Transporation, located in Hollywood, California, and 2) the California Air Resources Board at El Monte, California. Five (5) sets of instruments were used in the conduction of the survey. These instruments were mounted in the vehicle in a location which allowed easy access by the on-board observer without interfering with the driver. Vehicle scheduling depended totally on 1) an instrument being available for use and 2) the ability of an owner to deliver the promised vehicle. Initial operation program plans called for the instrumenting of four vehicles per day (assuming instrumentation availability) during normal working hours. In practice, however, only two vehicles proved to be the practical extent to which instrumentation installation could be expanded. This means that on the average four trucks could be tested per week, instead of eight, the number originally targeted.

Loss of a given day's operation for a vehicle because of instrument failure, or vehicle breakdown required the slippage of all subsequent vehicles. Most owners required a minimum of one day advance notice for vehicle insturmentation. This was necessary to allow for scheduling of a replacement vehicle to cover scheduled routes or tasks for that company's operation during the four to five hours required for instrument installation. In most cases, if slippage occurred due to a loss of data it was not known until late in the day. This meant owners scheduled for installation the next day were unavailable and cancellation of that vehicle meant a loss of as many days as needed for rescheduling or replacement. Close control of instrument repair, and quick response to in-operation failure reduced loss time substantially in Los Angeles, however, a total of fourteen (14) days were lost to this problem.

E. Vehicle Calibration

As will be discussed in more detail later in this report, the primary data parameters collected in the CAPE-21 survey were:

1. Road speed,
2. Load factor, and
3. Engine RPM.

Of the three parameters, load factor represented the most difficult parameter to measure. The reasons for this stem from the fact that when testing heavy-duty engines for compliance with emission control regulations, an engine dynamometer is used to exercise the engine through the test procedure. Power measurements are then engine shaft power.

For economical as well as practical reasons engine shaft power measurements were not possible while the vehicle was being operated in normal use as in the Los Angeles or CAPE-21 study. An alternative solution then would be to measure some other parameter more easily accessible and relative to engine shaft horsepower.

The relationship between fuel flow and power in diesel engines as well as manifold pressure in gasoline engines is well known in the automotive industry and was therefore used in the CAPE-21 study. This alone did not completely solve the unique problem created by the CAPE-21 program structure because the program did not allow for removal of the engine from the vehicle for calibration of the load factor measurement with shaft horsepower.

It was decided that calibration of load factor measurements could be accomplished by relating load factor measurements to the vehicles rear wheel horsepower and later adding the characteristic losses in transmissions, and differentials (i.e., drive train) to arrive at shaft horsepower. This assumption holds true when horsepower is expressed in terms of percent of maximum wheel horsepower and must equal 100% or maximum shaft horsepower, and can be expanded to intermediate power settings if one assumes the same relationship at all intermediate powers, i.e., drive train losses are linear with RPM. Later in other reports dealing with the CAPE-21 data analysis , this assumption will be shown to be false, but for discussion purposes, it will be maintained here.

F. Data Acquisition Package

The data acquisition system used included sensors to measure engine

RPM; vehicle speed; engine load factor; engine temperature; and throttle valve position; sensor signal conditioning electronics; and a digital data logger with integral clock and magnetic tape recorder. Manually operated switches were included to enable recording of road type and traffic conditions for subsequent correlation with the sensor data. The above signals, along with time of day from the data logger clock, were sampled and recorded at the rate of one data set every 0.863 seconds. A system block diagram is shown in figure 5.

1. Data Logger

The central component of the data acquisition system is the Metradata Model DL620B Data Logger, figure 6. This unit accepted eight differential data inputs of 0 to ± 1 Vdc, scanned them sequentially, and converted the analog signal to a 16-bit (3 digits plus sign) digital signal. These eight channels, plus two channels of time, pre-parity, and parity bits, were assembled into a scan which was recorded at a rate of 1.2 scans per second. This digital data was recorded on a 4-track, 1/4-inch tape in a BCD complement format at a density of 150 bits per inch. The tape was loaded in a 1200-foot endless loop cassette, which provided 12 hours of continuous recording. Front panel controls on the Data Logger included the POWER switch, Analog Display with CHANNEL SELECT switch, and TIME SET controls. Time was displayed on Channels 1 and 2 in the same manner as other channels. The channel format for all tests has been listed in Table 2.

2. Signal Conditioning Module

Signals from the transducers were fed into the Signal Conditioning Module. The Signal Conditioning Module provided interfacing and conversion between transducer and data logger.

3. Power Supply

A separate 12 V battery powered the data acquistion system, and was controlled by a front panel switch. An indicator switch showed system power status.

4. Road Type and Traffic Conditions

Manual inputs for road type (freeway arterial and local) and traffic conditions (heavy, medium, and light) were programmed by two sets of switches on the front panel of the signal conditioner. These switches were operated by the on-board observers, and were interlocked to prevent selection of more than one condition for either of the two parameters. Selection of a given road type or traffic condition switch applied one of three voltages to the recorder coded as follows:

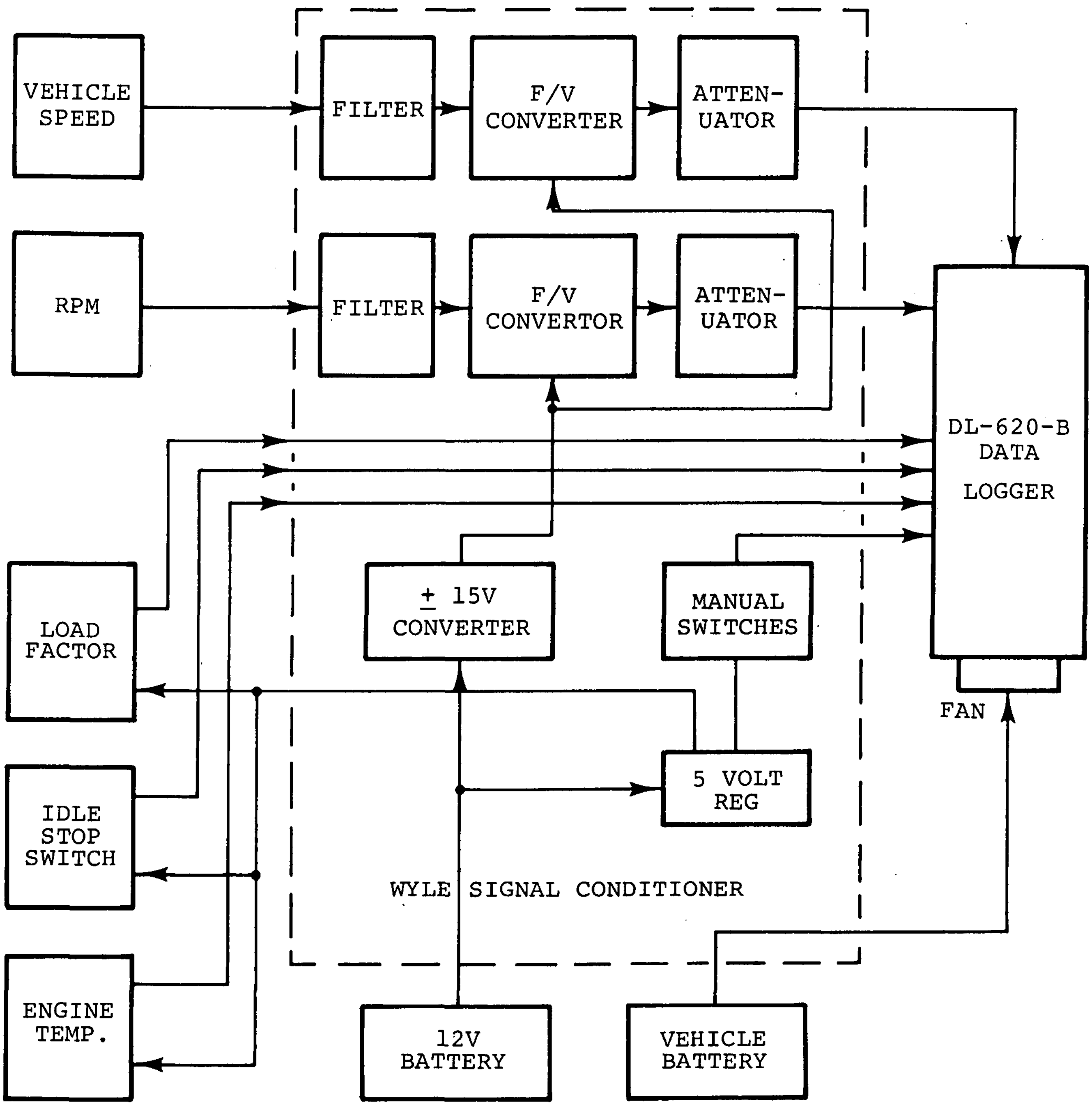
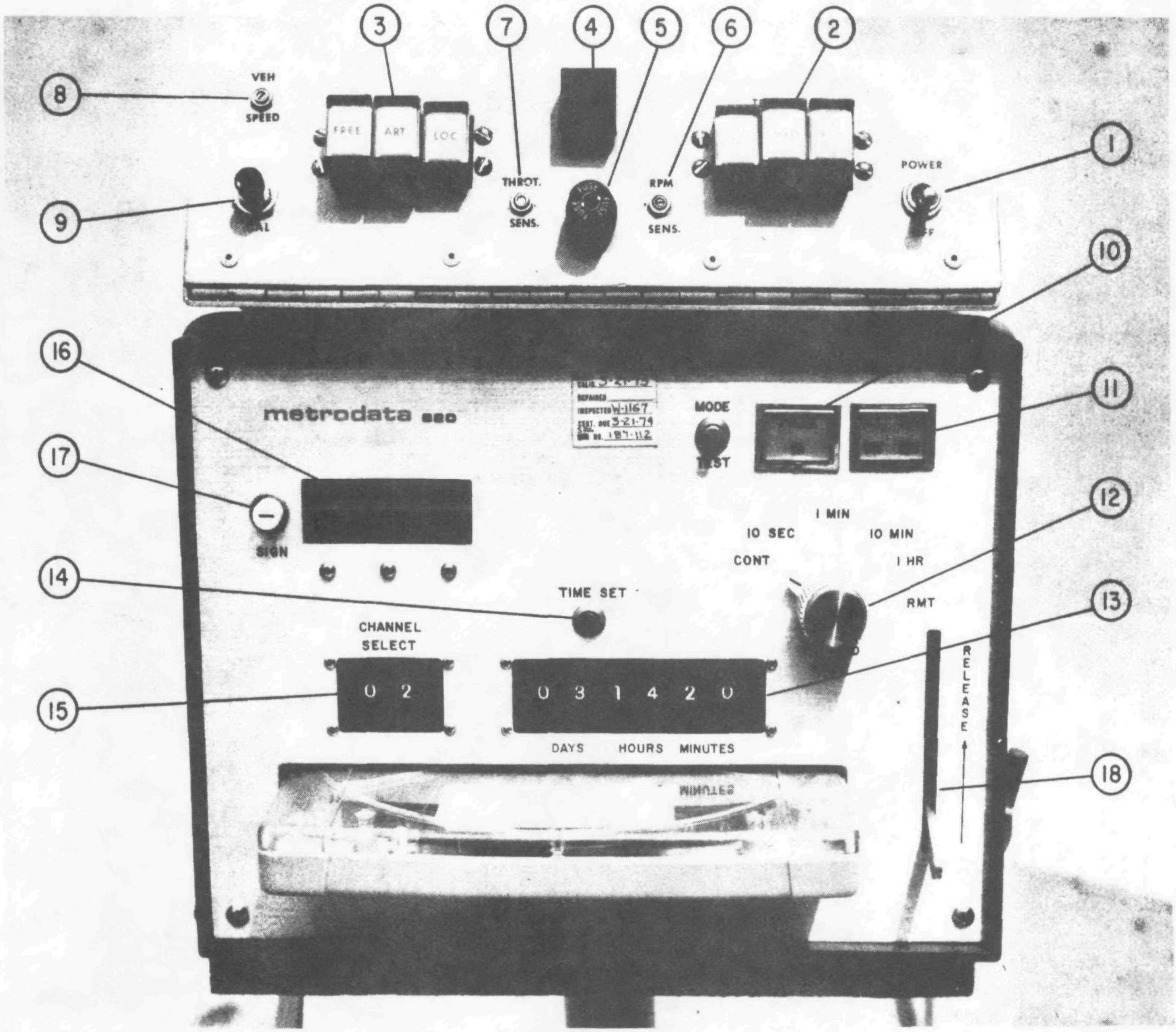


FIGURE 5

Block Diagram - Data Acquisition System



1. System Power
2. Manual Input - Traffic
3. Manual Input - Road Type
4. Power Indicator
5. 5 Amp. Power Fuse
6. RPM Sensitivity Adjust
7. Load Factor Sensitivity
8. Vehicle Speed Adjust
9. Inverter Power Fuse
10. Illuminated Power Switch
11. Illuminated Mode Switch - Standby/Record
12. Record Rate Switch (locked)
13. Thumbswitches to set Real Time
14. Time Reset Button - Starts Real Time
15. Channel Select - Displays in Item 16
16. Channel Data Display - 3-Digit + Sign
17. Polarity Display - Lights on (-)
18. Cassette Release Lever
19. Mode Test Switch

FIGURE 6

TABLE 2

CHANNEL ASSIGNMENTS DURING CALIBRATION

Channel No.	Measurement
1	Truck No. and Time (hours tens)
2	Time (hours units and minutes)
3	Engine RPM
4	Load Factor
5	Vehicle Speed
6	Road Type
7	Traffic Conditions
8	Slow Idle Position
9	Engine Temperature
10	Channel 5 Techgenerator Verification

Selected Switch	Condition	Coded Input Voltage Level
Road type	Freeway	-860 ± 30 mv
"	Arterial	0 ± 30 mv
"	Local	+860 ± 30 mv
Traffic Condition	Light	-860 ± 30 mv
"	Medium	0 ± 30 mv
"	Heavy	+860 ± 30 mv

5. Vehicle Speed

The input signal for vehicle speed was an AC signal from a Shaft Encoder. The frequency of the encoder was converted to a voltage level which was proportional to vehicle speed.

A recurrent problem with vehicle speed shaft encoders producing an output when the vehicle was not in motion was experienced during field operations. The problem was solved by installing an additional speed transducer, of the tachometer-generator type, in the speedometer cable drive. The output from this transducer was connected to Channel 10 on the data logger to indicate when the vehicle was stopped. The tachometer generator output was reliably zero when the vehicle was stopped. The presence of a signal from this unit was used to confirm the validity of the Channel 5 readings.

6. Engine RPM

The engine RPM input was derived from the ignition coil or a shaft encoder and was a series of pulses with a DC level of 0.5 to 6 volts and a frequency proportional to RPM. The resultant pulse train was converted to a DC signal proportional to input frequency by a frequency to voltage (F/V) converter and adjusted to a scale factor approximately 0.1 v/1000 RPM. An alternate RPM input to the Signal Conditioner was provided for on vehicles with mechanical tachometers. For engines which had a mechanical tachometer drive, engine RPM was measured by use of an optical shaft encoder.

7. Load Factor

Load factor signal sources were pressure transducers for gasoline and Cummins Diesel engines, and a displacement transducer for Detroit Diesel engines.

a. Gasoline Engines - The engine load factor for gas engines was obtained using a Bourns Model 556 Pressure Transducer with a range of 0-15 psig to measure intake manifold pressure. The unit was mounted on the inside of the signal conditioning box. The transducer connected to the intake manifold with a section of 1/4-inch automotive vacuum tubing approximately ten feet long. A snubber valve was placed in the vacuum line to protect the transducer from damage.

b. Detroit Diesel Engines - The engine load factor for Detroit Diesel engines was obtained by measuring the angular displacement of the rack using a Research Inc. Model 4045-3 linear displacement transducer. The "rack" is a mechanical device which alters the settings of the engines fuel injectors thereby changing the fuel charge to the cylinders which in turn control the available engine power.

c. Cummins Diesel Engines - The load factor transducer for Cummins Diesel engines was a 0-300 psig pressure transducer measuring rail pressure at the fuel pump outlet. The transducer used was a Viatran Model 218-12 strain-guage type. Rail pressure is the measurement of fuel pressure present in the fuel manifold to the engines fuel injection valves. This pressure varies as a function of throttle movement which in turn controls fuel pump pressure. Rail pressure is, then, directly relatable to engine horsepower and RPM.

8. Throttle Valve Closure

A microswitch, installed on the carburetor throttle linkage was used to sense closed throttle condition. This generated a step function voltage input to the signal conditioner to be recorded in Channel 8 to indicate closed throttle conditions.

9. Engine Temperature

To sense engine temperature, a themistor unit, type ID751 (National Laboratories Industries) was clamped to the coolant output header as close to the engine as possible. This unit provided a scaled analog voltage proportional to coolant temperature.

G. Support Equipment and Personnel

Support equipment used in the execution of the survey can be divided into three categories:

1. Instrumentation,
2. Transportation and,
3. Communications.

a. Support Equipment (Instrumentation)

Support equipment for the instrumentation ranged in type from standard electronic test equipment (volt meters, counters, function generators, etc.) used in basic trouble shooting and calibration, to a specially designed cathode ray tube (CRT) display used in verifying tape quality. Two heavy-duty chassis dynamometer were used in the vehicle calibration procedure. A listing of the major pieces of test equipment and their general use has been shown in Table 3.

TABLE 3

MAJOR TEST EQUIPMENT REQUIREMENTS

Item	Use
Cathode ray tube cassette reader	Tape quality control
Dead weight pressure standard	Fuel pressure transducer calibration
Function generator	Calibration of D/A converters (signal conditioners)
Tandom chassis dynamometers	Horsepower calibration of instrument installations
Varian model mini computer system	1/4 to 1/2 inch tape conversion

B. Support Equipment (Transportation)

Seven (7) vehicles were used to support the Los Angeles program: two (2) equipment vans, three (3) leased passenger cars, and two (2) General Service Administration (GSA) cars. A total of fifty-four thousand miles was driven in the vehicles during the program. The vans were equipped as portable instrument labs and carried a complete set of test equipment used in the service, maintenance, and calibration of the on-board recorders. These vehicles were primarily used during installation and maintenance operations, but were sometimes used as backup vehicles for servicing. Four of the five passenger cars were used as chase vehicles which meant they were the prime mode of transportation used when a test vehicle developed trouble while in the performance of its normal work duties. These vehicles were also used for performing normal on-board instrument servicing such as changing tape cassettes and batteries, and performing in-service checkout. A third use of these vehicles was to transport data tapes to the processing center. The fifth passenger car was used in the management of the program.

C. Support Equipment (Communications)

As mentioned earlier, the California program was totally dependent on operator participation for its success. In view of this, every effort was made to insure that once a vehicle was instrumented it completed its test period on schedule.

One important part of meeting schedules was the ability to respond to any situation which threatened to alter the schedule in any way. To accomplish this, a communication system was put into use which allowed all personnel to be in contact with each other and the program manager in a minimum amount of time (usually five (5) minutes) twenty-four hours a day. An area paging system was employed and each man on the two technical crews used in Los Angeles was given remote pagers. In addition to this, the project manager's vehicle was equipped with a mobile telephone which allowed him to communicate with any crewmember while enroute to or from any trouble spot. On-board observers could, using either the paging system or calling the mobile operator, contract any key survey personnel at any time to report problems with in service test vehicles.

D. Personnel

The personnel requirement for the Los Angeles survey consisted of technical as well as unskilled individuals. Two (2) crews of four qualified test technicians were used for equipment maintenance and installation. Five non-skilled persons were employed to act as onboard observers. Their responsibilities included operational monitoring of test equipment, manual input of selected data, and the manual recording of route information. In addition to these tasks, the observers were used as runners for tape delivery, parts and equipment pick-up, and general program assistance.

e. Program Logistics

In addition to the responsibility of arranging for the acquisition of test vehicles, OLI was also responsible for the program logistics. The question of logistical control was given highest consideration early in the program because of the early recognition of the problem of owner and program manager relations. The necessity for fast turnaround on request for equipment and personnel demanded that normal delays in these areas be reduced to bear minimums wherever possible. The use of OLI for purchasing, manpower acquisition, payroll administration, equipment rentals etc. proved to be the soundest approach to on-time completion of the program. Normal governmental channels would not have allowed this.

III. Data Collection

A. Type of Data

As previously mentioned, the CAPE-21 data base was intended for use in the development of heavy-duty test cycles for engine and/or chassis dynamometers. The optimum goal in the cycle development program was to develop cycles which are representative of the way heavy-duty vehicles are operated in normal service. To accomplish this, the Los Angeles portion of the CAPE-21 study was conducted using commercially owned and operated vehicles selected at random and operated in the normal service of the company by the company's normal drivers. Every precaution was taken to prevent interference with the operation of the driver of the vehicle during the survey period of a given vehicle. The primary data collected in the survey were that data which were considered vital to the testing of emission characteristics of heavy-duty engines or vehicles. These data consisted of RPM, load factor, and road speed measurements. The remaining data collected in the Los Angeles survey were time of day, road type, traffic condition, relative engine temperature, throttle closure, and vehicle identification. It is important that the logic associated with the methodology used in data collection and the type of data collected be reviewed at this time in order to clearly indicate the limits of the data base.

1. Vehicle Identification

Each vehicle tested in the Los Angeles survey was assigned an identification number. A complete listing of the vehicles tested in Los Angeles is given in table 4.

2. Time of Day

Time of day for operating periods was recorded in hours and minutes from a twenty-four hour interval clock. Since the data scan rate is .864 seconds, the time between minutes for any given scan location can be calculated. The scan rate was also used as a back-up for the normal time channels, hence data tape rejection for time channels was not necessary.

3. Engine RPM

Engine RPM was recorded in millivolts at a 10:1 ratio (RPM/millivolts). Because RPM was a pulse derived signal in all cases, precision calibration of the signal conditioner was achievable by use of a variable frequency function generator and an event/unit time counter (EPUT). Input versus output data was manually recorded during calibration so that crosschecking of the RPM to millivolt conversion could be accomplished at a later date, should the need arise.

TABLE 4

LOS ANGELES TRUCKS BY MANUFACTURER OF ENGINE

Manufacturer	Truck Number	Engine CID/Fuel	Year
		Ford	
Ford	7	V8-390/G	1973
Ford	10	V8-352/G	1965
Ford	11	V8-330/G	1972
Ford	12	V8-532/G	1966
Ford	16	V8-225/D	1968
Ford	17	V8-330/G	1974
Ford	18	V8-150/D	1972
Ford	19	V8- /G	1964
Ford	24	V8-361/G	1971
Ford	28	V8-391/G	1971
Ford	35	V8-391/G	1967
Ford	39	V8-534/G	1964
Ford	48	V8-361/G	
		International Harvester	
IH	8	V-549/G	1968
IH	13	I6-265/G	1968
IH	14	V-304/G	1969
IH	21	V8-345/G	1973
IH	26	V-304/G	1970
IH	40	V-345/G	1974
IH	43	V-549/G	1970
IH	47	V-304/G	1971
		Commins Engine	
Com.	9	NTC335/D/855	1969
Com.	20	NTC350/D/855	
Com.	31	NH220/D/743	1963
Com.	34	NTC290/D/855	1973
Com.	37	NTC335/D/855	1969
Com.	38	NH250/D/855	1969
Com.	44	NHC250/D/855	
Com.	46	NHC250/D/855	
		General Motors	
GMC	2	V6-305/G	1970
GMC	3	V6-351/G	1970

TABLE 4--Continued

Manu-facturer	Truck Number	Engine CID/Fuel	Year
		General Motors	
GMC	4	V8-350/G	1971
GMC	5	I6-250/G	1974
GMC	25	V6-305/G	1967
GMC	30	V6-351/G	1970
GMC	32	V8-350/G	1972
GMC	42	V8-366/G	1960
		Detroit Diesel	
DDAD	6	8V71/568/D	1974
DDAD	15	8V71N/568/D	1963
DDAD	22	8V71/568/D	
DDAD	23	8V71/568/D	1974
DDAD	27A	8V71/568/D	1973
DDAD	27	8V71/568/D	
DDAD	29	8V71T/568/D	1973
DDAD	41	8V71/568/D	1973
DDAD	41A	8V71/568/D	1971
DDAD	45	8V71/568/D	1974
		Dodge	
Dodge	36	V8-318/G	1969

G = Gasoline

D = Diesel

4. Load Factor

Load factor measurements taken in the Los Angeles portion of the CAPE-21 program were designed to relate rear wheel horsepower measurements to one of three (3) engine parameters depending on the engine fuel system. As discussed in section II F-7, the three fuel systems were:

a. Manifold vacuum in the case of gasoline engines,

b. Rail pressure in the case of vehicles equipped with Cummins Diesel engines, and

c. Rack position in the case of vehicles equipped with Detroit Diesel Allison division Diesel engines.

As previously discussed in section E of this report, it was originally proposed that load factor data recorded during the survey be converted to engine shaft horsepower through the use of math models derived for each vehicle from calibration data on that vehicle; i.e., engine shaft horsepower, can be considered linear to rear wheel horsepower at all RPMs when normalized to maximum power. This proposal was found to be inadequate in later phases of the data analysis program and the final procedure adopted is discussed in two EPA reports on the subject[3,4] which deal with the specifics of horsepower modeling techniques.

5. Road Speed

Vehicle road speed was taken from the speedometer take-off at the vehicle transmission or front wheel take-off in those vehicles so equipped. The accuracy associated with this measurement is equivalent to that associated with SAE standards for motor vehicle speed measurement systems. Some vehicles, however, were equipped with two speed uncompensated rear-ends which, under normal circumstances, introduce an error in the speedometer, and hence the road speed data. This error was corrected for in the CAPE-21 survey by the use of a road speed compensating network, which was manually activated by the on-board observer whenever the axle was placed in high gear by the driver.

6. Road Type

Road type information is a manual input accomplished by the on-board observer. Instructions to these observers on the operation of the switches controlling this input included not placing a road type switch in the "on" position until such time as the vehicle was actually on the particular road type indicated by that switch (i.e., freeway, arterial, or local street). This proved to be a most difficult requirement to control from the standpoint of accuracy in total time spent on a particular road type. For example, there is no way to determine precisely where the observer decided to change from one road type to another, i.e., at the on ramp to a freeway or after completing the merge with freeway traffic. Obviously, the total time associated with a given road type will depend on such a decision. Depending on the importance placed on this parameter by a user of this data during data analysis, a certain degree of special editing may be required to insure accuracy levels desired.

7. Traffic Condition

Traffic conditions were recorded in the same manner as was road data, that is, it was a manual input. It therefore, is subject to the same limitations in accuracy as the road type inputs discussed in item 6 above.

8. Throttle Position

Throttle position is a measure of driver demand rather than true throttle position. The measurement involves a detection system which simply indicates when the throttle is on the low speed stops, i.e., there is no demand for drive power.

9. Engine Temperature

Engine temperature is a relative measurement of thermal operating conditions. Because the sensing device was not physically located in the engine coolant system, only temperatures relative to ambient can be relied on, i.e., engine compartment temperatures which are predominantly made up of engine block temperature, but which are effected by temperatures associated with other devices in the engine compartment. Cold, warm, and hot operations can be identified by establishing cut points in temperature spreads, but assumed accuracies in absolute temperature beyond this is not recommended.

B. Data Format

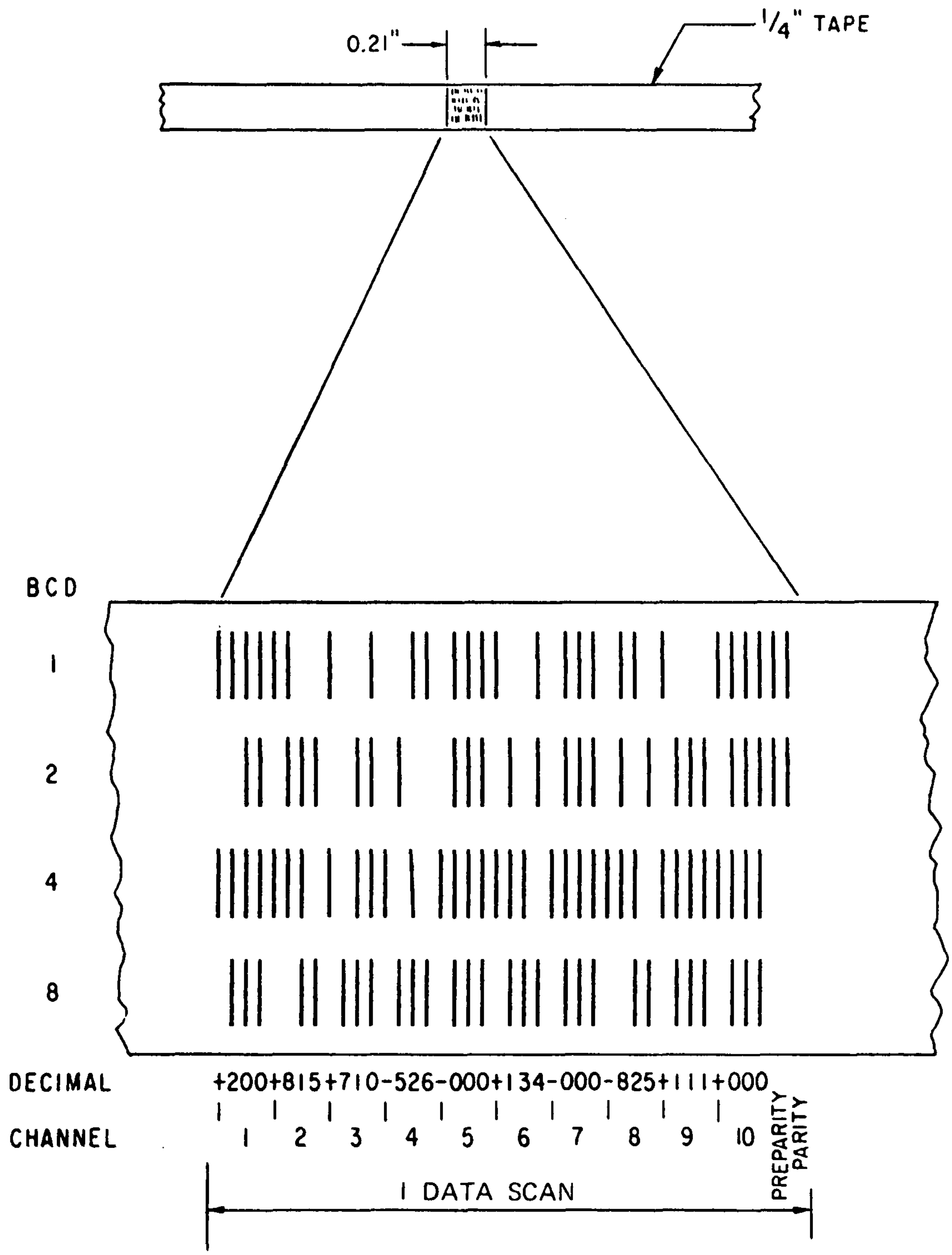
The data from the Los Angeles survey were stored on 1/4-inch magnetic tape cassettes.

1. Signal Levels and Recording Format

Data from each transducer were converted to single levels of 0, + or -1 V. The signals from the ten data channels were then multiplexed and converted to Binary Coded Decimal (BCD) form and recorded serially in four bit words, 4 bite/channel, see figure 7. Each data scan consisted of 56 words, thirty (30) data words (3 per channel x 10), eight sign words (one per channel except time and vehicle ID), and one preparity word and one parity word. The data are recorded in complement format at a density of 150 bits per inch.

C. Data Processing

Because the format described in Section B1 was not acceptable to



IDEALIZED CASSETTE DATA FORMAT

FIGURE 7

FIGURE 8

CASETTE CONVERSION - ZERO SCAN OUTPUT

```
Truck 3        Day 2

1                                                50
00058
00004
00001
zzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzz
zzzzzzzzzzzzzzzzzzzzzz 0001
zzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzz
zzzzz00001
zzzzzzz00001
zzzzzzzzzzz00001
zzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzz
zzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzz
zzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzz
00001
zzzzzzzzzzzzzzzzzzzzz00001
zzzzzzz00001
00001
zzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzz
zzzzzzzz00001
zzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzz00001
zzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzzz
zzzzzzzzzzzzzzz PE 0
RUN 7
SC 34,436
EC 78
```

most Automatic Data processing machines, a conversion process was required to convert the tape cassettes to, in this case, 9-track IBM compatible format.

During the conversion process a number of tests were performed on the data to establish the acceptability of the recorded information. These tests did nothing to substantiate the validity of the recorded data, but merely determined if, in fact, the recording format was correct. A test of this type was necessary because 1) the recorder when subjected to electrical noise could write erroneous data bits or characters, 2) the parity and/or pre-parity bits could be in error invalidating a particular data scan; and 3) the recorder had no provisions for read after write operation, and recorded data tapes were susceptible to skew errors caused by read head misregistration.

The test performed in the conversion process were:

a. "Z" test, this test checked the validity of a scan by checking the parity against the bit count in the scan. If the bit count did not match the parity word the scan was set to zero.

   The "Z" test, shown in figure 8, simply counted the number of zeroed records in a block of 60 consecutive records and printed a Z if none were zeroed, or the number equal to the total number of zeroed records counted.

b. Acceptance criterion check. This test, based on the "Z" test, rejected a tape if the total number of zeroed scans exceeded 10% of the total scans for the tape.

c. Readability check. This check consisted of dumping every 20th record to insure that the transcription process was producing a good IBM tape.

One additional task was performed during data processing, that task consisted of adding a header to the IBM tape which identified the vehicle by test number, indicated the number of days the vehicle was to be tested, and indicated the type of vehicle, i.e., Diesel or gasoline, number of cylinders, and the license number of the vehicle.

D. Data Tape Quality Control

To insure delivery of the best possible quality in data tapes to the processing center, a quality control process was used to allow rejection or acceptance of data tape cassettes in the field. The quality control procedure was also used as a diagnostic tool for isolating problems in instrumentation as well as personnel errors.

An on-board observer was assigned to each test vehicle. The observer was present at instrument installation and remained with the vehicle throughout testing. During testing it was the responsibility of each observer to read and manually record each data channel every thirty minutes. Because the readings taken from the recorder display did not reflect what was being written on tape (the recorder did not have read after write capability), a cathode-ray tube (CRT) display system was used to read each cassette after a days running. The CRT's electronics were programmed to read each scan of data and display that line, then when the parity word was read the CRT retraced and began writing the next scan of data directly under the first. If for any reason the parity word was incorrect there would be no retrace and the next line of data would be displaced indicating an error. Since the time channel could be used for locating any point in the data within 51 seconds (seconds were not recorded), the observer's log could be used to verify the approximate data that should have appeared on tape at a given time.

Using the CRT and the observer log, data tapes were checked after each days run. If for any reason the tape was found to be defective a decision was made as to what course of action could be taken to prevent loss of the vehicle to the survey, or the instrumenting of a new vehicle waiting for an entrance into the survey.

E. Resultant Data Base

At the end of the Los Angeles survey fifty-six vehicles were tested, the breakdown of which is:

1. 48 urban operated trucks,
2. 5 city buses,
3. 2 over-the-road (long haul) trucks (not intended for use in cycle development data base) and,
4. 1 over-the-road (long haul) bus.

Table 5 shows the final data base description.

TABLE 5

Truck Number	Day Number	Tape Error*	Total Zero Scans	Total Scans
1	4	1	154 + 60	23,758
1	5	0	206	44,446
1	6	0	308	28,162
1	7	0	70	26,211
1	8	0	116	38,328
1	9	0	41	26,628
2	2	0	58	19,260
2	3	0	56	20,228
3	1	0	30	22,672
3	3	0	76	16,742
3	4	0	38	5,008
4	1	0	12	7,834
4	2	0	122	17,162
4	4	0	46	16,809
5	1	1	133 + 60	12,049
5	2	0	62	5,820
5	4	0	121	8,070
6	1	0	78	22,668
6	2	0	19	18,664
6	3	0	33	24,771
7	2	0	66	4,529
7	3	0	17	23,714
7	4	0	20	21,624
7	5	1	22 + 60	22,008
8	1	0	914	29,573
8	2	0	17	32,074
8	3	0	140	35,929
8	4	0	102	31,954
9	1	0	103	31,648
9	2	0	30	27,468
9	3	0	1,257	27,667
9	4	0	5,715	40,110
9	5	0	3,086	40,018
10	1	0	357	11,213
10	2	0	1,012	21,918
10	3	0	37	14,686
10	4	0	25	13,300
11	2	0	21	19,897
11	3	0	730	18,523
11	4	0	86	17,667
11	5	0	42	16,378

*Note: If an error on 9-track tape happened during translation, the number of scans appears and 60 scans are added to the total zero scans for every tape error. 1 Record = 60 scans on 1/2 inch 9-track tape.

TABLE 5--Continued

Truck Number	Day Number	Tape Error*	Total Zero Scans	Total Scans
11	6	0	6	37,027
12	1	0	131	18,989
12	2	0	139	19,260
12	3	0	195	23,602
12	4	0	26	22,566
13	1	2	6 + 120	15,253
13	2	1	77 + 60	20,389
13	3	1	77 + 60	13,109
13	4	0	25	17,172
14	5	0	22	14,880
14	6	0	17	12,030
14	7	0	11	16,044
14	8	0	17	22,731
15	1	0	58	22,822
15	2	1	48 + 60	26,409
16	1	0	17	16,975
16	2	0	39	27,960
17	1	0	245	19,687
17	2	0	12	8,785
17	3	0	37	17,099
17	4	0	4,451	15,263
17	5	0	360	16,982
18	2	0	15	13,176
18	3	0	88	8,360
18	4	0	32	13,919
19	1	0	110	7,844
19	2	0	19	13,369
19	4	0	57	10,098
19	5	0	50	14,241
19	6	0	11	8,045
20	2A	0	486	15,490
20	2B	0	12	1,672
20	3	1	993 + 60	17,365
21	1	2	33 + 120	22,099
21	2	0	25	15,459
21	4	0	48	15,684
21	5	0	28	17,104
22	1	0	72	42,126
22	3	0	399	34,938
23	1	0	171	16,909
23	2	0	497	20,336
24	1	0	35	25,586
24	2	0	22	23,870
24	3	0	269	19,948

TABLE 5--Continued

Truck Number	Day Number	Tape Error*	Total Zero Scans	Total Scans
24	4	0	23	25,166
25	1	0	1,384	9,190
25	2	0	19	21,027
25	3	0	2,766	18,388
25	4	0	10	7,751
25	5	0	16	16,187
25	6	0	13	22,212
26	1	0	34	9,250
26	2	0	20	15,827
26	3	0	10	19,095
26	4	0	5	8,009
26	5	1	20 + 60	12,815
27	1	0	17	21,949
27	2	0	137	11,870
28	1	0	17	6,140
28	2	1	78 + 60	6,374
28	3	0	118	9,454
28	4	0	86	6,464
28	5	0	116	7,373
28	6	0	77	15,848
29	1	0	86	18,242
29	2	0	88	17,203
29	3	0	26	20,306
29	4	0	171	30,024
29	5	0	15	15,381
29	6	0	33	16,750
30	1	0	332	21,104
30	3	0	47	31,776
30	4	0	238	29,828
31	3	0	19	15,970
31	4	0	13	14,327
31	5	1	28 + 60	34,032
32	1	0	13	4,872
32	2	0	11	10,354
32	3	0	29	8,445
32	4	0	29	7,287
34	1	0	7	21,876
34	2	0	20	22,802
35	1	0	1,386	15,945
35	2	1	1,335 + 60	15,437
35	3	0	670	15,633
35	4	0	947	21,393
36	2	0	79	15,416
36	3	0	603	18,186

TABLE 5--Continued

Truck Number	Day Number	Tape Error*	Total Zero Scans	Total Scans
36	4	0	6	23,409
36	6	0	43	7,496
37	1	0	66	24,606
37	2	0	142	29,331
37	3	0	25	26,279
37	4	0	103	28,541
37	5	0	10	37,141
38	1	0	119	11,645
38	3	0	47	3,895
39	1	1	24 + 60	25,631
39	2	0	21	27,628
39	3	0	217	12,202
39	4	0	23	21,228
40	1	0	21	13,580
40	2	0	322	13,029
40	3	0	144	13,377
41A	1	0	808	15,857
41A	2	0	25	12,476
41	2	0	34	13,295
41	3	0	3,596	18,696
42	2	0	4,160	10,358
42	3	0	43	8,618
42	4	0	22	7,903
42	5	0	30	9,469
43	1	0	1,817	36,329
43	2	0	1,151	12,274
43	3	0	492	11,556
43	4	0	838	13,239
44	1	0	12	6,215
44	2	0	18	10,356
44	5	0	46	12,951
44	7	0	9	6,546
44	11	0	222	14,439
45	3	0	41	15,174
45	4	0	102	25,914
45	5	0	40	40,256
45	6	2	13 + 120	38,156
45	7	1	463 + 60	27,471
46	1	0	48	14,727
46	2	0	169	17,645
47	2	1	43 + 60	10,952
47	3	0	641	19,554
47	4	0	63	15,862
47	5	0	16	16,941

TABLE 5--Continued

Truck Number	Day Number	Tape Error*	Total Zero Scans	Total Scans
48	1	0	159	14,582
48	2	1	52 + 60	10,560
48	3	0	25	14,441
48	4	1	28 + 60	9,273
48	6	2	37 + 120	17,809
51	1	0	36	21,437
51	2	1	25 + 60	23,089
80	1	0	36	35,896
85	1	0	61	15,324
85	2	0	42	38,363
85	3	0	19	35,640
85	4	0	50	19,459
85	5	0	44	41,146
85	6	0	99	31,600
85	7	0	18	33,816

Bus Number	Day Number	Tape Error*	Total Zero Scans	Total Scans
90	1	0	403	17,468
90	2	1	24	24,418
90	4	0	101	25,560
91	1	0	78	58,658
91	2	0	48	57,658
91	3	0	152	56,808
92	3	1	51 + 60	45,469
92	4	1	20 + 60	12,298
92	5	0	209	40,058
93	1	0	77	50,167
93	2	0	93	49,707
94	2	1	102 + 60	46,725
94	3	0	166	43,084
94	1	1	199 + 60	44,693
95	1	0	32	84,198
95	2	0	5	19,408

IV. Summary

The combined, New York and Los Angeles CAPE-21 data base, represents the most comprehensive in-use heavy-duty truck study ever undertaken by any segment of the heavy-duty truck industry. There are still those who would comment that it is not complete. In any study of this magnitude, cost is the greatest restrictor to completeness, as was true in this case. The data collection, in the case of the CAPE-21 study, was confined to the needs of EPA for a data base designed for use in cycle development for heavy-duty truck testing. From this standpoint, the major parameters of interest were engine RPM, load factor, and vehicle speed. Other parameters measured during the survey may be used separately or in conjunction with the primary parameters, but only with a great deal of discretion.

Every possible precaution has been taken to insure that the data collected was of exceptional quality and presented in its purest form. But this is not to suggest that it was intended for use in all phases of heavy-duty truck testing or development. As previously mentioned, this report deals only with the particulars of data collection, the analysis of the collected data is the subject of another report, and will be presented at a later date. For this reason no reference has been made to any conclusions as to the validity of the data or its ability to meet the requirements of the cycle development goals of EPA.

LIST OF REFERENCES

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