FINAL REPORT

STUDY OF EMISSIONS IMPACT OF SELECTED AFTERMARKET PARTS

ARB CONTRACT NO. A0-138-32

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ABSTRACT

This study was conducted to determine the volume and pattern of sales of selected aftermarket parts in California, the differences in emissions, fuel economy and driveability between vehicles in the unmodified and modified states, and the factors which contribute to changes in emission levels. A survey of manufacturers/distributors and users of the aftermarket parts was conducted to determine the volume and pattern of sales. Four vehicles were obtained for testing. Two vehicles were used to evaluate exhaust headers and aftermarket intake manifolds. The other two vehicles were used to evaluate turbochargers. One vehicle from each group was used to evaluate the aftermarket parts in a "worst case" configuration, i.e. with a number of emission control components removed or disabled. The "worst case" configuration was representative of aftermarket parts which did not provide for reinstallation of emission control components and/or those persons installing aftermarket parts who would choose not to reinstall emission control components. The other vehicle from each group was used to evaluate the aftermarket parts in a "best case" configuration, i.e., with original emission control components installed and operating. The "best case" configuration was representative of aftermarket parts which provided for reinstallation of emission control components and those persons who would choose to reinstall those componenents if the aftermarket parts provided for their reinstallation. In the "worst case" configuration emissions increased substantially and fuel economy was generally improved, compared to original equipment configurations, by use of aftermarket parts. In the "best case" configuration emissions were increased slightly or were decreased, compared to original equipment, by use of aftermarket parts and fuel economy was generally increased.

ACKNOWLEDGEMENTS

This report was submitted in fulfillment of ARB Contract No. A0-138-32 "Study of Emissions Impact of Selected Aftermarket Parts" by Custom Engineering, Inc., under the sponsorship of the California Air Resources Board. Work was completed as of October 30, 1982.

DISCLAIMER

The statements and conclusions in this report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement for use or non-use of such products.

Section 1

SUMMARY

This report describes the conduct and findings of ARB Contract No. A0-138-32 "Study of Emissions Impact of Selected Aftermarket Parts". This section presents an overview of the program objectives and approach; summarizes the salient results; and states the conclusions of the program. Section 2 describes the sales and usage survey, the selection of aftermarket parts for testing, and the installation on test vehicles. Section 3 describes the test methodology. Section 4 discusses the results.

1.1 OBJECTIVES

Section 27156 of the California Vehicle Code requires that any add-on or modified part which alters or modifies the original design or performance of a vehicle's emission control system be exempted by the Air Resources Board before it can be legally sold for installation on on-road motor vehicles. The devices of particular concern, due to their potential adverse effect on emissions, are the following:

- replacement carburetors
- headers
- modified camshafts
- modified intake manifolds
- modified distributors
- turbochargers

These devices are often installed on recreational vehicles or "high performance" street vehicles and in some cases necessitate or encourage the removal of one or more emission control devices. For example, headers encourage catalyst removal and usually result in elimination of heated air intake and air injection ports. Headers may also affect the performance of back pressure modulated EGR valves and choke operation. The numbers of such devices sold and installed illegally and their impact on emissions has not been determined.

The purpose of this study was to determine the volume and pattern of sales of selected aftermarket parts in California, the differences in emissions between vehicles in the unmodified and modified state, and the factor(s) which contribute to changes in emission levels. The results of this study will be used to assess the impact of selected aftermarket parts on motor vehicles emissions and the need for control measures.

1.2 SCOPE

The program was divided into three tasks, as follows:

- Task 1: Survey of device sales and usage
- Task 2: Testing to determine the impacts of aftermarket parts
- Task 3: Analysis of data from Tasks 1 and 2 and preparation of the Final Report

Task 1 consisted of surveys of manufacturers/distributors and users of the six aftermarket parts listed in the program objectives. The survey sought to define the sales level and vehicle application of these aftermarket parts. Task 2 consisted of performing comparative (stock original equipment versus aftermarket) tests on two (2) vehicles which were equipped with headers and modified intake manifolds; and comparative tests on two (2) other vehicles which were equipped with turbochargers. The comparative tests entailed measurement of driveability demerits using the ARB's driveability procedure; and exhaust emissions and fuel economy during urban, highway, and steady speed driving modes. The Federal Test Procedure (FTP) was used for the urban driving mode. The Highway Fuel Economy Test (HFET) was used for the highway driving mode. The steady driving modes were 20, 30, 40, 50 and 60 mph at FTP road loads. During the steady speed tests, emissions, temperature and pressure were recorded to show the affect of the aftermarket part compared to the stock original equipment configuration. Task 3 consisted of an analysis of the collected data and a written report.

1.3 EXPERIMENTAL DESIGN

The test parts and vehicles tested were selected on the basis of the survey of sales and usage. Four vehicles were tested. Two vehicles were tested with headers and manifolds and two vehicles were tested with turbochargers. One vehicle in each group was tested in a configuration which retained related original equipment emission control components to the extent possible, when the aftermarket parts were installed. This configuration simulated the expected "best case" use in terms of impact on exhaust emissions. The other vehicle in each group was tested in a configuration in which related original equipment emission control system components were removed or disabled when installing the aftermarket parts to simulate the expected "worst case" use in terms of impact on emissions.

The test protocol consisted of baseline testing to determine whether each vehicle met the applicable emission standards. However, three of the four vehicles exceeded at least one of the three measured emission standards. The selected parts were then installed and the test sequence repeated. Headers and manifolds were tested using the FTP, HFET and driveability tests. In addition, steady-state tests were performed at 20, 30, 40, 50 and 60 miles per hour. Turbochargers were tested using the FTP, HFET and steady-state tests, all at normal road load and, for the Corvette only, at twice normal road load. The VW overheated and could not be tested at twice or even 1.5 times normal road load.

1.4 RESULTS

1.4.1 Survey of Device Sales and Usage

The survey of aftermarket parts industry firms was expected to provide an estimate of the annual unit sales in California for each type of aftermarket part. Unfortunately, the response rate was poor and the annual sales estimates shown below are somewhat uncertain.

Part Type		Estimated Annual Sales (1981)
Headers	-	68,000
Modified intake manifolds	-	32,000-40,000
Turbochargers	-	2,000
Modified distributors	-	50,000
Camshafts	-	66,000
Carburetors	-	27,000

The most common engine on which parts were installed were the small block Chevrolet V-8 (305, 327, 350 CID). The only significant exception was for turbochargers which were frequently installed on 4 cylinder engines. Most of the vehicles (80%) on which aftermarket parts were installed were registered for street use but most vehicles were not the owner's primary vehicle. Almost 60 percent of the automobiles owned by survey respondents had 2 or more of the selected aftermarket parts installed.

1.4.2 Exhaust Headers Compared To Original Equipment

The worst case aftermarket exhaust header configuration used in this program increased all three of the measured exhaust emissions by a minimum of 25%, improved fuel economy 10%, degraded cold drivability, and improved acceleration (0-70mph) time by four seconds compared to the stock original equipment configuration. The best case exhaust header configuration increased hydrocarbon (HC) emissions by 21%, decreased carbon monoxide (CO) emissions by 41%, and did not significantly change oxides of nitrogen (NO_x) emissions. Fuel economy improved 41% while driveability was degraded, but acceleration time decreased five seconds during the 070 mph acceleration.

1.4.3 Modified Intake Manifolds Combined With Exhaust Headers Compared to Original Equipment

Modified intake manifolds were tested in combination with the aftermarket exhaust headers. For the best case manifold/header package, HC emissions increased 152%, CO and NO_x emissions decreased approximately 30%, fuel economy increased 23%, driveability was degraded and acceleration time decreased 2 seconds. For the worst case manifold/header configuration, HC emissions increased 266%, NO_x emissions increased 107%, CO emissions were not significantly affected, and fuel economy increased 21%. Driveability improved considerably and acceleration times decreased 5 seconds.

1.4.4 Turbochargers Compared to Original Equipment

Turbochargers were tested alone. For the best case turbocharger configuration, a California exempted kit was used. Hydrocarbon (HC) emissions increased 12%, CO emissions increased 52%, NO_x emissions decreased 26% and fuel economy decreased22% on the FTP and 15% on the HFET. For the worst case turbocharger configuration, a non-exempted kit was used and the catalytic converter was removed. All three exhaust emissions increased several fold and fuel economy was marginally improved. Driveability evaluations of the turbochargers were not conducted.

1.5 CONCLUSIONS

The following general conclusions can be drawn from this study:

- Aftermarket parts sold in California are generally used on vehicles registered for street use.

- The sales volume of aftermarket parts is ranked in the following order:

  headers > camshafts > distributors > intake manifolds > carburetors > turbochargers

- Aftermarket parts can cause significant adverse emissions impact when their use causes removal or inoperability of emission control components.

- Installation of currently marketed parts, such as those evaluated in this study, increases at least one of the three regulated exhaust emissions and generally degrades driveability. Fuel economy was generally improved with the use of headers/manifolds, however, it is important to note that the fuel economy percentage increase observed in this study was much greater than typical.

- There is insufficient data to draw meaningful conclusions from pressure measurements in terms of predicting emissions impact of aftermarket turbochargers or in establishing the factors contributing to emissions impact.

- The temperature and pressure measurements taken revealed that headers/manifolds do change the operating characteristics of an engine. Although emissions generally increased with after market parts usage, the increase was attributable to the effect these parts had on installation or function of other emissions related components; i.e., carburetors, EGR valves, secondary air, catalysts, etc.

Section 2

AFTERMARKET TEST PARTS

This section describes the survey of device sales and usage, the selection of parts for specific vehicles and the installation of parts.

2.1 DEVICE SALES AND USAGE

No published data were available. Therefore, Custom Engineering contracted with CIC Research, Inc., to conduct an independent direct survey of sales and usage of exhaust headers, modified intake manifolds, distributors, turbochargers, camshafts and carburetors. The objectives of this survey were to provide a basis for selecting the specific vehicle type and parts for testing. The complete survey is attached as Appendix A. The following paragraph summarizes the survey report in terms of:

- survey of firms manufacturing aftermarket parts
- survey of households
- data preparation and analysis
- results of survey

2.1.1 Survey of Firms Manufacturing Aftermarket Parts

The sample frame for the survey of business firms was developed jointly by CIC Research, Custom Engineering, and the ARB. The starting point was the Specialty Equipment Manufacturers Association (SEMA) Membership Directory, from which the names of all manufacturers and distributors of aftermarket parts were taken. A total of 178 firms were selected to be contacted in the survey of firms. From the list 15 firms were randomly selected for face-to-face interviewing, while the remaining 163 were slated for telephone interviews.

The survey instrument was developed by CIC Research with input from Custom Engineering and the ARB. An introductory letter was also designed for mailing to each firm before being telephoned by an interviewer. It was anticipated that SEMA would endorse the survey and a statement to that effect would be included in the letter of introduction. However, SEMA endorsement was not received.

Letters of introduction were mailed in three waves in late October and early November 1981. Telephoning began approximately one week after the first mailing and continued through January 6, 1982. A total of 38 firms out of 178 contacted were interviewed in the firm survey. Only three of the selected 15 firms completed a personal interview.

From an analytical standpoint, the survey of firms in the aftermarket parts industry was not highly successful. Of the 178 firms for which contact was attempted, almost 40 percent indicated they did not participate in the selected aftermarket parts industry. Additionally, 12 percent of the sampled firms appear to have left the industry. Direct refusals and the "unable to contact" category significantly diminished the response set. The 38 firms interviewed represent 42.6 percent of the firms which realistically could be part of the selected aftermarket parts industry. However, the information obtained should be considered in terms of its qualitative significance only.

2.1.2 Survey of Households

After discussions between CIC, Custom Engineering, and the ARB, it was determined that the sample frame for the household survey would be current subscribers of two popular car magazines who reside in Southern California. After several delays, during which one publisher changed his mind about providing their mailing list, a list of subscribers to Hot Rod Magazine was eventually received. However, the list was not useful because it contained names of subscribers nationwide and insufficient California residents to complete the survey. The second mailing list was also inaccurate in that it contained only Los Angeles and a few Orange County residents rather than subscribers representative of all Southern California counties. However, given the delays encountered already, it was felt that it was better to work with the sample frame in hand rather than suffer another delay.

The sample was 1,250 randomly selected names from the mailing list of 5,000 Hot Rod subscribers. Then, using telephone directory assistance, CIC's interviewers attempted to secure a telephone number for each of the selected subscribers. Interviewers were able to get numbers for less than half of the subscribers chosen which necessitated randomly selecting additional names in order to complete a quota of 300 interviews.

Interviewing for the household survey began on November 23, 1981, and was concluded on January 15, 1982. Three young men were specifically selected for the interviewing task because of their extensive knowledge of automobiles and aftermarket parts. A briefing was held on November 23 prior to the start of interviewing.

Interviews were conducted from 4:30 p.m. to 9:30 p.m. on weekdays and 10:00 a.m. to 6:30 p.m. on weekends in CIC's central telephone facility. At least four attempts were made to contact a knowledgeable respondent in each household. Callbacks were arranged when requested by the respondent as the interview often became lengthy due to the number of parts purchased by household members.

Over one half of the contacted households reported not having purchased aftermarket parts in the last three years. Therefore, a total of 1,024 phone numbers were required to complete a quota of 300 interviews. In general, the subscribers to Hot Rod Magazine tended to be somewhat different from the general California population in that their automotive preferences were skewed toward U. S. (General Motors) car products, and they were younger with higher income than the median Californian.

2.1.3 Data Preparation and Analysis

A supervisor was present at all times during the interviewing to answer questions as they arose and to edit the completed questionnaires. After the questionnaires were edited, a codebook was designed and each questionnaire was then coded using the prepared codebook.

After being coded and edited, the questionnaire data were entered onto computer tape via a remote keyboard terminal. A data edit program monitored the keypunched data as they were entered for correct range, completeness and illogical response. In this way, the data set was quality audited in preparation for the data analysis.

The data were analyzed using the Statistical Package for the Social Sciences (SPSS). Appropriate descriptive statistics, frequency distributions, and test statistics were computed. In addition, extensive cross-tabulations were performed. Complete tabulations are contained in Appendix A.

2.1.4 Results of Survey

Based on survey responses, the distribution (Table 2-1) of business activity within the aftermarket parts industry differs depending on the equipment in question. The greatest percentage of firms indicated business activity with headers (i.e., 65 percent). Firms involved with turbochargers and carburetors represented the smallest percentage of activity (21 and 26 percent respectively).

Table 2-1. MARKET ACTIVITIY OF RESPONDENT FIRMS

	Respondent Category	
Type of Part	Percentage of Firms Indicating Activity Within the Market	Percentage of Active Firms With More than One Function Within the Chain of Distribution
Header	65.3%	61.9%
Intake Manifold	33.7	36.4
Turbocharger	21.1	62.5
Distributor	31.6	58.3
Camshaft	34.2	46.2
Carburetor	15.8	50.0

Source: CIC Research, Inc., Survey of Aftermarket Parts Firms, 1981

As was anticipated, firms within the industry tended to provide multiple functions within the chain of distribution. It was not uncommon for a firm to distribute and retail a particular aftermarket part. As Table 2-1 indicates, firms dealing with headers and turbochargers tended to provide multiple functions more prevalently than other parts firms. Alternatively, firms that dealt with intake manifolds tended to provide single functions (e.g., manufacturing only).

Firms were asked to indicate their sales activities for 1978, 1979, and 1980. The data collected indicated that little variance in activity was perceived by the respondents for those years. In addition, it would appear that firms had difficulty estimating sales activity in 1978 and 1979.

Firms were also asked to note make, engine size/type, year, prevalent model, and percentage of sales for each selected aftermarket part that they handled. With very small subsample sizes, it is difficult to rank this type of information. However, Table 2-2 provides the top ranked combinations as indicated by the firms for each aftermarket part. In the case of intake manifolds, Chevrolet 350 CID engines and Volkswagens with unknown displacements were mentioned equally.

In order to develop Table 2-2, all years and cars were aggregated. On the whole, the firm's most popular parts tended to be related to the same car maker as the most popular part (usually just a different engine size).

Table 2-2 MAKE, ENGINE SIZE, AND TYPE FROM FIRM SURVEY*

Part Category	Make(s)	Engine Size (Cubic Inches)	Type
Headers	Chevy	Chevy Small Block	V8
Intake Manifolds	Chevy	Chevy Small Block	V8
	VW	Unknown	Opposed 4
Turbochargers	Chevy	Chevy Small Block	V8
Distributors	Chevy	Chevy Small Block	V8
Camshafts	Chevy	Chevy Small Block	V8
Carburetors	Chevy	Chevy Small Block	V8

*Data contained in this table have qualitative significance only.
Source: CIC Research, Inc. Survey of Aftermarket Parts Firms, 1981.

The application of the item (i.e., street use or racing use) according to the firms is provided in Table 2-3. Again, small sample sizes precluded definitive statements being made. However, on a qualitative basis, it would appear that the items in question are expected to be used on the street.

Table 2-3

FIRMS' ESTIMATE OF STREET USE FOR SELECTED AFTERMARKET PARTS*

Part Category	Firm Subsample Size	Mean	Median
Headers	10	75%	80%
Intake Manifolds	3	43	50
Turbochargers	3	97	98
Distributors	6	45	43
Camshafts	5	58	63
Carburetors	3	60	68

*Data contained in this table have quantitative significance only.

Source: CIC Research, Inc., Survey of Aftermarket Parts Firms, 1981

2.1.5 Purchase and Usage Description

Almost 40 percent of the Hot Rod Magazine subscribers contacted indicated that they had purchased at least one of the selected aftermarket parts in the last three years. Table 2-4 summarizes the distribution of purchases by part type. Not too surprisingly, turbochargers represented the least-purchased item (5%), while headers (64%) and carburetors (69%) represented the most often purchased equipment. In addition, as the table indicates, respondents commonly purchase more than one of the selected aftermarket parts.

The overwhelming majority of respondents indicated that the part was installed on an eight-cylinder engine. The notable exception was the turbocharger (i.e., half were installed on four-cylinder automobiles). In general, the six-cylinder market appeared to be the least active from the respondent's point of view.

Respondents were asked if the vehicle into which the aftermarket part was installed was registered for street use and if it was the primary transportation. The largest proportion of these parts appear to be used on California streets, although the vehicle is the primary transportation for less than one-half of the respondents.

Table 2-4

DISTRIBUTION OF PURCHASES
IN THE LAST THREE
YEARS BY EQUIPMENT TYPE

Purchase Category	Headers	Intake Manifold	Turbo-Chargers	Distributors	Camshafts	Carburetors
None	36.0%	51.7%	94.7%	57.7%	59.0%	30.7%
1	51.7	39.7	5.0	36.3	31.0	55.0
2	10.0	7.0	0.0	4.7	7.3	8.0
3	1.7	1.0	0.3	0.7	1.0	4.0
4 or more	0.6	0.6	0.0	0.7	1.6	2.4
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: CIC Research, Inc., Survey of Aftermarket Parts Users, 1981

Table 2-5 summarizes the make, engine, size, type, and years for the top five ranked engines for each part type. The Chevrolet 350 CID V-8 is by far the most popular engine on which aftermarket parts were installed, accounting for approximately 25 percent of all applications. The major exception to this rule appears to be in the turbocharger category.

Recognizing the limitations of the data, estimates of annual California sales may be made. The survey results indicate that approximately 68,000 headers are sold in California each year. The sales of intake manifolds appear to fall between 32,000 and 40,000 annually. Turbocharger sales in California seem to be less than 2,000 units. Based on the survey's market share estimates, the California sales of distributors averaged 50,000 units while camshaft sales averaged 66,000 units. California carburetor sales appear to be about 27,000 units annually.

2.2 SELECTION OF TEST PARTS

The results of the survey discussed above were used to select the test parts and the test vehicles. The recommendation was submitted for ARB approval.

2.2.1 Aftermarket Parts Recommended For Testing

This contract was directed specifically toward testing exhaust headers, intake manifolds, and turbochargers. These components were ranked in order of utilization as follows by the survey:

Firm Survey	Household Survey
Headers	Carburetors
Camshafts	Headers
Manifolds	Manifolds
Turbochargers	Distributors
Carburetors	Camshafts
Distributors	Turbochargers

For the three parts of primary contractual interest, both surveys confirmed the ranking of:

Headers > Manifolds > Turbochargers

The experimental approach consisted of testing headers individually, headers and intake manifolds in combination and, turbochargers individually. These parts were evaluated in a "best case" configuration (original emission controls installed and operating) and a "worst case" configuration (certain emission controls removed or disabled).

Table 2-5

MAKE, ENGINE SIZE, TYPE AND YEARS: TOP RANKED ITEMS FROM USERS SURVEY

Rank	Make	Size (Cubic Inches)	Type	Percent of Cars	Years
			HEADERS		
1	Chevy	350	V8	29.5%	1969, 1970, 1972
2	Chevy	327	V8	6.7	1967
3	Ford	351	V8	5.8	1969, 1971
4	Ford	289	V8	4.9	1965, 1967
5	Ford	302	V8	4.0	1970, 1978
			INTAKE MANIFOLDS		
1	Chevy	350	V8	30.6%	1969, 1970, 1972
2	Chevy	327	V8	8.3	1964
3	Ford	289	V8	5.7	1965, 1967
4	Chevy	396	V8	4.5	1965, 1969
5	Ford	351	V8	3.8	1972
5	Chevy	400	V8	3.8	--
5	Ford	302	V8	3.8	1969
			TURBOCHARGER		
1	VW	98	Opposed 4	14.3%	1969, 1978
1	VW	104	Opposed 4	14.3%	1973
			DISTRIBUTORS		
1	Chevy	350	V8	27.3%	1969, 1970, 1972
2	Ford	289	V8	5.8	1965, 1966
2	Chevy	327	V8	5.8	1967
2	VW/Datsun	98	Opposed 4/ Straight 4	5.8	1966, 1969, 1972
3	Ford	351	V8	5.0	1971
			CAMSHAFTS		
1	Chevy	350	V8	23.2%	1970, 1971, 1972
2	Chevy	327	V8	8.5	1967
3	Ford	289	V8	4.9	1965
3	Ford	302	V8	4.9	1969
3	Ford	351	V8	4.9	1972
3	Chevy	396	V8	4.9	1965
			CARBURETORS		
1	Chevy	350	V8	24.6%	1970, 1972
2	Chevy	327	V8	7.7	1968
3	Ford	289	V8	4.4	1965
4	Ford	351	V8	4.0	1972
4	Chevy	396	V8	4.0	1968

Source: CIC Research, Inc., Survey of Aftermarket Parts Users, 1981.

2.2.2 Vehicle Application of Aftermarket Parts

The survey identified the Chevrolet 350 CID engine as the most popular single engine for installation of most parts. Approximately 80% of parts were installed on V-8 engines. Turbochargers, however, were disproportionately installed on four cylinder engines (approximately 50%) rather than eight cylinder engines (36%). Based on the survey, the recommended vehicles were two V-8 engines for header and manifold evaluations and one V-8 and one opposed 4 cylinder engine for the turbocharger evaluation. The ARB specified that vehicles be late model (1978 or newer) and equipped with California certified emission controls.

Based on the parts and vehicle applications, a specific selection of components was made. This selection was based on choosing the predominate or available manufacturer of a part suitable for the recommended vehicle. Table 2-6 shows the final recommendation.

2.3 INSTALLATION OF PARTS

2.3.1 Procurement and Preparation of Vehicles

The four cars shown in Table 2-7 were procured for testing. The four cars were rented and were returned to the rental agency after testing. The cars all had California certified emission configuration. When received at Custom Engineering, each car was inspected to ensure that it met manufacturer's specifications. This process included a pre-test cold FTP to determine if the car complied with California emission standards. Three of the four cars failed California emission standards even after functional checks of emission controls, tune-ups, and carburetor overhaul. Once the pre-test data were accepted by ARB, the vehicle was accepted for testing and the specific temperature probes or measurement ports required for each car were added prior to the baseline test. Table 2-8 shows the test cases for each car.

2.3.2 Installation of Exhaust Headers

Exhaust headers were evaluated on two cars, the Chevrolet Malibu and the Ford Granada. The headers were installed by Turbo International in accordance with manufacturer installation instructions. For the Chevrolet Malibu, the original equipment emissions system was changed as follows: air injection ports, heat riser, and catalyst were removed. This configuration simulated the worst case use of headers. The installations are shown in Figures 2-1 through 2-4. Thermocouple and pressure probe installations are shown in Figure 2-5 for the original equipment configuration.

TABLE 2-6. RECOMMENDED VEHICLE AND DEVICE SELECTION FOR AFTERMARKET PARTS SURVEY

	Headers & Manifolds		Turbochargers	
	Vehicle #1 & 3	Vehicle #2 & 4	Vehicle #5	Vehicle #6
MODEL YEAR:	1978 - 1979	1978 - 1979	1979	1978 - 1979
MAKE:	GM	Ford	Camaro	VW
MODELS:	Impala, Caprice Nova, El Camino Corvette, Camaro Phoenix, Firebird Omega, Skylark	Ford, Mercury Granada Fairmont, Monarch Mustang, Zephyr	Corvette (No Other Models Types Exempted)	Rabbit, Dasher Scirocco
ENGINE TYPE:	350 V-8	302 V-8	350 V-8	97 Inline 4
FAMILY:	78 810J4S 79 910L4RU	79 5.0 AV 78 302AV	910L4RU	37C
CARBURETOR:	4V	2VV	4V	FI
TRANSMISSION:	A-3	A-3	A-3	A-3
EMISSION CONTROLS:	AIR-EGR-OC	AIR-EGR-O	AIR-EGR-OC	OC-EGR-MFI
HEADER TYPE:	Eagle[1]	Hooker[2]	Turbo International[3]	Callaway[4]
MANIFOLD TYPE:	Holley Z Manifold[5]	Edelbrock SP2P[6]		

1. Order Header w/o: Hot Air Duct, Air Injection Ports, EFE or Heat Riser, if applicable. — Headers connected to standard street adapter. A Y pipe must be used to join headers for single exhaust using OEM muffler. Catalyst is removed before the evaluation. 2-2 1/2 inch single exhaust without catalyst.

2. Order Header with: Hot Air Duct and EFE Valve (if applicable) — Headers connected to standard street adapters. A Y pipe must be used to connect headers to calayst inlet. Catalyst must be retained in the same OEM position with pipe and headers installed.

3. Install California exempted kit only
4. Catalyst must be removed when kit is installed
5. Order manifold w/o EGR valve connection and w/choke extension kit. Use Holley gaskets for installation
6. Order manifold w/EGR (or install manifold w/EGR valve). Use Edelbrock gaskets for installation

Table 2-7

BASELINE VEHICLE CONFIGURATION

MAKE	CHEVROLET	FORD	CHEVROLET	VOLKSWAGEN
MODEL	MALIBU	GRANADA	CORVETTE	RABBIT
YEAR	1979	1976	1976	1980
VIN	1W27H9Z449726	6W82F170267	1Z37L65438271	17A0915614
ENGINE FAMILY	910L4RU	302 "A"-ICFE	11K4	37C
ENGINE	305 V8	302 V8	350 V8	97 I4
TRANSMISSION	A-3	A-3	A-3	A-3
FUEL SYSTEM	4V	2V	4V	FI
INERTIA WEIGHT	3500	4000	3625	2250
ROAD LOAD HP	10.3	13.2	9.9	6.8

Table 2-8

AFTERMARKET PARTS TEST CASES

MAKE	CHEVROLET	FORD	CHEVROLET	VOLKSWAGEN
MODEL	MALIBU	GRANADA	CORVETTE	RABBIT
PARTS	HEADER/MANIFOLD	HEADER/MANIFOLD	TURBOCHARGER	TURBOCHARGER
CASE	WORST	BEST	BEST	WORST
EXHAUST HEADER	EAGLE	HOOKER	NE	NE
INTAKE MANIFOLD	HOLLEY Z	EDELBROCK SP2P	NE	NE
TURBOCHARGER	NE	NE	TURBO INTN'L	CALLAWAY
EMISSION CONTROLS	AIR-EGR-OC	AIR-EGR-OC	AIR-EGR-OC	TWC/CL-MFI
CATALYST REMOVED	YES	NO	NO	YES
EGR REMOVED	YES	NO*	NO	NO
AIR REMOVED	YES	NO	NO	NO
EFE REMOVED	YES	NO	NO	NE

NOTES:

NE - Not equipped

EGR - Exhaust gas recirculation

AIR - Air injection system

EFE - Early fuel evaporation (heat riser)

OC - Oxidation catalyst

MFI - Mechanical fuel injection

* - Replaced with 1978 model year EGR valve

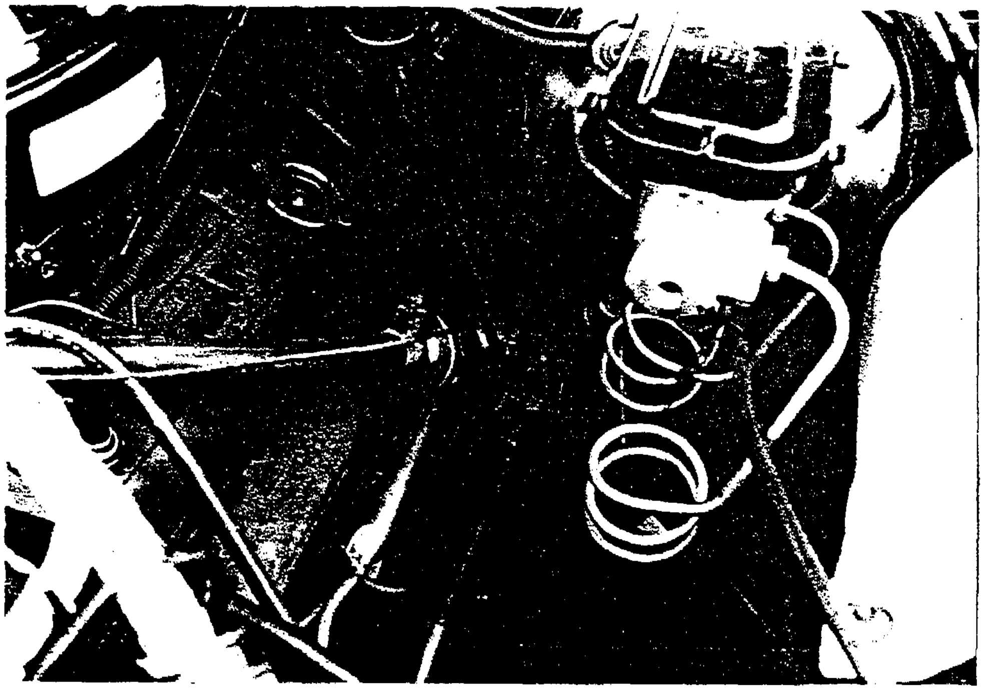

Figure 2-1. Chevrolet Malibu With Original Exhaust Manifold Showing Engine Oil Thermocouple

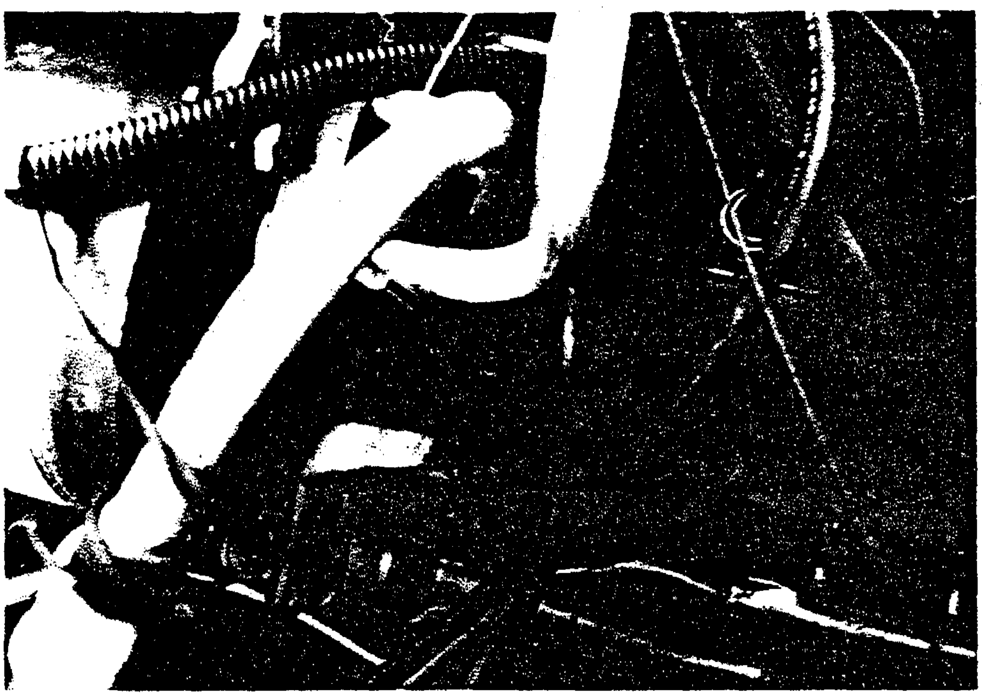

Figure 2-2. Chevrolet Malibu With Original Exhaust Manifold Showing Thermocouple Installation

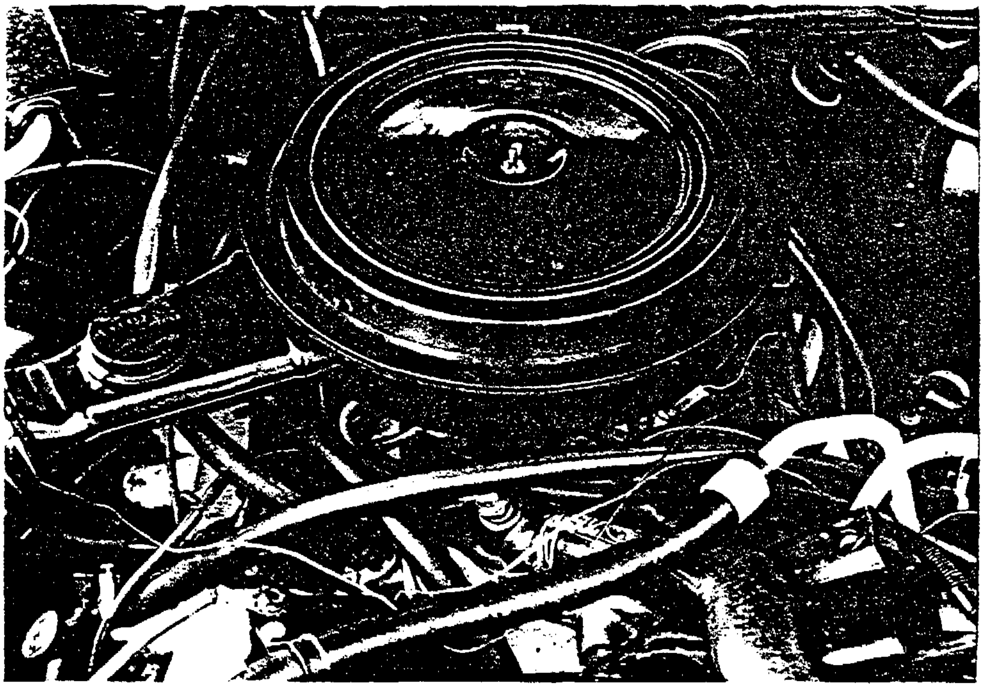

Figure 2-3. Chevrolet Malibu Showing Exhaust Header Installation Ready For Test

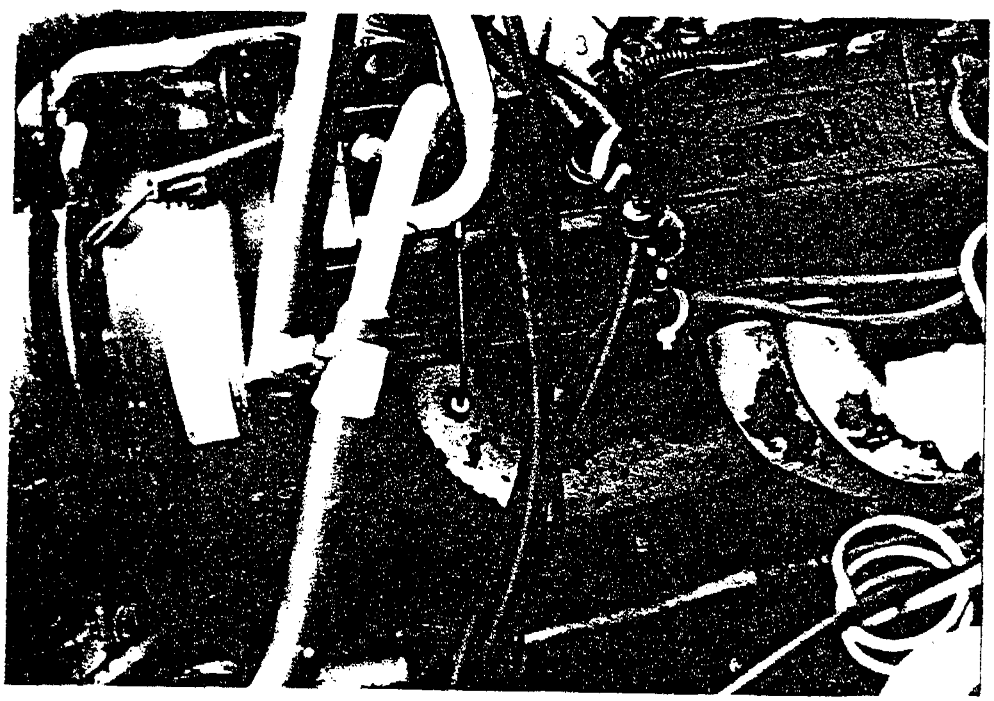

Figure 2-4. Chevrolet Malibu Showing Exhaust Header Installation and Thermocouple

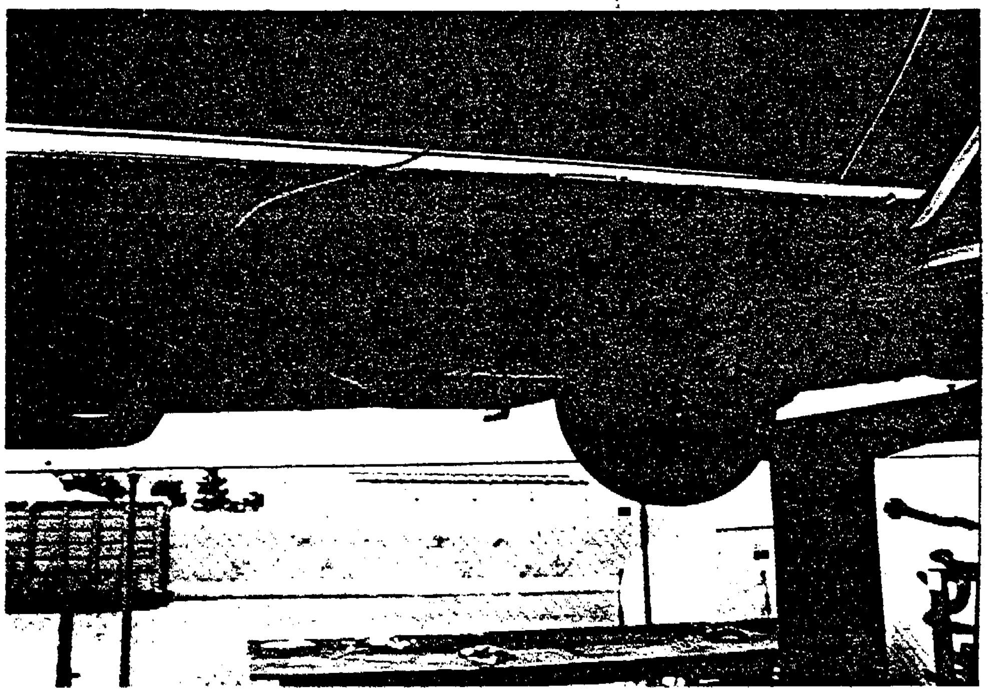

Figure 2-5. Chevrolet Malibu Showing Thermocouple and Pressure Probes Before and After Catalyst

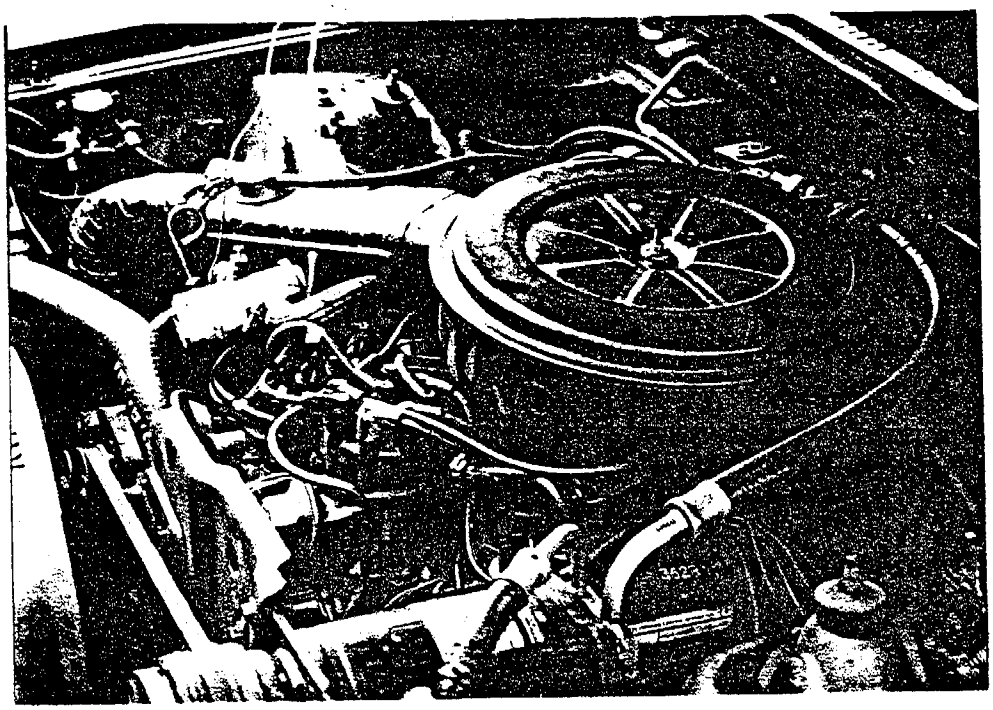

Figure 2-6. Ford Granada Showing Original Equipment Configuration

For the Ford Granada, the original equipment emission system components were left intact. The air injection ports were in the heads, not the exhaust manifold or headers. This configuration simulated the best case use of headers. The original equipment configuration is shown in Figure 2-6. Figure 2-7 shows the thermocouple in the original exhaust manifold. Figure 2-8 shows the exhaust header installed. Figure 2-9 shows the locations of thermocouples and pressure ports before and after the catalyst. Also shown in Figure 2-9 are the exhaust header collectors.

2.3.3 Installation of Intake Manifolds

Modified intake manifolds were tested on the same two cars as the exhaust headers and were tested in combination with the exhaust headers. The best and worst case simulations were maintained. Figures 2-10 and 2-11 show the installation of the Holley Z manifold without EGR on the Chevrolet. Figure 2-12 shows the Edelbrock SP2P manifold installed on the Ford. During installation, the original equipment 1976 EGR valve was replaced with a 1978 model year EGR valve because the SP2P manifold had the flange bolt pattern used on the later model EGR valves. A flange adapter available from Edelbrock which would have permitted installation of the 1976 EGR valve was not used. Figure 2-13 shows both the manifold and the headers installed on the Ford. Figure 2-14 shows the Ford with the Edelbrock SP2P manifold and Hooker headers ready for test.

2.3.4 Installation of Turbochargers

A turbocharger was installed on the Chevrolet Corvette and VW Rabbit. For the Corvette, the original equipment emission controls were retained. However, the carburetor hot air system was removed and the original equipment air cleaner was replaced with one recommended by the turbocharger manufacturer. These changes were required during installation due to limited underhood clearance. This configuration simulated the best case use of turbochargers. Figures 2-15 through 2-17 show the Turbo International installation from various angles. For the VW, the original equipment catalyst was removed during installation of the Callaway turbocharger. All other emission control components were retained intact. Figures 2-18 through 2-19 show the installation. Figure 2-20 shows the straight pipe replacement for the catalyst. This configuration represented the worst case use of turbochargers.

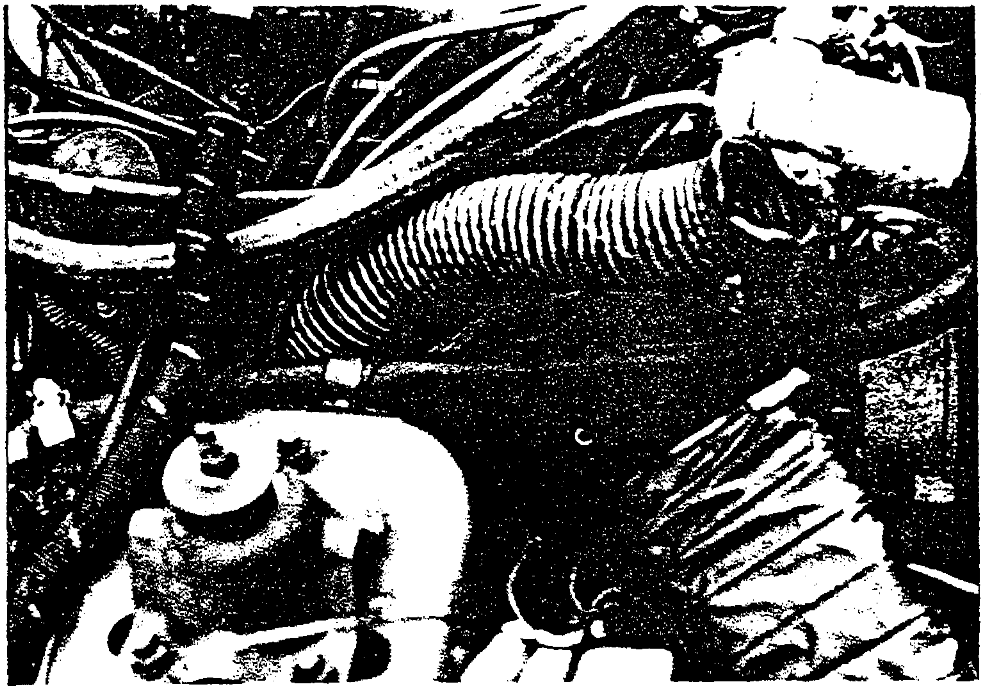

Figure 2-7. Ford Granada Showing Thermocouple in Original Exhaust Manifold

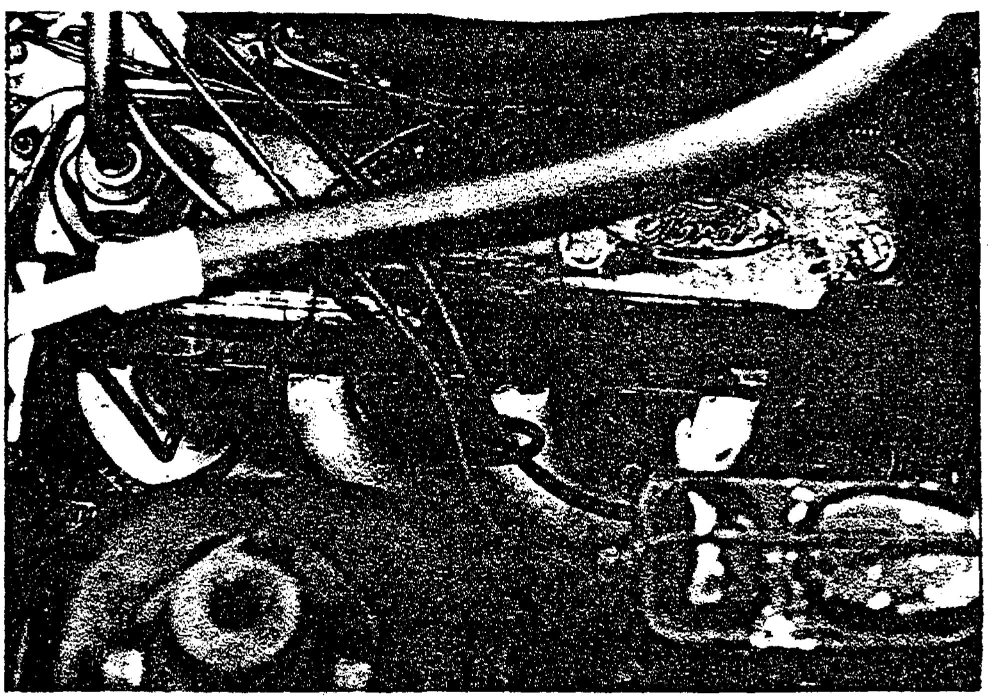

Figure 2-8. Ford Granada Showing Exhaust Header

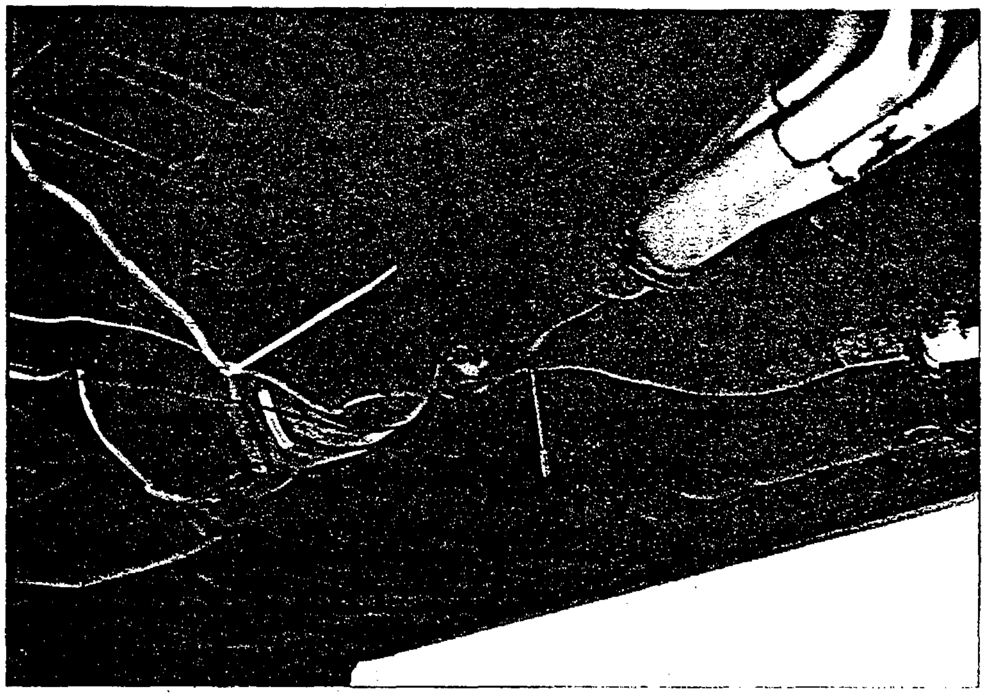

Figure 2-9. Ford Granada with Exhaust Headers Showing Pressure Ports and Thermocouples Before and After Catalyst

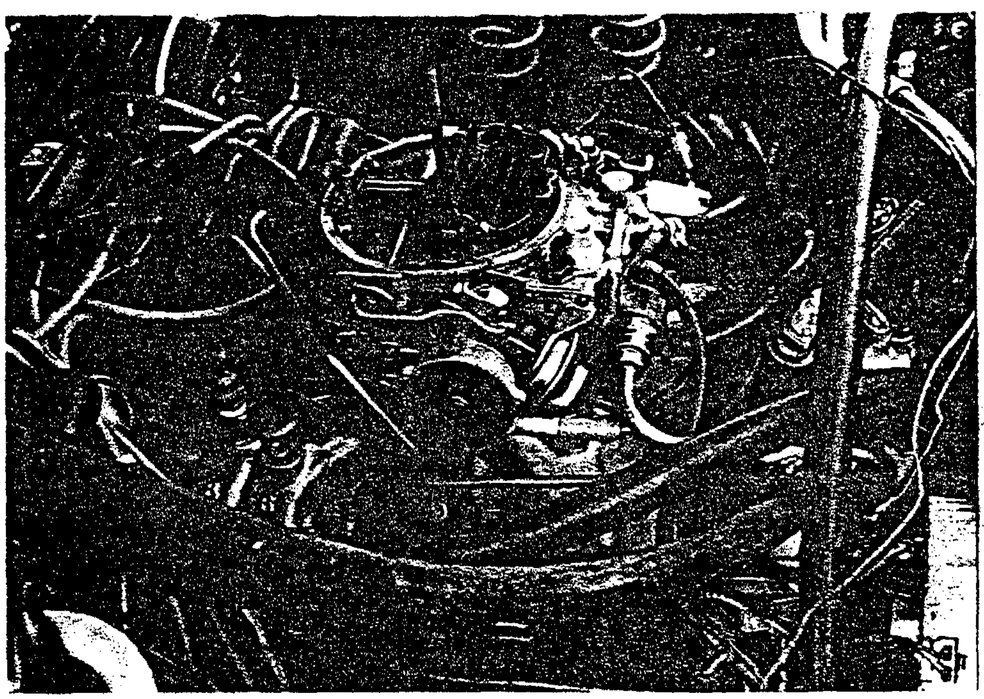

Figure 2-10. Chevrolet Malibu Showing Intake Manifold From Passenger's Side

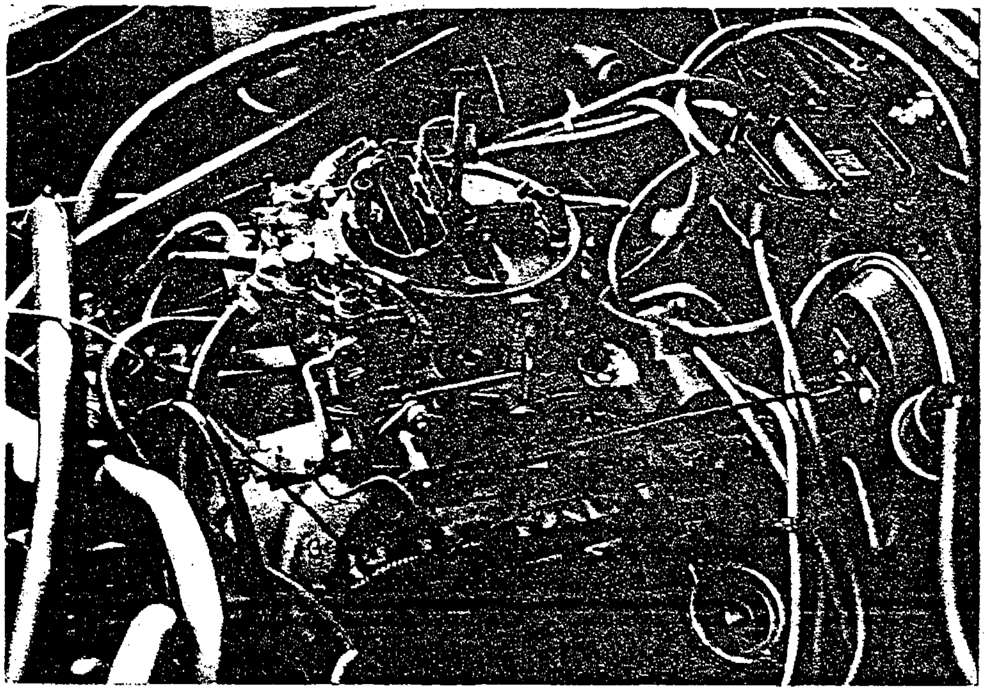

Figure 2-11. Chevrolet Malibu Showing Intake Manifold From Driver's Side

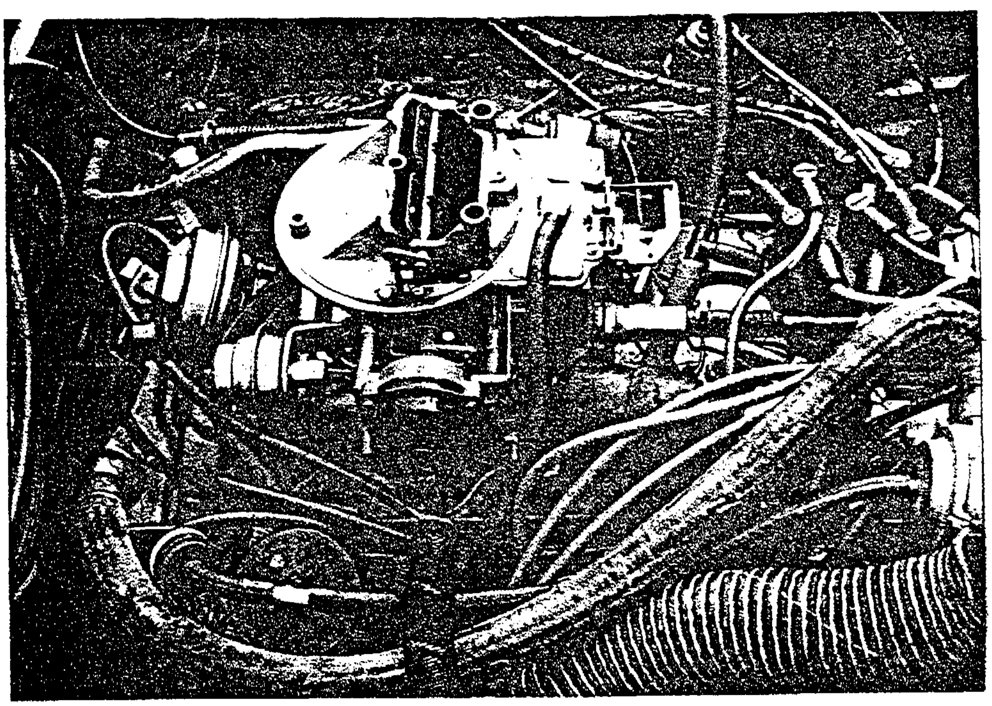

Figure 2-12. Ford Granada Showing Modified Intake Manifold

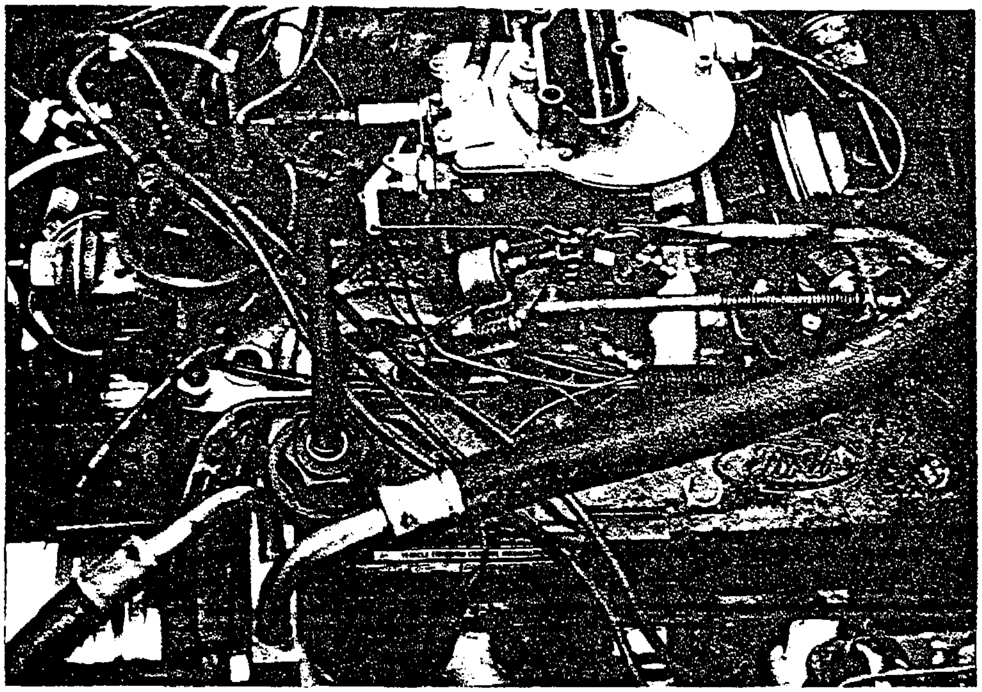

Figure 2-13. Ford Granada Showing Modified Intake Manifold and Exhaust Headers

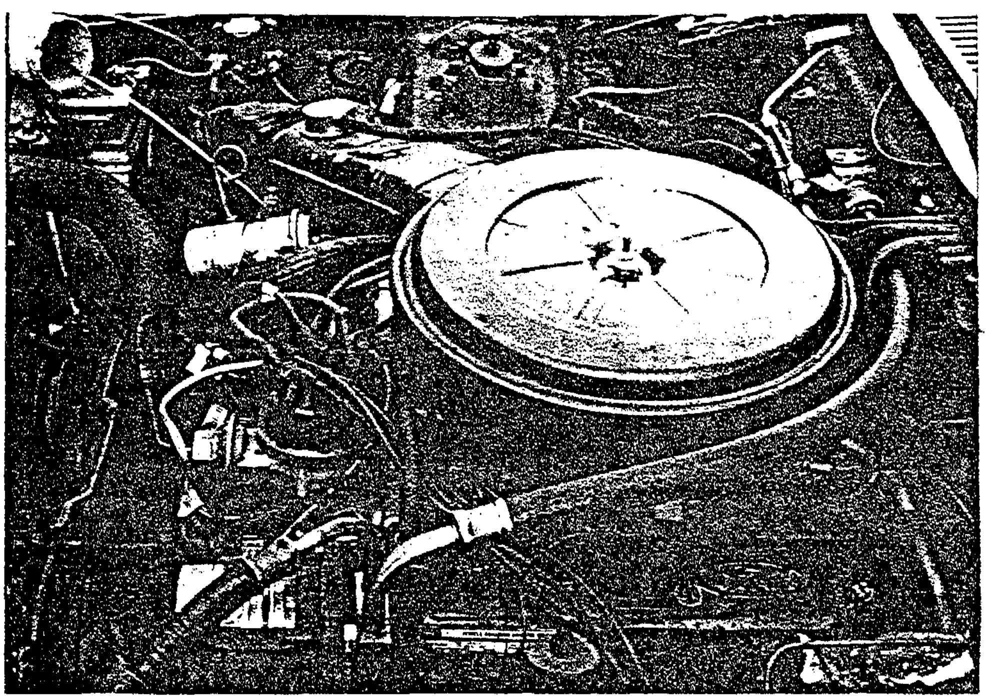

Figure 2-14. Ford Granada Showing Modified Intake Manifold Installation Ready for Test

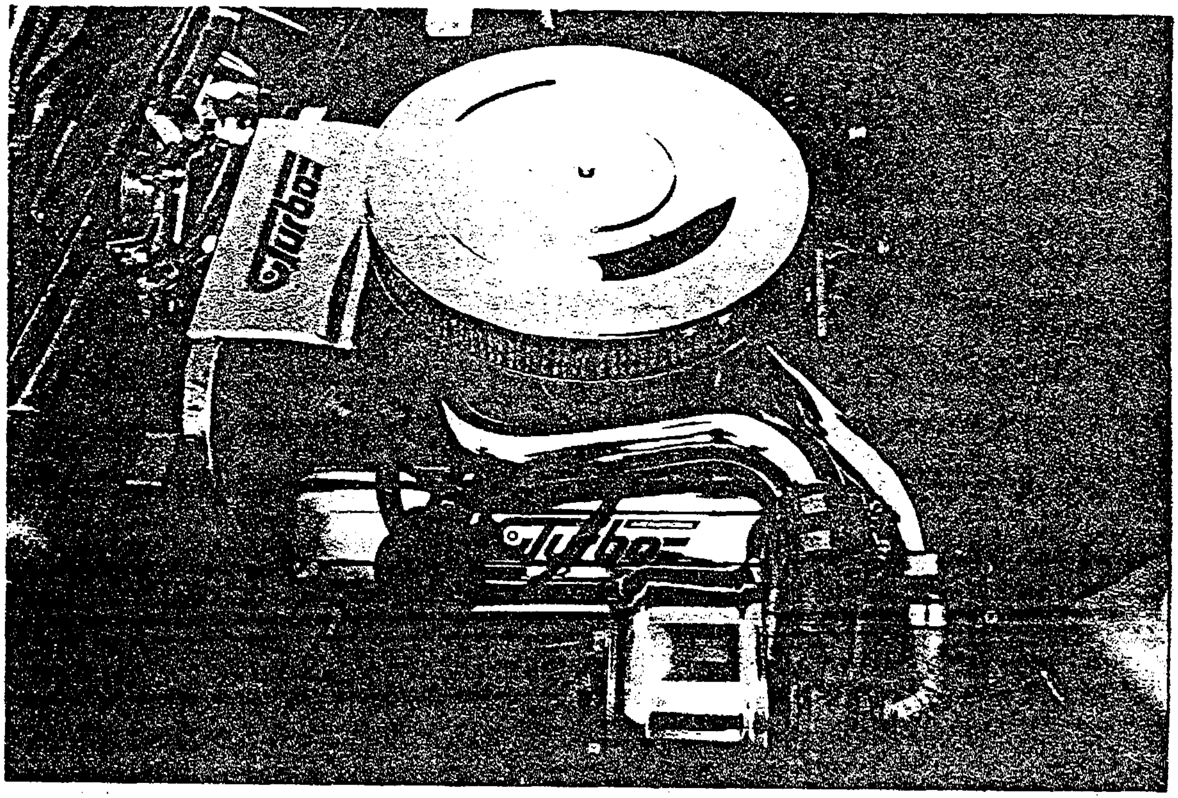

Figure 2-15. Chevrolet Corvette with Turbocharger Viewed From Passenger's Side

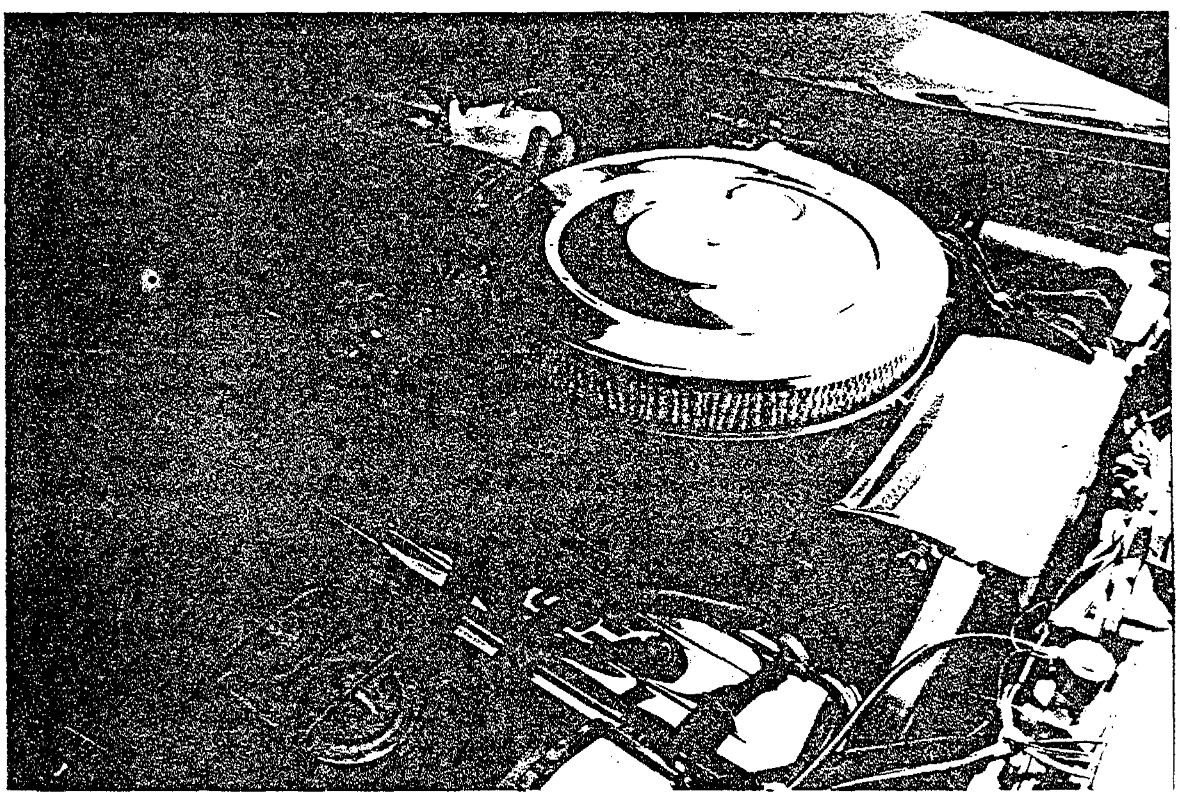

Figure 2-16. Chevrolet Corvette with Turbocharger Viewed From Driver's Side

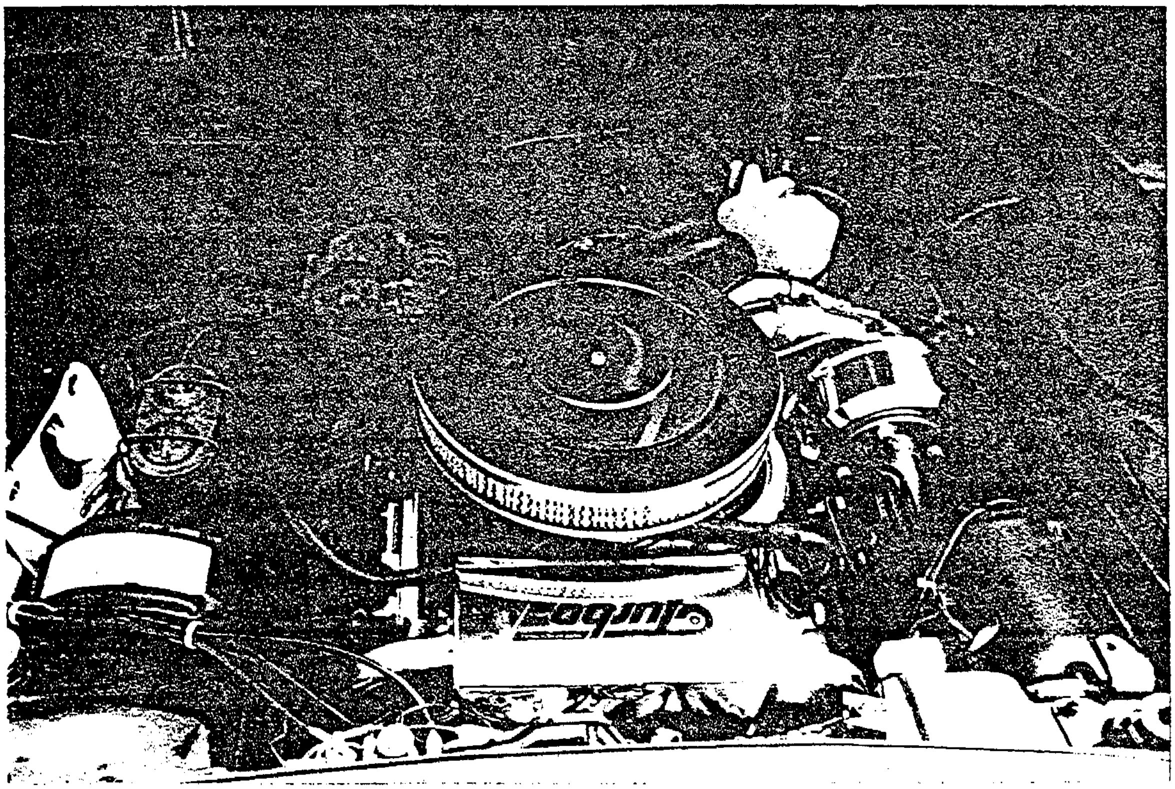

Figure 2-17. Chevrolet Corvette with Turbocharger Viewed From Windshield Looking Forward

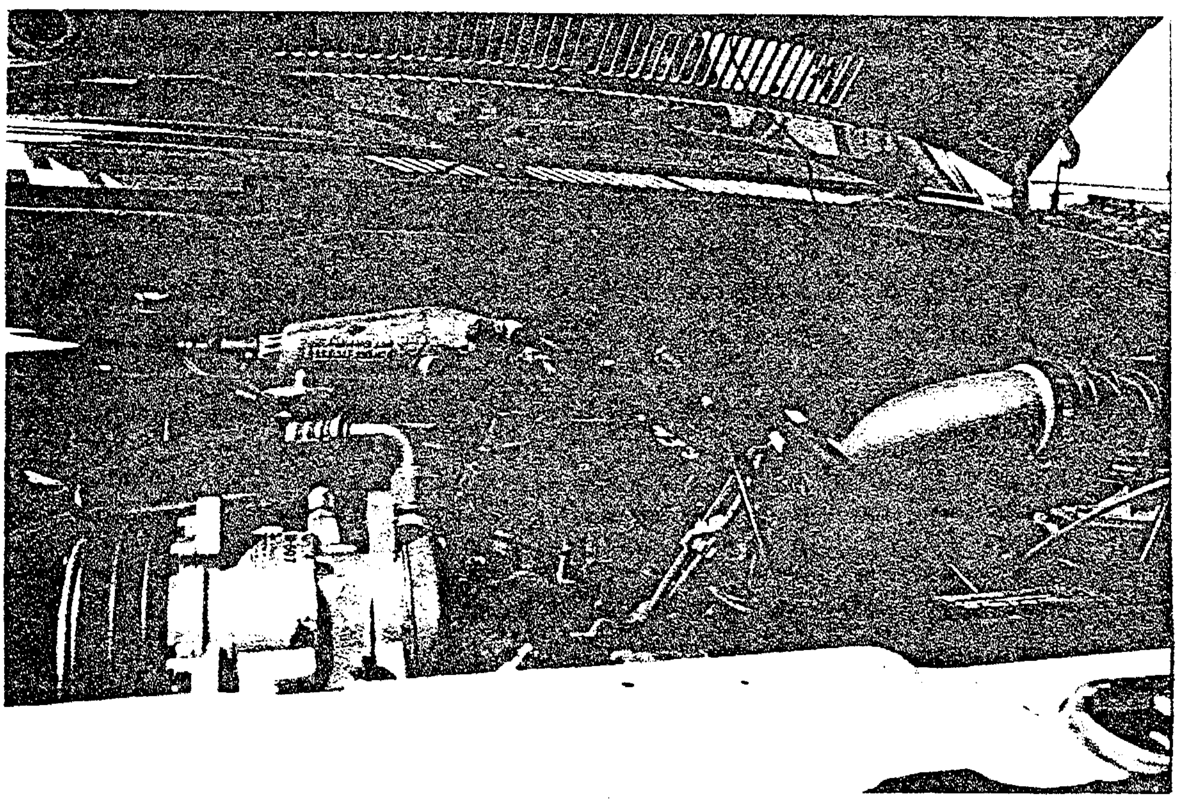

Figure 2-18. VW Rabbit With Callaway Turbocharger Viewed From Front of Car

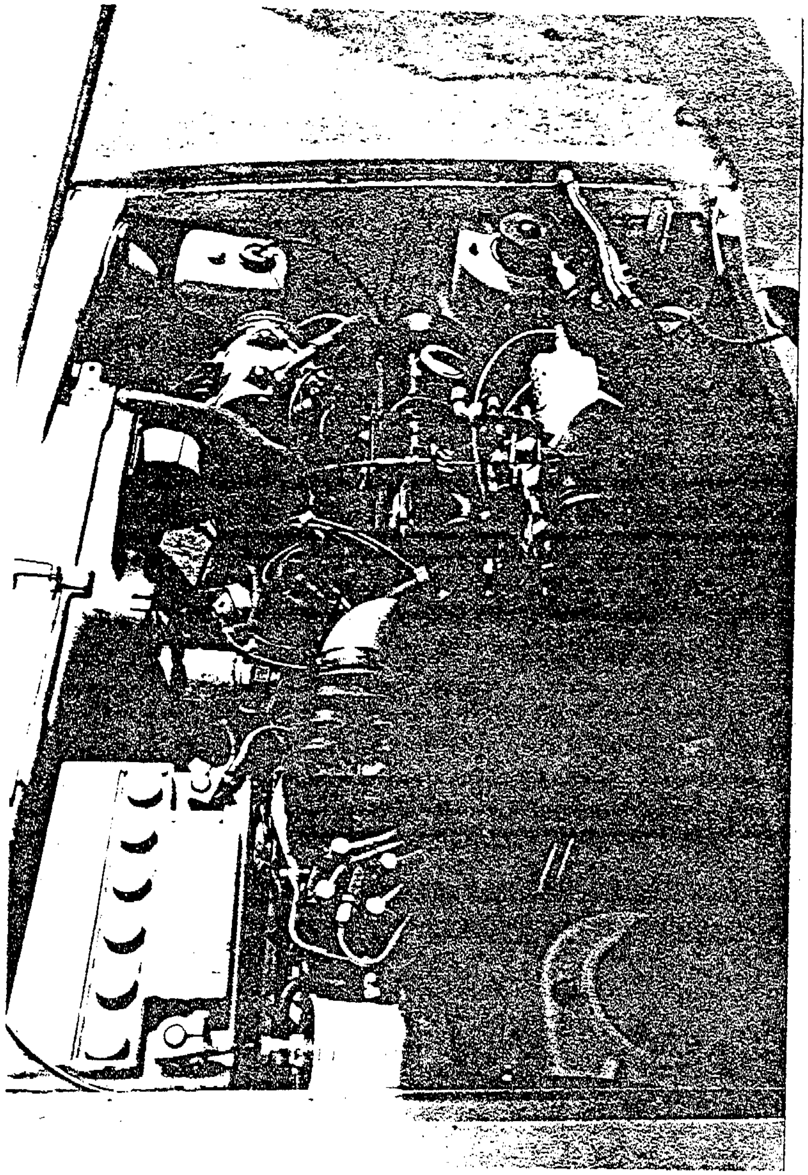

Figure 2-19. VW Rabbit With Callaway Turbocharger Viewed From Driver's Side

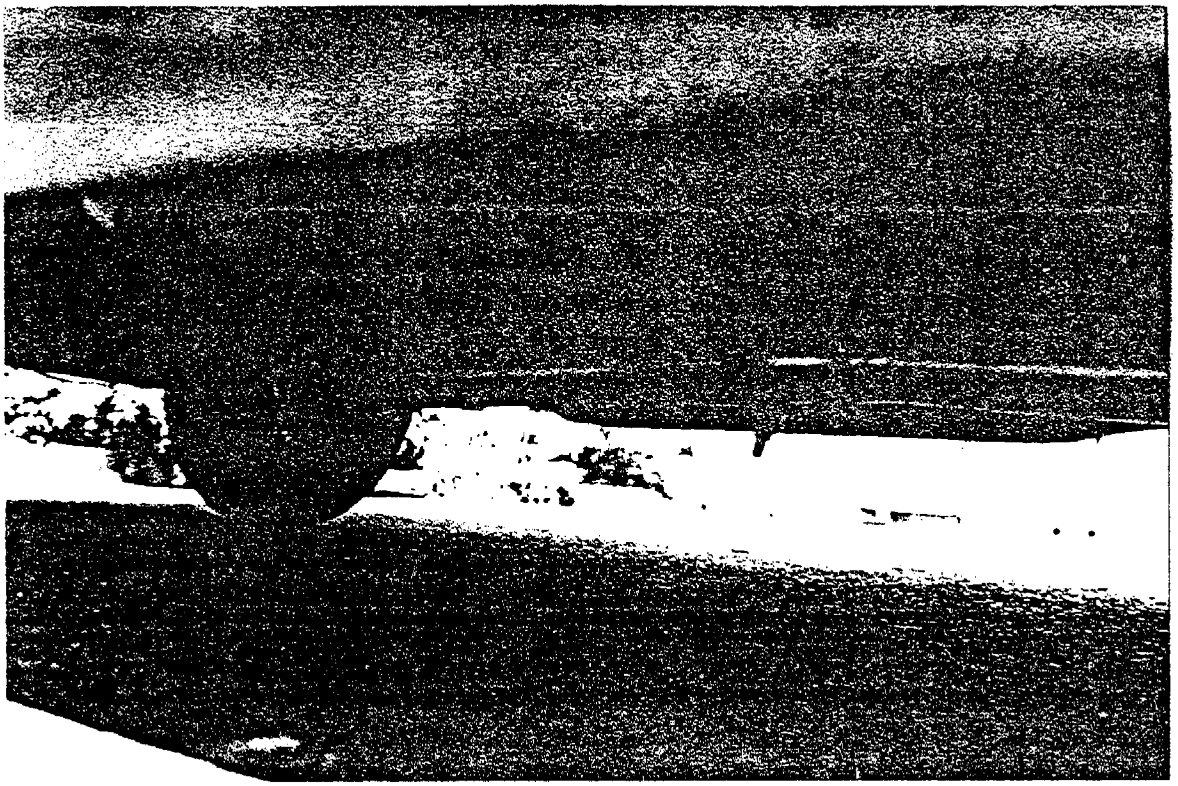

Figure 2-20. VW Rabbit Showing Straight Pipe Replacement For Catalyst

Section 3

METHODOLOGY

This section describes the methodology and facility used in performing the tests. Separate paragraphs address the test sequence, test procedures, and the test laboratory.

3.1 TEST SEQUENCE

Each test vehicle experienced a slightly different sequence of events depending on the component(s) being evaluated. For that reason, each aftermarket device test sequence will be described separately:

3.1.1 Exhaust Headers

Exhaust headers were evaluated on two cars. The baseline and exhaust header tests consisted of the following test procedures:

- 1975 Federal Test Procedure
- Highway Fuel Economy Test
- Steady state tests (idle and 20, 30, 40, 50 and 60 mph)
- Driveability evaluation

The specific sequence of events consisted of the following steps:

- procure selected cars
- perform vehicle inspection to ensure the car meets manufacturers adjustment and functional specifications
- install thermocouples at the inlet and outlet of the catalyst, the center of the outside skin of the catalyst, approximately one inch from the head surface of the original equipment exhaust manifold and at the outlet of the equipment exhaust manifold
- install static pressure ports at least two exhaust pipe diameters upstream and downstream of the catalyst
- install oil temperature thermocouple

- o conduct baseline tests listed above while recording temperatures before, during at 30 second intervals, and 15 minutes after both the FTP and HFET tests; and pressure measurements during the steady state tests.
- o for the Chevrolet Malibu, remove the original equipment exhaust manifold, Y pipe and catalyst; install the Eagle header without hot air duct, air injection ports, early fuel evaporation valve (heat riser) using a standard street adapter and Y pipe to connect to a single 2 to 2-1/2 inch diameter exhaust pipe
- o for the Ford Granada, remove the original equipment exhaust manifold and Y pipe; install the Hooker header with hot air duct, and early fuel evaporation valve (heat riser) using a standard street adapter and Y pipe to connect to the original equipment catalyst and tailpipe.
- o install thermocouples at the inlet of the exhaust header for number one cylinder and one inch downstream of the collector for the exhaust header
- o install static pressure ports at least two diameters downstream of the collector of the exhaust headers
- o perform header evaluation tests as described for the baseline test

Neither the Chevrolet nor the Ford baseline tests met the applicable emission standards even after functional tests, a tune-up and carburetor overhaul were performed. In addition, the catalytic converter on the Chevrolet was replaced. Since the test vehicles could not be repaired by the contractor to meet the applicable emission standards and in view of the difficulties experienced in procuring suitable test vehicles, the ARB allowed continuation of the test program with the vehicles in their optimum repaired condition.

3.1.2 Intake Manifolds

Intake manifolds were not tested individually. Rather, an intake manifold was installed on the Chevrolet Malibu and Ford Granada after completion of the exhaust header test on each car. For the intake manifold evaluation, the test procedures included the FTP, the HFET, and a driveability evaluation. The sequence of events was as follows:

- remove original equipment intake manifold and determine the volume and sizes of the flow control orifices for the EGR passages.
- for the Chevrolet Malibu, install the Holley Z manifold without EGR ports but with the choke extension kit
- for the Ford Granada, install the Edelbrock SP2P manifold with EGR ports and 1978 model year EGR valve
- for the aftermarket manifolds, perform the inspections defined above for the original equipment intake manifold
- perform the intake manifold evaluation tests listed above (temperature and pressure measurements not required)
- remove the test probes and aftermarket parts and restore cars to original equipment configuration

3.1.2 Turbocharger Systems

Turbocharger systems were evaluated on two vehicles. The test procedures included the FTP, the HFET, steady state tests at 20, 30, 40, 50 and 60 mph at normal test horsepower and at twice normal test horsepower. Following the dynamometer tests, the driveability evaluation was performed.

The sequence of events in conducting the turbocharger evaluation was as follows:

- procure selected cars
- perform vehicle inspection to ensure that cars meet manufacturer adjustment and functional specifications
- install static pressure probes two diameters up and downstream of the inlet and outlet of the catalyst, a manifold pressure probe
- performs baseline test on original equipment configuration as described above
- for the Chevrolet Corvette, install a California exempted Turbo International turbocharger
- for the VW Rabbit, install a Callaway turbocharger and remove the catalyst, replacing it with a straight pipe section
- perform the turbocharger device evaluation test as described above
- remove turbocharger and test parts and restore cars to original equipment configuration

The Corvette baseline test did not meet emission standards even after functional checks, a tune-up, and carburetor overhaul were performed. ARB approved proceeding with the test program.

3.2 PROCEDURES

Each test consisted of one or more of the following procedures:

- o Federal Test Procedure
- o Highway Fuel Economy Test
- o Steady State Tests
- o ARB Driveability Test

Each emission test was always run as one sequence. The ARB driveability test was performed the day before or the day after the emission test due to the requirement for a soak and cold start.

3.2.1 Federal Test Procedure

Emission tests included the 1975 Federal Test Procedure (FTP) without evaporative emissions or prescribed LA-4 preconditioning cycle. These tests were performed in accordance with requirements defined in the Federal Register, Volume 42, Part 86. Tests were run using Indolene Clear. Each test was preceeded by a 505 dynamometer or 10 minute road preconditioning cycle and a 12 to 24 hour cold soak between 68 and 86°F. The procedural precautions discussed in Appendix C were followed on all tests.

3.2.2 Highway Fuel Economy Test

Following the FTP, the Highway Fuel Economy Test (HFET) was performed. The measured test was preceded by one HFET cycle without exhaust sampling. If the vehicle had soaked more than three hours since the FTP, an additional 5 minutes at 50 mph was performed. The procedural precautions discussed in Appendix C were followed on all tests.

3.2.3 Steady State Tests

Steady state tests consisted of 8 minute cruises at 20, 30, 40, 50, and 60 mph using FTP road loads and twice road load for the Corvette. Mass emissions in grams per mile were reported along with temperature and pressure measurements required for each aftermarket part evaluation.

3.2.4 ARB Driveability Test

The ARB driveability test was performed on a road route originating from Custom Engineering. Each test consisted of one cold start evaluation and one hot start evaluation. The cold start and hot start evaluations were not necessarily performed on the same day and could either precede or follow the emission test sequence. All driveability tests on one car were performed by one driver. Figures 3-1 and 3-2 show the ARB driveability test data sheets.

Figure 3-1 COLD START AND DRIVEAWAY EVALUATION

Vehicle No. ____________ License No. ____________ Sheet 1 of 2

Date: ____________ Time: Start ______ Finish ______ Odo.: Start ______ Finish ______

Vehicle	Engine	Weather	Crew
Make ______	Disp. ______ Type ______	Temp.: Start °F ______	Driver: ______
Model ______	Nom. C.R. ______	End °F ______	Recorder: ______
Year ______	Carb.: Mfg. ______	Road Conditions:	Observer(s): ______
Trans. ______ A/C ______	Model ______	Wet ______ Dry ______	______
P/B P/S	Choke:	Soak Time (hrs.)	______

Remarks: ______

Start Time (sec.) ______ ______ Attempts ______

Miles	Mode		RPM	Idle: Satis.	Idle: Rough*	Idle: Stall	Accel.: Satis.	Accel.: Hesit.*	Accel.: Stumble*	Accel.: Stall		Back Fire*
Start	Hi-Cam											
Start	Tap	N										
Start	Throttle	Dr										
0	PT D/A (0-25)											
.2	WOT Accel (25-35)											
.3	PT Accel (25-30)											
.4	PT Accel (25-30)											
.5	Idle (30 sec.)											
	PT D/A (0-25)											
.6	WOT Accel (25-35)											
.7	PT Accel (25-30)											
.8	PT Accel (25-30)											
.9	PT Accel (25-30)											
1.0	Idle (30 sec.)											
	WOT D/A (0-25)											
1.1	WOT Accel (25-35)											
1.2	PT Accel (25-30)											
1.3	PT Accel (25-30)											
1.4	PT Accel (25-30)											
1.5	Idle (30 sec.)											
	PT D/A (0-25)											
1.6	WOT Accel (25-35)											
1.7	PT Accel (25-30)											
1.8	PT Accel (25-30)											
1.9	PT Accel (25-30)											
2.0	Idle (30 sec.)											
	PT D/A (0-25)											
2.1	WOT Accel (25-35)											
2.2	PT Accel (25-30)											
2.3	PT Accel (25-30)											
2.4	PT Accel (25-30)											

Miles	Mode	RPM	Idle: Satis.	Idle: Rough*	Idle: Stall	Accel.: Satis.	Accel.: Hesit.*	Accel.: Stumble*	Accel.: Stall	Lean	Back Fire
2.5	Idle (30 sec.)										
	PT D/A (0-25)										
2.6	WOT Accel (25-35)										
2.7	PT Accel (25-30)										
2.8	PT Accel (25-30)										
2.9	PT Accel (25-30)										
3.0	Idle (30 sec.)										
	PT D/A (0-25)										
3.1	WOT Accel (25-35)										
3.2	PT Accel (25-30)										
3.3	PT Accel (25-30)										
3.4	PT Accel (25-30)										
3.5	Idle (30 sec.)										
	PT D/A (0-25)										
3.6	WOT Accel (25-35)										
3.7	PT Accel (25-30)										
3.8	PT Accel (25-30)										
3.9	PT Accel (25-30)										
4.0	Idle (30 sec.)										
	PT D/A (0-25)										
4.1	WOT Accel (25-35)										
4.2	PT Accel (25-30)										
4.3	PT Accel (25-30)										
4.4	PT Accel (25-30)										
4.5	Idle (30 sec.)										
	PT D/A (0-25)										
4.6	WOT Accel (25-35)										
4.7	PT Accel (25-30)										
4.8	PT Accel (25-30)										
4.9	PT Accel (25-30)										
5.0	Idle (30 sec.)										

*T - Trace; M - Moderate; H - Heavy

Figure 3-2 Warm Vehicle Driveability Test Form

Vehicle ______________________ License ______________________

Date ______________ Time: Start ____________ a.m./p.m. Finish ____________ a.m./p.m.

Odometer Reading: Start ______________________ Finish ______________________

Temperature: Start ______________________ Finish ______________________

Test Driver: ______________________ Observer ______________________

Remarks: (overheating, vapor lock, dieseling, stall at start or driving, etc) ______________________

MODE		RPM	Hg	Idle: Satisfactory	Idle: Rough*	Idle: Stall	Drive Mode: Satisfactory	Detonation*	Hesitation*	Stumble*	Stretchiness*	Backfire	Surge#
Idle	N												
	D												
Road Load	20 mph												
	30 mph												
	40 mph												
	50 mph												
	55 mph												
WOT Accel.	20-30 Manual Transmission or 0-30 Auto Transmission												
	Sudden Throttle Opening												
	Moderate Throttle Opening												
	Slow Throttle Opening												
PT Accel.	20-30 Manual Transmission or 0-30 Auto Transmission												
	1/4 Throttle												
	1/2 Throttle												
	3/4 Throttle												
PT Crowd	20-55												
	15" Hg												
	10" Hg												
	5" Hg												
PT Tip In From 20 mph	1												
	2												
From 30 mph	1												
	2												
Accel. Time 0-55 mph			sec.										
Decel. Time 70-30 mph			sec.										
Soak	Number of Start Attempts												
	Total cranking time		sec.										
Idle	Neutral	RPM	Hg										
	Drive	RPM	Hg				*T-Trace			M-Moderate			

Section 4

IMPACT OF AFTERMARKET PART USAGE

This section presents the results of the test program. The results and test data are presented by vehicle since each vehicle was treated differently during the program. The discussion, however, is presented for headers, intake manifolds (with headers) and turbochargers. The emissions, fuel economy, driveability, and performance impact of the aftermarket parts is in comparison to baseline test results with all original equipment componenets installed and functioning.

4.1 EXHAUST HEADERS

Two emission controlled vehicles (Chevrolet Malibu and Ford Granada) were tested with headers. The worst case vehicle's (Chevrolet) original equipment catalyst, EGR, air injection and heat riser were all removed. The best case vehicle's (Ford) original equipment catalyst, air injection, heat riser were retained and the original equipment EGR valve was exchanged for a 1978 model year valve. The test data for both cars are shown in Appendix B.

4.1.1 Emissions Impact

The worst case (Chevrolet) installation of exhaust headers resulted in significantly increased FTP emissions of HC (+347%), CO (26%) and NO_x (36%). Steady state emissions of HC and CO also increased several times at all steady speeds while emissions of NO_x decreased 20% to 30% at all steady speeds. These changes were attributed to removal of original emission control components.

The best case (Ford) installation of exhaust headers resulted in a moderate increase of HC (21%), a significant decrease in CO (41%) and no significant change in NO_x emissions during the FTP. Steady speed emissions were variable. At low speeds (20 mph) HC emissions were reduced (63%), CO emissions were increased (79%) and NO_x emissions were increased slightly (13%). At higher speeds, CO emissions were decreased 70-80% and NO_x emissions were increased, although the amount of increase was quite variable (35 to 175%). Emissions of HC were highly variable at higher speeds ranging from a 29% decrease at 30 mph to a 91% increase at 60 mph.

4.1.2 Fuel Economy Impact

Exhaust headers increased fuel economy on both cars. For the worst case, FTP fuel economy increased 10% and HFET fuel economy increased 17%. For the best case FTP fuel economy increased 40% and HFET fuel economy increased 35%.

4.1.3 Exhaust System Pressure and Temperature

Exhaust system pressure and temperature measurements were recorded. Exhaust system pressures with headers were lower than for original equipment in both cases. For the Chevrolet, pressure reductions were greater than for the Ford at 30, 40 and 50 mph. Both vehicles showed the greatest reduction in exhaust pressure at lower speeds.

Temperatures in the #1 cylinder and oil were lower with headers than with the original equipment. Temperatures of the exhaust gas in the exhaust collector were lower compared to original equipment for both cases. The best case (Ford) showed the greatest reduction. Headers tend to radiate heat more than cast iron manifolds, which explains the lower exhaust gas temperatures. Engine oil temperatures were lower using headers for the Ford, but higher for the worst case (Chevrolet).

4.1.4 Driveability

Performance as measured by acceleration times was improved by exhaust headers (reduced 20%). Driveability as measured by total weighted demerits from the ARB driveability test was degraded 20% for the best case (Ford) and 45% for the worst case (Chevrolet) by use of headers. The driveability impact on the Chevrolet was much greater than on the Ford and included several stalls during wide open throttle accelerations.

4.1.5 Factors Contributing to Emission Changes

The most significant factor affecting emissions was removal of original equipment emission controls components; i.e. catalyst, EGR, air pump and heat risers. Headers in the best case configuration reduced exhaust system back pressure resulting in improved pumping efficiency of the engine. The improved efficiencies contributed to lower fuel consumption, leaner operation and lower exhaust, gas, oil, and engine temperatures. The lower temperature and leaner operation contributed to increased HC emissions and lower CO emissions and higher driveability demerits during the evaluation.

4.2 INTAKE MANIFOLDS IN COMBINATION WITH EXHAUST HEADERS

The same two cars tested with headers were also tested with aftermarket intake manifolds. Data are shown in Appendix B. Unfortunately, no direct measurement of the impact of manifolds was made. Therefore the impact of manifolds was measured in combination with headers relative to the original equipment baseline test.

4.2.1 Emissions Impact

The worst case (Chevrolet) installation of exhaust headers with an aftermarket intake manifold resulted in significantly higher FTP emissions of HC (266%) and NO_x (107%). Interestingly, CO emissions were not significantly higher than baseline. Steady speed emissions of HC and CO emissions were higher than baseline at all speeds, while NO_x emissions were higher than baseline at most speeds.

The best case (Ford) installation of exhaust headers with an aftermarket intake manifold resulted in significantly higher HC (152%) and moderately lower CO (-30%) and NO_x (-32%) emissions during the FTP. Steady speed emissions of HC were higher than baseline at all speeds, while CO and NO_x emissions were higher than baseline at most steady speeds. The effect on HC and NO_x emissions was due in large part to substituting the 1978 model year EGR valve for the original equipment 1976 model year valve.

4.2.2 Fuel Economy Impact

The modified intake manifold in combination with exhaust headers gave higher FTP and HFET fuel economy for the worst case (Chevrolet) compared to original equipment (21%). For the best case (Ford), the modified intake manifold in combination with exhaust headers gave higher (20-30%) fuel economy than baseline original equipment.

4.2.3 Driveability Impact

For the worst case (Chevrolet), installation of the manifold eliminated stretchiness and nearly eliminated cold start stumble, hesitation and stalling presen both baseline and header tests. Driveability demerits were reduced 91% compared to baseline. The installation of the manifold also reduced 0-70 mph acceleration times by 5 seconds compared to baseline. These changes were due primarily to emission control components, i.e., EGR valve and catalyst.

For the best case (Ford), however, driveability demerits increased 197% and the 0-70 mph acceleration time decreased only two seconds compared to baseline. The degraded driveability was probably due to the later model year EGR valve which was calibrated for lower NO_x levels than the original equipment valve.

4.2.4 Factors Contributing to Emission Changes

The intake manifold/headers installed on the Chevrolet (worst case) increased HC and NO_x emissions and fuel economy relative to baseline. This is consistent with better pumping efficiency due to removal of emission controls. The intake manifold installed on the Ford (best case) increased HC, but decreased CO and NO_x emissions relative to baseline. This is probably due to higher EGR flow due to the later model EGR valve. The internal volumes of the Ford original equipment and aftermarket (Edelbrock SP2P) manifold were measured. The original equipment manifold had 234 milliliters from the heads to the EGR valve, 18 milliliters from the inlet to the EGR valve and 16 milliliters from the EGR valve to the outlet. The SP2P manifold had 199 milliliters from inlet to the EGR crossover and 20 milliliters from the EGR valve to the venturi. The total volume of the original equipment manifold was 268 milliliters compared to 219 milliliters of the SP2P manifold.

4.3 TURBOCHARGERS

A turbocharger was evaluated on two vehicles, the Chevrolet Corvette and VW Rabbit. The data are shown in Appendix B. The Corvette was tested with a California exempted turbocharger with all emission control systems operative (best case). The VW was tested with an unexempt turbocharger and the catalyst removed (worst case). The Corvette was tested at normal road load and twice road load. The VW however, was not able to operate at twice or even 1.5 times normal road load without severe overheating.

4.3.1 Emissions Impact

Emissions impact was different on each car. The Corvette showed a slight (12%) increase in HC emissions, a 52% increase in CO emissions and a 26% decrease in NO_x emissions during the FTP. The VW, however, showed large (~300%) increases in all three emissions during the FTP, which was due primarily to removal of the catalytic converter.

Steady state emissions data for the Corvette showed higher emissions at 20 mph and 60 mph using the turbocharger but lower emissions at 30, 40 and 50 mph. The VW showed consistently higher emissions at all steady state speeds using the turbocharger.

The higher test horsepower on the Corvette resulted in higher emissions for both baseline and turbocharger configurations. At twice road load horsepower, the HC emission increase from the turbocharger compared to baseline doubled (21% compared to 12%), the CO emission increase was the same (51% compared to 52%) and the NO_x emission decrease was one-half (-12% compared to -26%) that observed at road load. Steady state data were variable with no consistent pattern between the impact of the turbocharger at normal and two times normal road load.

4.3.2 Fuel Economy Impact

The turbocharger installation on the Corvette decreased fuel economy 22% and 15% on the FTP and HFET respectively. At twice road load, the fuel economy decrease on the Corvette was essentially the same as at normal road load. The turbocharger installation improved FTP fuel economy 5.7% but decreased HFET fuel economy 1.9% for the VW Rabbit.

4.3.3 Exhaust Pressure Measurements

Exhaust pressure measurements were made at steady state speeds on both cars. For the Corvette, catalyst inlet pressures were the same with and without the turbocharger at 20, 50 and 60 mph. At 30 and 40 mph the inlet pressure was higher with the turbocharger. Catalyst outlet pressures were not affected by the turbocharger installation. At twice road load, catalyst inlet and outlet pressures were nearly the same as at normal road load both in baseline and turbocharger configurations.

For the VW, the turbocharger installation (with catalyst removal) resulted in large (90-100%) decreases in exhaust system pressures at all speeds.

4.3.4 Factors Contributing to Emission Changes

Removal of the catalytic converter was the most significant factor contributing to increased emissions. For the Corvette there was no consistent relationship between steady-state emissions and catalyst inlet or outlet pressures. However, during the FTP the Corvette showed higher HC and CO emissions and lower NO_x emissions and a poorer fuel consumption using the turbocharger, which is consistent with the turbocharger showing higher exhaust gas back pressure at the EGR valve. Data requested from turbocharger manufacturers (compressor map, maintenance schedule, boost limits, and horsepower versus speed curve) were not provided by them. Boost limits and horsepower versus speed curve were not measured by Custom Engineering.

A P P E N D I X   A

DEVICE SALES AND USAGE SURVEY

A SURVEY OF SALES AND USAGE OF SPECIALTY AFTERMARKET DEVICES IN CALIFORNIA

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EXECUTIVE SUMMARY

Custom Engineering is currently in the process of studying the Emissions Impact of Selected Aftermarket Parts for the California Air Resources Board. As a part of that study, information pertaining to the sales and usage of specialty aftermarket parts is required. The present study reports the results of a survey of firms involved in the aftermarket parts industry and a survey of the users of such devices.

In the course of the surveys, attempts were made to contact 178 firms, and 300 interviews were conducted with households using these specialty devices. The major findings of the survey included the following:

- Firms within the selected aftermarket parts industry tend to provide multiple functions within the chain of distribution.
- From the firm's point of view, the most popular engine appears to be the Chevrolet 350.
- In general, firms expected the bulk of their aftermarket parts to be used on the street.
- Almost four out of 10 of the households surveyed, based on a selected sampling universe, indicated that they had purchased at least one of the specified aftermarket parts in the last three years. Headers and carburetors appear to be the most-often-purchased items.
- By far the largest proportion of aftermarket parts were applied to eight-cylinder engines. The exception appears to be the application of turbochargers to four-cylinder engines.

- Roughly 80 percent of the vehicles on which aftermarket parts were installed were registered for street use.

- Less than half of the vehicles with aftermarket parts applied were used for primary transportation.

- Users indicated that the most popular engine to which the selected aftermarket part was installed is the Chevrolet 350.

- Almost 60 percent of the automobiles had two or more of the selected aftermarket parts installed.

- The firm data are not sufficiently robust to permit quantitative estimates of total unit sales in California.

- Recommendations and other research findings may be found in the body of the report.

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INTRODUCTION

SCOPE AND PURPOSE

The California Vehicle Code requires that any add-on or modified part which alters the original design or performance of a vehicle's emission control system be exempted by the Air Resources Board before it can be sold for installation to on-road motor vehicles. The devices which particularly concern the Air Resources Board due to their potentially adverse effects on emission are: headers, modified intake manifolds, turbochargers, modified ditributors, modified camshafts, and replacement carburetors. In order to assist the Board in determining the emission impacts of these selected aftermarket parts, a contract has been awarded to Custom Engineering.

Before Custom Engineering can determine the emission's impact of selected aftermarket parts, the sales volume and composition of the market for these specialty parts needs to be ascertained. In addition, the usage patterns by aftermarket parts consumers were essentially unknown. Since no published secondary data are available, a direct survey became necessary. To this end, Custom Engineering commissioned CIC Research, Inc., to design and conduct a survey of firms within the specified aftermarket parts industry and a survey of ultimate consumers of these specialty parts. This report summarizes the findings of both surveys.

GENERAL METHODOLOGY

Although a number of primary data collection methods were considered, the final design incorporated a dual-frame sampling technique. In the dual-frame approach, firms within the specialty parts industry, particularly manufacturers, were interviewed. The second sample frame addressed the ultimate consumer of these products. The surveys together could then be used to develop the required information dealing with sales volume, market composition, and usage patterns.

Both the firm and the household surveys were conducted by telephone. A telephone survey method was chosen over other methods of administration for a number of reasons. First, given scarce research resources, telephone interviewing permits good productivity along with high levels of quality control. Second, telephone interviewing allows better control and identification of non-respondents. This characteristic was thought to be especially important in terms of the firm survey. Third, the overall timing of the data collection effort tends to be more within the control of the researchers than the respondents. All telephone interviews were conducted from CIC's central phone room in San Diego.

Once the interviews were completed, the questionnaires were edited, coded, and keypunched. After these data were quality assured, data analysis was performed using a Statistical Package for the Social Sciences (SPSS). SPSS was used to generate descriptive statistics, selected cross-tabulations, and test statistics. The analysis focused on sales volume, market composition, and usage patterns for the specified aftermarket parts.

REPORT ORGANIZATION

The balance of this report is divided into four chapters. The first of these chapters details the survey methodology employed including sample frames, questionnaire development, and survey administration. In addition, summaries of survey effort are provided for both surveys. Chapter 3 provides the survey results as they pertain to firms including a description of the activity within California. Chapter 4 summarizes the purchasing and usage of the specified aftermarket parts. Considerable attention is given to demographic comparisons with residents of California as a whole. Chapter 5 develops estimates of total unit sales and provides survey-based recommendations. The appendices provide the actual questionnaires used and the total firm sample frame.

METHODOLOGY

Using the dual-frame approach, the firm and household surveys were conducted simultaneously. This section of the report details the methodology used in both the surveys.

SURVEY OF FIRMS

Preparation

The sample frame for the survey of business firms was developed jointly by CIC Research, Custom Engineering, and the ARB. The starting point was the Specialty Equipment Manufacturers Association (SEMA) Membership Directory, from which the names of all manufacturers and distributors of aftermarket parts were taken. A total of 178 firms were selected to be contacted in the survey of firms (see Appendix A). From the list, 15 firms were selected for face-to-face interviewing, while the remaining 163 were slated for telephone interviews.

The survey instrument was developed by CIC Research with input from Custom Engineering and the ARB. An introductory letter was also designed for mailing to each firm before being telephoned by an interviewer. (See Appendix B for copies of these survey materials.) It was anticipated that SEMA would endorse the survey and a statement to that effect would be included in the letter of introduction. However, SEMA endorsement was not received.

The Survey

Letters of introduction were mailed in three waves in late October and early November 1981. Telephoning began approximately one week after the first mailing and continued through January 6, 1982. A total of 38 firms were interviewed in the firm survey. Table 1 shows the dialing results for the survey of firms.

Table 1

SURVEY OF FIRMS
SUMMARY OF DIALING RESULTS

Call Result	Number
Completed interviews	38
Letter returned/no phone number found/ number no longer in service	22
Refusals	13
Could not reach respondent (an average of eight attempts per firm)	34
Firm doesn't manufacture or distribute these parts	67
Total firms attempted	178

While the overall stated refusal rate was less than 8 percent, this figure is probably understated. Certainly, a proportion of the respondents who could never be reached are probably "indirect" refusals. It can be noted that firms in this last category received an average of eight telephone calls in an attempt to reach the designated respondent. No firm received less than four attempts. The firm's secretaries did a good job of screening and some of the respondents were very elusive. No doubt, a few firms in the last category, "Firm doesn't manufacture or distribute these parts," were refusals. What information was received was often sketchy as firms were reluctant to release information in any detail in case their name should be connected with it or it should be released to competitors. Some firms simply declined to participate.

The face-to-face portion of the survey suffered the same fate as the telephone portion. First, preliminary phone calls were made to set up appointments for personal visits. Three of the 15 firms completed the survey. The remainder were divided almost evenly between outright refusals, an inability to find a convenient appointment time for the interview, and a failure to complete the interview when the interviewer arrived under the guise of "I can't do the interview now -- I'll keep the questionnaire, gather the data later and send it to you." All firms which completed an interview were requested to forward to CIC a copy of their most current catalog. Appendix C lists the 22 firms who sent their catalogs to CIC.

SURVEY OF HOUSEHOLDS

Preparation

After discussions between CIC, Custom Engineering, and the ARB, it was determined that the sample frame for the household survey would be current subscribers of two popular car magazines who reside in Southern California. After several delays, during which one publisher changed his mind about providing their mailing list, a list of subscribers to Hot Rod Magazine was eventually received. However, the list was useless because it contained names of subscribers nationwide and insufficient California residents to complete the survey. The second mailing list was also inaccurate in that it contained only Los Angeles and a few Orange County residents rather than subscribers representative of all Southern California counties. However, given the delays encountered already, it was felt that it was better to work with the sample frame in hand rather than suffer another delay.

The survey instrument was designed by CIC with the assistance of Custom Engineering and the ARB. Copies of all household survey materials are included in Appendix D. The second page of the questionnaire was color coded and interviewers received extra copies of the sheet for interviews where respondents had purchased more than one piece of equipment.

The sample frame was prepared by randomly selecting 1,250 labels from the mailing list of 5,000 Hot Rod subscribers. These labels were attached to call records (see Appendix D). Then, using Directory Assistance, CIC's interviewers attempted to secure a telephone number for each of the selected subscribers. Interviewers were able to get numbers for less than half of the subscribers chosen which necessitated randomly selecting additional names in order to complete a quota of 300 interviews.

<u>The Survey</u>

Interviewing for the household survey began on November 23, 1981, and was concluded on January 15, 1982. Three young men were specifically selected for the interviewing task because of their extensive knowledge of automobiles and aftermarket parts. A briefing was held on November 23 prior to the start of interviewing.

Interviews were conducted from 4:30 p.m. to 9:30 p.m. on weekdays and 10:00 a.m. to 6:30 p.m. on weekends in CIC's central telephone facility. At least four attempts were made to contact a knowledgeable respondent in each household. Callbacks were arranged when requested by the respondent as the interview often became lengthy due to the number of parts purchased by household members.

Over one half of the contacted households contacted not having purchased aftermarket parts in the last three years. Therefore, a total of 1,024 phone numbers were required to complete a quota of 300 interviews. A summary of dialing results for the household survey is shown on Table 2.

Table 2

SURVEY OF HOUSEHOLDS
SUMMARY OF DIALING RESULTS

Completed interviews	300
Business number or number not in service	24
Unable to contact (no answer, callback, unable to reach appropriate respondent, etc., after four or more attempts)	72
No aftermarket parts purchased	482
No English spoken	7
Refusals	139
Total phone numbers attempted	1,024

DATA PROCESSING AND ANALYSIS

A supervisor was present at all times during the interviewing to answer questions as they arose and to edit the completed questionnaires. After the questionnaires were edited, a codebook was designed and they were then coded using the prepared codebook.

After being coded and edited, the questionnaire data were entered onto computer tape via remote keyboard terminal. A data entry program was written that monitored the keypunched data as they were entered for correct range, completeness and illogical response. In this way, the data set was quality assured in preparation for the data analysis.

The data were analyzed using the Statistical Package for the Social Sciences (SPSS). Appropriate descriptive statistics frequency distributions, and test statistics were computed. In addition, extensive cross-tabulations were performed.

SUMMARY

A dual-frame survey approach of firms and households was conducted. During the survey process, contact with 178 firms thought to be involved in the aftermarket parts industry was attempted. Interviews were conducted with 300 households who had purchased the selected aftermarket parts in the last three years. The collected survey data were coded, edited, keypunched, and analyzed.

FIRM SURVEY RESULTS

From an analytical standpoint, the survey of firms in the aftermarket parts industry was not highly successful. Of the 178 firms for which contact was attempted, almost 40 percent indicated they did not participate in the selected aftermarket parts industry. Additionally, 12 percent of the sampled firms appear to have left the industry. The direct refusals and the "unable to contact" categories significantly diminished the response set. The 38 firms interviewed represent 42.6 percent (i.e., 38 ÷ 89) of the firms who realistically could be part of the selected aftermarket parts industry. However, the information contained in this section should be considered in terms of its qualitative significance only.

DESCRIPTION OF THE AFTERMARKET PARTS FIRMS

Based on survey responses, the distribution of business activity within the aftermarket parts industry differs depending on the equipment in question. The greatest percentage of firms indicated business activity with headers (i.e., 65.3 percent). Firms involved with turbochargers and carburetors represented the smallest percentage of activity (see Table 3).

As was anticipated, firms within the industry tended to provide multiple function within the chain of distribution.

Table 3

RESPONDENT FIRM MARKET ACTIVITY

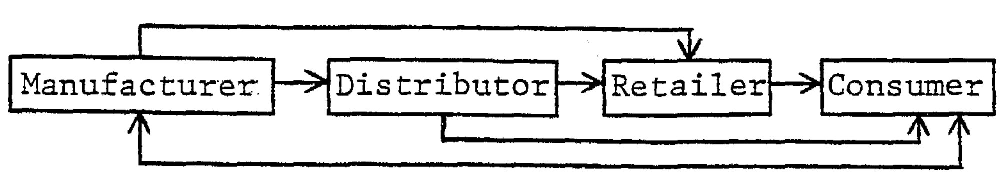
Type of Part	Respondent Category: Percentage of Firms Indicating Activity Within the Market	Respondent Category: Percentage of Active Firms With More than One Function Within the Chain of Distribution
Header	65.3%	61.9%
Intake Manifold	33.7	36.4
Turbocharger	21.1	62.5
Distributor	31.6	58.3
Camshaft	34.2	46.2
Carburetor	15.8	50.0

Source: CIC Research, Inc., Survey of Aftermarket Parts Firms, 1981

It was not uncommon for a firm to manufacture, distribute, and retail a particular aftermarket part. As Table 3 indicates, firms dealing with headers and turbochargers tended to provide multiple functions more prevalently than other parts firms. Alternatively, firms that dealt with intake manifolds tended to provide single functions (e.g., manufacturing only). Figure 1 depicts the various relationships in the chain of distribution found within the firm survey.

Figure 1

AFTERMARKET PARTS INDUSTRY CHAIN OF DISTRIBUTION



MARKET ACTIVITY, USAGE AND RANKINGS

Firms were asked to indicate their sales activities for 1978, 1979, and 1980. Essentially, the data collected indicate that little variance in activity was perceived by the respondents for those years. In addition, it would appear that firms had difficulty estimating sales activity in 1978 and 1979.

Firms were also asked to note make, engine size/type, year, prevalent model, and percentage of sales for each selected aftermarket part that they handled. With very small subsample sizes, it is difficult to rank this type of information. However, Table 4 provides the top ranked combinations as indicated by the firms for each aftermarket part. In the case of intake manifolds, Chevrolet 350's and Volkswagens with unknown displacements were mentioned equally.

In order to develop Table 4 all years and cars were aggregated. On the whole, if the firm's most popular product was a header for a Chevrolet 350 in 1980, the same held true for 1978 and 1979. In addition, the second and third most popular parts tended to be related to the same car maker as the most popular part (usually just a different engine size).

Firms were also asked to indicate the number of items sold and the percentage sold in California. Table 5 summarizes the survey results. As the table indicates, the average sales figures are based on a very small sample size. Many firms considered this information proprietary, although they were willing to answer other questions. Unfortunately, the data in Table 5 are clearly not definitive.

Table 4

MAKE, ENGINE SIZE, AND TYPE FROM FIRM SURVEY*

Part Category	Make(s)	Engine Size (Cubic Inches)	Type
Headers	Chevy	350	V8
Intake Manifolds	Chevy	350	V8
	VW	Unknown	Opposed 4
Turbochargers	Chevy	350	V8
Distributors	Chevy	350/Big Block	V8
Camshafts	Chevy	Small Block	V8
Carburetors	Chevy	350	V8

*Data contained in this table have qualitative significance only.

Source: CIC Research, Inc. Survey of Aftermarket Parts Firms, 1981.

Table 5

AVERAGE NUMBER OF ITEMS SOLD AND PERCENTAGE SOLD IN CALIFORNIA*

Part Category	Firm Subsample Size	Average Number Sold	Percentage Sold In California
Headers	10	2,762	44%
Intake Manifolds	2	7,500	15
Turbochargers	4	193	53
Distributors	4	12	46
Camshafts	4	3,868	59
Carburetors	2	50	43

*Data contained in this table have qualitative significance only.

Source: CIC Research, Inc., Survey of Aftermarket Parts Firms, 1981.

The use of the item (i.e., street use or racing use) according to the firms is provided in Table 6. Again, small sample sizes precluded definitive statements being made. However, on a qualitative basis, it would appear that the items in question are expected to be used on the street.

Table 6

FIRMS' ESTIMATE OF STREET USE FOR SELECTED AFTERMARKET PARTS*

Part Category	Firm Subsample Size	Mean	Median
Headers	10	75%	80%
Intake Manifolds	3	43	50
Turbochargers	3	97	98
Distributors	6	45	3
Camshafts	5	58	63
Carburetors	3	60	68

*Data contained in this table have quantative significance only.

Source: CIC Research, Inc., Survey of Aftermarket Parts Firms, 1981.

SUMMARY

The survey of firms does not provide a definitive picture of the aftermarket parts industry. Poor cooperation on the part of these firms diminished the quantitative value of the information obtained. However, from a qualitative standpoint, the data may be quite useful.

HOUSEHOLD SURVEY RESULTS

In conjunction with the firm survey, a survey of households was conducted based on subscribers to Hot Rod Magazine. Generally, these subscribers appear to be somewhat demographically different from the general California population. In addition, their automotive preferences appear to be heavily skewed toward U.S. car products. Thus, interpreting the data presented below should proceed with caution.

PURCHASE AND USAGE DESCRIPTION

Almost 40 percent of the subscribers contacted indicated that they had purchased at leas one of the selected aftermarket parts in the last three years. Table 7 summarizes the distribution of purchases by part type. Not too surprisingly, turbochargers represented the least-purchased item, while headers and carburetors represented the most often purchased equipment. In addition, as the table indicates, respondents commonly purchase more than one of the selected aftermarket part.

Table 8 distributes purchase by number of cylinders in the automobile for each selected part. The overwhelming majority of respondents indicated that the part was installed on an eight-cylinder engine. The notable exception was the turbocharger (i.e., half were installed on four-cylinder

Table 7

DISTRIBUTION OF PURCHASES
IN THE LAST THREE
YEARS BY EQUIPMENT TYPE

Purchase Category	Headers	Intake Manifold	Turbo-chargers	Distributors	Camshafts	Carburetors
None	36.0%	51.7%	94.7%	57.7%	59.0%	30.7%
1	51.7	39.7	5.0	36.3	31.0	55.0
2	10.0	7.0	0.0	4.7	7.3	8.0
3	1.7	1.0	0.3	0.7	1.0	4.0
4 or more	0.6	0.6	0.0	0.7	1.6	2.4
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: CIC Research, Inc., Survey of Aftermarket Parts Users, 1981.

Table 8

PURCHASES BY NUMBER
OF CYLINDERS

Cylinders	Headers	Intake Manifold	Turbo-chargers	Distributors	Camshafts	Carburetors
4	11.1%	8.6%	50.0%	14.4%	8.6%	10.0%
6	6.0	4.6	14.3	6.8	6.5	6.3
8	82.9	86.8	35.7	78.8	84.9	83.7
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: CIC Research, Inc. Survey of Aftermarket Parts Users, 1981.

automobiles). In general, the six-cylinder market appears to have had the least amount of activity from the respondent's point of view.

Respondents were asked if the vehicle into which the aftermarket part was installed was registered for street use. Table 9 indicates the percentage of street registration by specified aftermarket part. By far the largest proportion of these parts appear to be used on California streets.

In addition, the survey asked if the vehicle on which the aftermarket part was installed was used for primary transportation. Those vehicles not so used average 1,830 to 5,004 miles per year. Alternatively, the vehicles used for primary transportation average 12,000 to 14,000 miles annually (See Table 10).

Table 11 provides the make, engine, size, type, and years for the top five ranked engines for each part type. The Chevy 350 is by far the overwhelming engine on which aftermarket parts were installed. The major exception to this rule appears to be in the turbocharger category. The 350 engine accounts, however, for approximately 25 percent of the installation in all other categories.

The survey indicated that aftermarket parts users tended to install more than one category of equipment. Table 12 shows that almost 60 percent of the respondents indicated two or more parts were installed on their vehicles. In addition, it should be noted that 300 respondents installed aftermarket parts on 400 vehicles. The information given in Table 12 may

Table 9

STREET USE REGISTRATION BY PART PURCHASE CATEGORIES

	Headers	Manifolds	Turbochargers	Distributors	Cam-shafts	Carburetors
Registered for Street Use	85.7%	84.1%	71.4%	84.8%	79.6%	88.7
Not Registered for Street-Use	14.3	15.9	28.6	15.2	20.4	11.3

Source: CIC Research, Inc., Survey of Afeermarket Parts Users, 1981.

Table 10

PRIMARY TRANSPORTATION, AVERAGE MILES DRIVEN
BY PART PURCHASE CATEGORIES

	Headers	Intake Manifolds	Turbo-chargers	Distributors	Camshafts	Carburetors
Used for primary transportation	45.9%	37.2%	46.2%	40.1%	36.2%	44.7%
Average miles driven annually	14,298	13,105	13,000	12,135	12,658	12,716
Not used for primary transportation	54.1%	62.8%	53.8%	59.9%	63.8%	55.3%
Average miles driven annually	4,982	4,352	1,830	4,000	3,724	5,004

Source: CIC Research, Inc., Survey of Aftermarket Parts Users, 1981.

Table 11

MAKE, ENGINE SIZE, TYPE AND YEARS: TOP RANKED ITEMS FROM USERS SURVEY

Rank	Make	Size (Cubic Inches)	Type	Percent of Cars	Years
			HEADERS		
1	Chevy	350	V8	29.5%	1969, 1970, 1972
2	Chevy	327	V8	6.7	1967
3	Ford	351	V8	5.8	1969, 1971
4	Ford	289	V8	4.9	1965, 1967
5	Ford	302	V8	4.0	1970, 1978
			INTAKE MANIFOLDS		
1	Chevy	350	V8	30.6%	1969, 1970, 1972
2	Chevy	327	V8	8.3	1964
3	Ford	289	V8	5.7	1965, 1967
4	Chevy	396	V8	4.5	1965, 1969
5	Ford	351	V8	3.8	1972
5	Chevy	400	V8	3.8	--
5	Ford	302	V8	3.8	1969
			TURBOCHARGER		
1	VW	98	Opposed 4	14.3%	1969, 1978
1	VW	104	Opposed 4	14.3%	1973
			DISTRIBUTORS		
1	Chevy	350	V8	27.3%	1969, 1970, 1972
2	Ford	289	V8	5.8	1965, 1966
2	Chevy	327	V8	5.8	1967
2	VW/Datsun	98	Opposed 4/ Straight 4	5.8	1966, 1969, 1972
3	Ford	351	V8	5.0	1971
			CAMSHAFTS		
1	Chevy	350	V8	23.2%	1970, 1971, 1972
2	Chevy	327	V8	8.5	1967
3	Ford	289	V8	4.9	1965
3	Ford	302	V8	4.9	1969
3	Ford	351	V8	4.9	1972
3	Chevy	396	V8	4.9	1965
			CARBURETORS		
1	Chevy	350	V8	24.6%	1970, 1972
2	Chevy	327	V8	7.7	1968
3	Ford	289	V8	4.4	1965
4	Ford	351	V8	4.0	1972
4	Chevy	396	V8	4.0	1968

Source: CIC Research, Inc., Survey of Aftermarket Parts Users, 1981.

Table 12

DISTRIBUTION OF SELECTED
AFTERMARKET PARTS INSTALLATION

Parts Installed	Number of Automobiles	Percent
1	166	41.5%
2	82	20.5
3	55	13.8
4	57	14.2
5	39	9.8
6	1	0.2
	400	100.0%

Source: CIC Research, Inc., Survey of Aftermarket Parts Users, 1981.

be of interest during the physical testing process particularly when choosing the number of parts to be installed.

DEMOGRAPHIC CHARACTERISTICS OF SURVEY HOUSEHOLDS

From a demographic point of view, the survey households, (i.e., Hot Rod Magazine subscribers) are not very representative of the California population in general. First, the sample's income distribution is much higher than what would be expected in California. Table 13 provides some comparison between the sample and California as a whole. Even accounting for inflation between 1970 and 1981, the sample's income distribution is much higher than the rest of California. However, the grouped mean income for the sample is $32,910 annually, while inflation-adjusted mean income for all California would be approximately $33,747.

Second, the household composition for the sample is much different than for California as a whole. As Table 14 indicates the average household size is not too different for the sample than for California as a whole. However, the sampled households tend to have a larger proportion of adults. Although California's household composition is expected to have changed from 1970, the degree will not approximate the sample.

Tables 15 and 16 provide comparative information on housing-type distribution and housing ownership. As can be expected with higher incomes, the sample reflects greater prevalence of single-family housing than does California as a whole. Similarly, a much greater proportion of the sample own their homes than do the rest of California.

Table 13

HOUSEHOLD INCOME DISTRIBUTION

Income Category	Sample	Income Category	California
Under $10,000	2.0 %	Under $10,000	45.3%
$10,000-15,000	1.0	$10,000-15,000	28.0
$15,000-20,000	7.0		
		$15,000-24,000	20.6
$20,000-30,000	31.0		
		$25,000-44,000	5.2
$30,000-40,000	16.0		
$40,000 or more	32.3		
		Over $50,000	0.9
Don't know--refused	10.7		
	100.0%		100.0%

Sources: CIC Research, Inc., Survey of Aftermarket Parts Users, 1981.

1970 U.S. Census, General and Economic Characteristics, California.

Table 14

HOUSEHOLD AGE DISTRIBUTION

Category	Average Number In Sample	Average in California 1970
Adults 18 or older	2.62	1.19
Children under 18	.76	2.28
Average household size	3.38	3.47

Source: CIC Research, Inc., Survey of Aftermarket Parts Users, 1981.

1970 U.S. Census, General and Economic Characteristics, California.

Table 15

DISTRIBUTION OF SAMPLE BY HOUSING TYPE

Housing Type	Sample	California
Single-Family	84.3%	64.2%
2 - 4 Units	7.0	13.0
5 or more Units	7.7	20.0
Mobile Home	0.3	2.8
DK/Refused	0.7	--
	100.0%	100.0%

Source: CIC Research, Inc., Survey of Aftermarket Parts Users, 1981.

1970 U.S. Census, Detailed Housing Characteristics, California.

Table 16

HOUSING OWNERSHIP

Category	Sample	California
Rent	21.3%	47.5%
Own	77.3	52.5
DK/Refused	1.4	--
	100.0%	100.0%

Source: CIC Research, Inc., Survey of Aftermarket Parts Users, 1981.

1970 U.S. Census, General and Economic Characteristics, California.

Table 17 provides information about the age distribution of the respondents. Well over one half of these individuals were under 35 years of age. However, as the table indicates, the instatllation of aftermarket parts does not belong to the young alone.

SUMMARY

The survey of aftermarket parts users indicates that the usage activity revolves heavily around the Chevy 350 engine. The bulk of the cars on which these parts are installed are registered for street use. These cars, however, are not necessarily the owners' primary transportation vehicle. Unfortunately the demographic characteristics of the sample do not closely match the overall characteristics found in California as a whole.

Table 17

AGE DISTRIBUTION OF THE RESPONDENT

Age Category	Distribution
Under 18 years	3.3%
18 - 24	29.7
25 - 34	25.7
35 - 44	21.0
45 - 54	13.0
55 - 64	4.3
65 and over	1.7
DK/Refused	1.3
	100.0%

Source: CIC Research, Inc., Survey of Aftermarket Parts Users, 1981.

ANALYSIS AND RECOMMENDATIONS

ESTIMATED TOTAL UNITS IN CALIFORNIA

Essentially, the survey of aftermarket parts industry firms was anticipated being used to estimate total unit sales in California of each kind of equipment. Unfortunately, the response rate of firms surveyed was not large enough to permit significant estimates to be made. Specifically, the relatively large non-response set makes point estimates of sales tenuous.

However, recognizing the limitations of the data, estimates of annual California sales may be made. The survey results indicate that approximately 68,000 headers are sold in California each year. The sales of intake manifolds appear to fall between 32,000 and 40,000 annually. At the time of the survey, turbocharger sales in California seem to be less than 2,000 units. Based on the survey's market share estimates, the California sales of distributors averaged 50,000 units while camshaft sales averaged 66,000 units. Carburetor sales appear to be about 27,000 units annually. Needless to say, each California sales estimate should be viewed with caution.

Alternatively, total sales in California could have been estimated from the household portion of the survey. The purchasing behavior of the respondents could have been expanded to California as a whole. In order to have used this method of expansion, a statistically significant prevalence rate of aftermarket parts users would have had to be made available from a general population survey, and the demographic characteristics of the respondents would have to match all Californians. Unfortunately, neither condition is met by the current data set.

SURVEY-BASED RECOMMENDATIONS

Although the results of the firm survey were disappointing, the data collected from the users has utility. In light of the total information-collecting effort, the following recommendations are made:

1. The choice of engines should be governed by the results of the users survey. To some extent, the firm survey documents what users indicated were the most prevalent engines in use.

2. Multiple item tests (i.e., more than one aftermarket part) should be performed. It is suggested that the distribution of such tests follow the survey results (Table 12).

3. Because of the modest applications found for turbochargers, any diminished testing effort, if necessary, should focus on this item.

4 Due to the lack of cooperation by firms in the industry, it is recommended that no further effort be expanded in collecting data from them.

5 Statistical tests indicate that the firm data are not of sufficient quality to produce reasonable estimates of total unit sales in California due primarily to non-response. Thus, this data base should not be used to make expanded, quantitative estimates.

6. Because of an unknown prevalence rate for aftermarket parts users in California, and because the household demographics are significantly different, the household survey data cannot provide quantitative estimates of total sales in California.

7. Should the emissions tests indicate that aftermarket parts adversely impact air quality, it is recommended that the sales and usage estimates be developed through a statistically valid household survey since further involvement with firms is not likely to produce the necessary information.

In addition, the data base, particularly the household information, should be made available to ARB automotive researchers for applications other than the present one.

APPENDIX A

SAMPLE FRAME FOR THE SURVEY OF FIRMS

SAMPLE FRAME FOR THE SURVEY OF FIRMS

Mr. Ralph C. Hansen
Accel Performance Ignition P.O. Box 142 Branford, CT 06405

Mr. Richard Corgiat Advance Adapters, Inc. 14903 Marquardt Street Santa Fe Springs, CA 90670

Mr. Joe Alphabet Alphabet's Custom West Corporation 12572 Western Avenue Garden Grove, CA 92641

Mr. Gene Scott Antique Auto Parts, Inc. 9113 E. Garvey Avenue Rosemead, CA 91770

E.E. Lohn
Ansen Enterprises 8924 Bellanca Ave. Los Angeles, CA 90045

Mr. James A. Law
ANSA Mufflers Corporation P.O. Box 1288 Fitzgerald, GA 31750

Ms. Donna Thorstenson Appliance Industries 23920 S. Vermont Ave. Harbor City. CA 90710

ARC International, Inc. 4788 Library Road Bethel Park, PA 15102

Mr. Gary Armstrong Armstrong Race Engineering 2552 Albatross Way Sacramento, CA 95815

Mr. Fred Thornley Armor-All Products P.O. Box 19039 Irvine, CA 92713

Mr. Keith Holden ARP Muffler Service 11757 Hadley Whittier, CA 90601

Auto America 6440 Flying Cloud Drive Minneapolis, MN 95344

Mr. Lenny Stitz Autocraft Accessories 2210 W. Lincoln Ave. Anaheim, CA 92801

Ms. Diana Geddes Automark Enterprises, Inc. 1536 Stone Canyon Road Los Angeles, CA 90024

T.H. Foraker Automotive Alliance, Inc. P.O. Box 565 Santa Ynez, CA 93460

Mr. Robert W. Tucker Automotive Energy Systems, Inc. 4827 North Sepulveda Blvd.
Suite 410 Sherman Oaks, CA 91403

Mr. Rick Boulton Bolt-On-Parts, Inc. 14120 NW 7th Avenue
Miami, FL 33168

Mr. Bob Brooks Brooks Racing Components, Inc. 7091 Belgrave
Ave. Garden Grove, CA 92641

Mr. Douglas H. Buck D.H. Buck Company, Inc. 180 E. La Jolla
Placentia, CA 92670

Mr. Gerald A. Logan Bushwacker Products P.O. Box 2846 Portland,
OR 97208

Mr. William C. Longo
C-P Auto Products 3869 Medford St. Los Angeles, CA 90063

Mr. Troy Stephens Cal Custom/Hawk 23011 S. Wilmington Carson,
CA 90745

Mr. Phil Braysbrooks California Hi-Performance
Wholesale 3230 Motor Circle Drive Riverside, CA 92504

Mr. Ed Barzda California Speed & Sport 298 Jersey Avenue New
Brunswick, NJ 08901

Mr. Stan Seaman California Trophy 84 Page Street San Francisco,
CA 94102

Mr. Noel Carpenter Noel Carpenter & Associates The Autoscene
31220 La Baya Dr.
Suite 111 Westlake Village, CA 91361

Mr. Bill Johnson Cartech Manufacturing 11144 Ables Lane
Dallas, TX 75229

Mr. A.A. Morey, Jr. Carter Carburetor 9666 Olive Street Road
St. Louis, MO 63132

Mr. Jim Hairston Casler Performance Products P.O. Box 3397
Ontario, CA 91761

Mr. Dick Cepek Inc., 9201 California Avenue, South Gate, CA 90280

Mr. Robert E. Stewart III Chassis Engineering & Speed 2584
Fenter, Suite E Fullerton, CA 92631

Mr. Scott A. Barrera Christian Diversified 4769 Live Oak
Canyon Rd. La Verne, CA 91750

Mr. G.R. Checkley
Chrysler Corporation-Direct
Connection P.O. Box 857 Detriot, MI 48288

Mr. Jack L. Clifford Clifford Research & Development Company, Inc. 1670 Sunflower Ave. Costa Mesa, CA 92626

Mr. Ivars Smiltnieks Competition Cams, Inc. 2806 Hanger Road Memphis, TN 38118

Mr. Art Soares Competition Parts Warehouse 2240 De La Cruz Blvd. Santa Clara, CA 95050

Competition Specialties 1315 Knollwood Circle Anaheim, CA 92801

Mr. Tom Shedden Cragar Industries, Inc. 19007 South Reyes Ave. Compton, CA 90221

Mr. Harvey J. Crane, Jr. Crane Cams, Inc. P.O. Box 160 Hallandale, FL 33009

Mr. Bruce Crower Crower Cams & Equipment Co. 3333 Main Street Chula Vista, CA 92011

Mr. Derek Torley Crown Manufacturing Co. P.O. Box 2860 Newport Beach, CA 92663

Mr. John Lundberg Cyclone Automotive Products 7040 Lankershim Blvd. N. Hollywood, CA 91605

Deane, Snowdon, Shutler, Garrish & Gherardi 555 Pier Avenue Suite 6 Hermosa Beach, CA 92054

Discount Parts & Tires P.O. Box 43279 Middletown, KY 40243

Mr. Keith Duesenberg K.W. Duesenberg, Inc. 711 W. 17th St. E-10 Costa Mesa, CA 92627

Mr. David Kentish Durimex, Inc. 414 West Rowland Ave. Santa Ana, CA 92707

Mr./Ms. Pat Usher Dynotronics 14800 NW Pioneer Road Beaverton, OR 97005

Mr. Robert Fouts Earl's Supply Co. 14611 Hawthorne Blvd. Lawndale, CA 90260

Mr. Vick Edelbrock Edelbrock Corporation 411 Coral Circle Drive El Segundo, CA 90245

Mr. Stan Lipsey Elixir Industries Window Division 17809 S. Broadway Gardena, CA 90248

Ermie Immerso Enterprises, Inc. 18700 Susana Rd. Rancho Dominguez, CA 90221

Mr. Sig Erson Sig Erson Racing Cams, Inc. 15881 Chemical Lane Huntington Beach, CA 92649

Mr. Bruce Esajian Esajian Enterprises, Inc. 527 L Street Fresno, CA 93721

Mr. Ron Walden Exzostec, Inc. P.O. Box 1278 Paramount, CA 90723

Mr. Don Wharton The Factory 7741 Alabama St., #1 Canoga Park, CA 91306

FAZA 2538 S. Ridgewood Daytona, FL 32019

Mr. Jim Feuling Feuling Engineering 7159 Vineland N. Hollywood, CA 91605

Mr. Thomas Fileman Flagship Marine Engine Co., Inc. 159 S. Main Street Freeport, NY 11520

Mr. Timothy Perry Florida Rod Shop 3019 Alt. 19 N. Palm Harbor, FL 33563

Mr./Ms. Gale Banks Gale Banks Engineering 929 S. San Gabriel Blvd. San Gabriel, CA 91776

Mr. Bob Dalton Gator Products P.O. Box 33 Willingford, PA 19086

Mr. Mickey Katsumata Gemini Tube Fabrications, Inc. 1360 S. Ritchey St. Santa Ana, CA 92705

Mr. Jim Thomas Genuine Suspension 2902 Daimler St. Santa Ana, CA 92705 Mr. Peter Wright Gidon Industries, Inc. Thrush Performance Products 172 Bethridge Rd. Rexdale, Ontario, Canada M9W 1 N3

Mr. John Gladney Gladney Brothers Wood Products 929 W. Baker Costa Mesa, CA 92626

Mr. Harvey L. Goldberg Harvey L. Goldberg & Associates 7745 Alabama Ave., #4 Canoga Park, CA 91304

Mr./Ms. E.H. Tutun W.R. Grace & Co. Automotive Specialties Group 1114 Avenue of the Americas New York, NY 10036

Gratiot Auto Supply P.O. Box 2805-B-101 Troy, MI 48084

Mr. W. Craig Hendrickson H-O Racing Specialties, Inc. 4708 W. Compton Blvd. Lawndale, CA 90260

Mr. Don Hardy Don Hardy Race Cars, Inc. 202 W. Missouri St. Floydada, TX 79235

Mr. Robert Vandergriff Hedman Manufacturing P.O. Box 2126 Culver City, CA 90230

Mr. Don Smith High Performance Distributors 1755 Mission Rd. S. San Francisco, CA 94080

Mr. Jim Parks Area 6 Director High Performance Distributors 1755 Mission Road S. San Francisco, CA 94080

Mr. Stanley Jursek Holley Replacement Parts 11955 E. 9 Mile Road Warren, MI 48090

Mr. Jim Hairston Hooker Headers P.O. Box 4090 Ontario, CA 91761

Houston Speed & Sport, Inc. 7477 Southwest Freeway Houston, TX 77074

Mr. Robert Stack International Parts Corp. 4101 W. 42nd Place Chicago, IL 60632

Iskenderian Racing Cams 16020 S. Broadway Gardena, CA 90247

Mr. Tom Easterday Jacobs Electrical Products 3578 Eagle Rock Blvd. Los Angeles, CA 90065

Mr. Pete Jackson Pete Jackson Gear Drives 1905 Victory Blvd., #9 Glendale, CA 91201

Mr. Andrew de Janasz Janasz Corporation 137-139 Nevada St. El Segundo, CA 90245

Mr. Kurt L. Dhaien J-Mark, Inc. 800 Kasota Ave. Minneapolis, MN 55414

Mr. Ken John K&N Engineering, Inc. 561 Iowa Ave. P.O. Box 1329 Riverside, CA 92502

Mr. Don Turney Keystone Products 1333 S. Bon View Ave. Ontario, CA 91761

Mr. Jim Bell Kenne-Bell 212 San Lorenzo Pomona, CA 91766

Mr. Ed Sprague Kerker Division Kendrick Engineering, Inc. 7900 Deering Ave. Canoga Park, CA 91304

Mr. Dennis Klein KM Products 10164 Tujunga Canyon Blvd. Tujunga, CA 91042

Speed & Sport, Inc. 7477 Southwest Freeway Houston, TX 77074

Mr. Robert Stack International Parts Corp. 4101 W. 42nd Place Chicago, IL 60632

Iskenderian Racing Cams 16020 S. Broadway Gardena, CA 90247

Mr. Tom Easterday Jacobs Electrical Products 3578 Eagle Rock Blvd. Los Angeles, CA 90065

Mr. Pete Jackson Pete Jackson Gear Drives 1905 Victory Blvd., #9 Glendale, CA 91201

Mr. Andrew de Janasz Janasz Corporation 137-139 Nevada St. El Segundo, CA 90245

Mr. Kurt L. Dhaien J-Mark, Inc. 800 Kasota Ave. Minneapolis, MN 55414

Mr. Ken John K&N Engineering, Inc. 561 Iowa Ave. P.O. Box 1329 Riverside, CA 92502

Mr. Don Turney Keystone Products 1333 S. Bon View Ave. Ontario, CA 91761

Mr. Jim Bell Kenne-Bell 212 San Lorenzo Pomona, CA 91766

Mr. Ed Sprague Kerker Division Kendrick Engineering, Inc. 7900 Deering Ave. Canoga Park, CA 91304

Mr. Dennis Klein KM Products 10164 Tujunga Canyon Blvd. Tujunga, CA 91042

Mr. John T. Stewart Lazar Power Systems 1211B Whittier Blvd. Whittier, CA 90602

Mr. Steven Weimer Le Van Specialty Company 14923 Proctor Ave. Industry, CA 91746

Mr. Mike Pollam Luben Industries 233 S. Seventh Ave. Industry, CA 91744

Mr. Jack McCoy McCoy Racing Products, Inc. 553 S. Seventh St. Modesto, CA 95351

Mr. Philip H. McGee McGee Cams & Injections Co. P.O. Box 67 Burbank, CA 91503

Mr. P.G. "Red" Roberts McLeod Industries, Inc. 1125 N. Armando Anaheim, CA 92806

Mr. Jim Lillo Mallory Electric Corporation 1801 Oregon Street Carson City, NV 89701

Mr. Barry Meguiar Meguiar's Mirror Bright 17275 Daimler Irvine, CA 92714

Mr. William M. Black Mercury Tube Industries 8015 Dolores St. Los Angeles, CA 90065

Mr. John D. Strock Merit Abrasive Products 201 W. Manville St. Compton, CA 90024

Mr. Randy Hays Midway Industries Stinber Products 15116 Adams St. Midway City, CA 92655

Mr. Marvin E. Miller Marvin Miller Mfg. 7745 Greenleaf Ave. Whittier, CA 90702

Mr. Don Alderson Milodon Engineering Co. 25601 W. Ave. Stanford Valencia, CA 91335

Mr./Ms. L.G. Gustafson Mitchell Mfg. Co., Inc. and Sales Company 146 S. Palm Ave. Alhambra, CA 91802

Mr. Loren Elisworth
Mothers Products 13811 Artesia Blvd. Cerritos, CA 90701

Mr. Jeffery M. Nelson Nelson Fuel Systems & Equipment 940 S. Vail Ave. Montebello, CA 90640

Mr. Mike Thermos Nitrous Oxide Systems 2520 Gundry Ave. Long Beach, CA 90806

Mr. Fred Offenhauser Offenhauser Sales Corp. 5232 Alhambra Ave. Los Angeles, CA 90032

Mr. David Ebbert Orange Performance Dist. 14311 Chambers Rd. Tustin, CA 92680

Mr. Woody Harrah Pace-Setter 3455 S. La Cienega Los Angeles, CA 90016

Mr. George Parker Parkers Magnetos 4865 Pasadena Ave. Sacramento, CA 95841

Mr. Joe Goldblatt Performance Innovations 445 Enterprise St. Fremont, CA 94538

Ms. Sheila Rech Performance Innovations, Inc. 1931 Old Middlefield Way Mountain View, CA 94030

Performance Oriented People P.O. Box 1454 S. Bowie, MD 20716

Mr. Mike Deschenes Performance Marketing Inc. 1903 E. Deere Ave. Santa Ana, CA 92705

Mr. Rich Cholakian Performance Sales 1320 S. Brand Blvd. Glendale, CA 91204

Mr. Dick Van Cleve Petersen Publishing 8490 Sunset Blvd. Los Angeles, CA 90069

Mr. Murray Diamond Planticolor Molded Products 211 Fee Ana St. Placentia, CA 92670

Mr. Robert Armistead Pollution Controls Industries 1974 S. Blackstone P.O. Box 1322 Tulare, CA 93275

Mr. George Elliott Popular Hot Rodding 12301 Wilshire Blvd. #316 Los Angeles, CA 90045

Mr. Cedric Kotowicz Products for Power Division of Ced's, Inc. 512 West Winthrop Addison, IL 60101

Mr. Herb Goldstein Pro-Trac Tire Co., Inc. 425 N. Robertson B.vd. Los Angeles, CA 90048

Mr. Michael R. Rao R&R Marketing Consultants 2952 Garden Grove Blvd.
Suite B Garden Grove, CA 92644

Mr. Racer Brown Racer Brown, Inc. 9270 Borden Ave. Sun Valley, CA 91352

Mr. Donald Tognotti Racing Products Warehouse 2511 Fulton Ave. Sacramento, CA 95821

Mr. Lawrence H. Beasley Rajay Industries, Inc. 2600 E. Wardlow Rd. P.O. Box 207 Long Beach, CA 90801

Mr. Gene Shook Rancho Supply P.O. Box 5429 Long Beach, CA 90805

Mr. John Ugirn Rapid Cool, Inc. 1521 Pomona Road Corona, CA 91720

Mr. John Reed Reed Cams, Inc. 114 New Street Decatura, GA 30030

Mr. Raymond L. Bleiweus Rocket Industries, Inc. 9935 Beverly Blvd. Pico Rivera, CA 90660

Mr. James Thornton Roto-Master 7101 Fair Avenue N. Hollywood, CA 91605

Mr. Lonnie Woods Rough Country, Inc. 1080 North Marshall Ave. El Cajon, CA 92020

Mr. Dave Russell Russell Performance Products 20420 S. Susana Rd. Carson, CA 90745

Mr. John Cottell S&E Industries, Inc. 12221 Rivera Road Whittier, CA 90606

Mr. Ken Bomar S&S Headers, Inc. 3565 Cadillac Ave. Costa Mesa, CA 92626

Mr. Fred Sanderson
Sanderson Headers Division of Precision Products, Inc. 1126 San Mateo Avenue S. San Francisco, CA 94080

Mr. Bud Bulmer Scat Enterprises, Inc. 1400 Kingsdale Ave. P.O. Box 1220 Redondo Beach, CA 90278

Mr. Tom Scribner Scribner's Electronics, Inc. 4568 Industrial St. Simi Valley, CA 93065

Mr. Terry Furusho Shades of Competition 650 Nuttman St. #107 Santa Clara, CA 95050

Mr./Ms. Pat Shelby Carroll Shelby Industries, Inc. 19021 S. Figueroa Gardena, CA 90248

Mr. George B. Spears Spearco Performance Products, Inc. 10936 S. La Cienega Blvd. Inglewood, CA 90304

Ms. Donna Imrie Specialty Equipment Market Association 11534 E. Saluson Ave. Whittier, CA 90606

Mr./Ms. D.L. Peppin Speed-Pro Engine Parts Sealed Power Corp. 100 Terrace Plaza Muskegon, MI 49443

Mr. Jerry Light Speed Warehouse 411 W. A Street Hayward, CA 94541

Mr. Richard M. Frazer Sperex Corporation 1613 S. Maple Avenue Gardena, CA 90248

Mr. Peter Broeker Stebro Automotive Manufacturing, Ltd. St. Anne Road, R.R. 1 L'Original, Ontario, Canada LOB 1KO

Mr. Ray Hulbert Stop & Go Products 320 W. Coast Hwy. Newport Beach, CA 92663

Mr. Phil Moulton Storm Vulcan, Inc. Division of the Scranton Corp. 2225 Burbank St. P.O. Box 35667 Dallas, TX 75235

Mr./Ms. W.C. Ruffulo Stull Industries, Inc. 7331 Orangethorpe Buena Park, CA 90621

Mr. Victor Strand Strand Art Company 350 E. Orangethorpe #12 Placentia, CA 92670

Summit Racing Equipment 580 CC110 Kennedy Rd. Akron, OH 44305

Mr. Victor Strand Strand Art Company 350 E. Orangethorpe #12 Placentia, CA 92670

Mr. Tom Beckley Sun Electric Corp. 1560 Trimble Rd. San Jose, CA 95131

Mr. Ray Brown Superior Industries International, Inc. 7800 Woodley Avenue Van Nuys, CA 91406

Mr./Ms. T.K. Davis TRW Replacement Division TRW, Inc. 8001 E. Pleasant Valley Rd. Cleveland, OH 44131

Mr. George F. Milledge Technibilt Corporation Interstate Division Grand Products One West Alameda Avenue Burbank, CA 91502

Mr. Tony Shumaker Mickey Thompson Products, Inc. 1970 Placentia Avenue Costa Mesa, CA 92627

Mr. Paul Escoe Doug Thorley Headers, Inc. 7403 Telegraph Rd. Los Angeles, CA 90040

Mr. Bill Tidwell Bill Tidwell Marketing 19782 MacArthur Blvd. #201 Irvine, CA 92715

Mr. Stu Haggart The Toy Store 342 Sunset Ave. Venice, CA 90291

Mr. Carl Chapin Trans-Dapt of California 1635 Gaylord St. Long Beach, CA 90813

Mr. Jay Scott Tru-Spoke, Inc. 1800 Tablot Way Anaheim, CA 92805

Mr. Russ Smith Turbo International 12272 Monarch St. Garden Grove, CA 92641

Mr. Mike Howe United Industries 15281 Graham Street Huntington Beach, CA 92649

Mr. Peter Castelan Ultra Seal International Inc. 1100 N. Wilcox Ave. Los Angeles, CA 90038

Mr. Al Morris United Speed Wholesale 2670 Albatross Way Sacramento, CA 95815

Mr. Dennis McSorley Valley Industries Division of the Scott & Fetzer Co., 1313 S. Stockton
Lodi, CA 95240

Mr. Robert M. Hirashima Viam Corporation 119 E. Star of India Lane Carson, CA 90746

Mr. Curtis Moscini W.C. Performance, Inc. 1855 Grant St. Santa Clara, CA 90505

Mr. Harry J. Weber Web-Cam, Inc. 1663 Superior Ave. Costa Mesa, CA 92626

Mr./Ms. Pat Peterson Weber Performance Products 236 N. Sunset Ave. Industry, CA 91744

Ms. Joan Weiand Weiand Automotive Industries, Inc. 2316 San Fernando Road P.O. Box 65977 Los Angeles, CA 90065

Mr. Jim Kavanagh Western Wheel A Division of Rockwell International 6861 Walker St. La Palma, CA 90623

Mr./Ms. H. Seymour Xantech Corporation 13038 Saticoy St. N. Hollywood, CA 91605

Mr. Bud Yancer Yancer Specialty, Inc. 2939 N. 17th Ave. Phoenix, AZ 85015

APPENDIX B

SURVEY MATERIALS FOR THE SURVEY OF FIRMS

CIC RESEARCH, INC.

Economic Research • Marketing Research • Environmental Research • Survey Research

October, 1981

Mr. John Doe
President
JD Racing Components, Inc.
555 ABC Street
Anywhere, CA 90001

Dear Mr. Doe:

CIC Research is conducting a study of the use of aftermarket parts on California vehicles for the California Air Resources Board. Essentially we are trying to determine the size of the aftermarket specialty parts market for California vehicles and specifically onto which vehicles these parts are being installed.

We need your help in two ways. In order to determine the aftermarket parts market, CIC will be contacting all major manufacturers of these parts in the U.S. within the next few days. So that you will be aware of our purpose when we call let me describe the type of information we will be requesting. Basically we are interested in six major aftermarket parts:

- exhaust headers
- modified intake manifolds
- turbo-chargers
- modified ignition distributors
- modified cam-shafts
- carburetors

We will be asking the approximate number of these parts which you manufactured and sold for use on California vehicles for the years 1978-80 and what you think your share (percentage) of the market was for those years. We also need your best estimate of the makes, models, and years of the vehicles on which the majority of these parts are being installed.

The second way you can help is by sending a copy of your most recent catalog and/or price list to my attention at the address below. If there is a charge for these materials, postage, or handling, please include a statement and you will be reimbursed promptly.

1215 CUSHMAN AVENUE • SAN DIEGO, CALIFORNIA 92110
TELEPHONE (714) 296-8844

In closing let me stress two important points. First, participation in the survey is voluntary, but we need your help if the study is going to be accurate and meaningful. In order for the ARB to use this data to make wise decisions in the best interest of all, we will need the help of all manufacturers and distributors, not just a few. All information provided will be kept strictly confidential and will be used only in the aggregate. We are tyring to construct a picture of the industry as a whole and no information on individual firms will be released by CIC Research, not even to the ARB.

Second, we realize that the kind of information we are requesting probably cannot be obtained directly from your company records. We know your time is valuable and we don't expect you to perform lengthy calculations in order to provide us with this information. We are simply asking for your best estimates in order to construct an overall picture of the aftermarket parts industry.

We hope you will take a few minutes to talk with our interviewer when he or she calls. Please feel free to call me if you have any questions regarding the study at any time. We appreciate your time and cooperation very much.

Sincerely,

Joyce G. Revlett
Director, Survey Research

JGR/hs

AFTERMARKET PARTS - CARB #624

Company Name ______________________________

Address ______________________________

Letter sent to: ______________________________

Respondent's Name & Title ______________________________

Hello, Mr. _________. This is ________ calling from CIC Research. Did you receive a letter we sent to you last week telling the purpose of my call today (IF NOT, INDICATE ANOTHER WILL BE MAILED AND VERIFY MAILING ADDRESS. IF SO, PROCEED.) Do you have a few minutes now to answer a couple of questions about the aftermarket parts mentioned in the letter? It will take only a few minutes of your time. (IF RESPONDENT SUGGESTS ANOTHER TIME WOULD BE BETTER, MAKE AN APPOINTMENT TO CALL BACK. IF HE HESITATES, ENCOURAGE HIM TO COMPLETE THE SURVEY NOW SO YOU WON'T HAVE TO BOTHER HIM AGAIN.)

Q1. As I read a list of specialty aftermarket parts, please tell me which items you deal with and exactly what your function is, that is, do you manufacture, serve as a distributor, or retail the product? Please indicate as many functions as apply to each item. (MULTIPLE RESPONSES POSSIBLE.) (IF MORE THAN ONE FUNCTION PER ITEM, ASK WHICH FUNCTION HE CONSIDERS TO BE PRIMARY AND CIRCLE THAT FUNCTION.)

	Manufacturer	Distributor	Mail Order Retailer	Outlet Retailer
a) exhuast headers	____	____	____	____
b) modified intake manifolds	____	____	____	____
c) turbo-chargers	____	____	____	____
d) modified ignition distributors	____	____	____	____
e) modified camshafts	____	____	____	____
f) non-OEM carburetors	____	____	____	____

Q2. As I read the list again, please tell me who you sell each of these items to, that is, do you sell them only to distributors, to other retail outlets or mail order companies, or directly to your own customers by mail order or through your own retail outlet? (ASK ONLY THOSE ITEMS MENTIONED IN Q1. FOR EACH OUTLET MENTIONED ASK:) What portion of your (part) would you say you sell to (outlet)?

	Distrib-utors*	Other Mail Order Firms	Other Retail Outlets	Your Own Mail Order Customers	Your Own Retail Outlet Customers
a) exhaust headers	______	______	______	______	______
b) modified intake manifolds	______	______	______	______	______
c) turbo-chargers	______	______	______	______	______
d) modified ignition distributors	______	______	______	______	______
e) modified cam-shafts	______	______	______	______	______
f) carburetors	______	______	______	______	______

* (IF RESPONDENT IS MANUFACTURER WHO SELLS ANY PORTION OF HIS PRODUCT TO DISTRIBUTORS, ASK:) Who and where is the distributor(s) who serves the California market?

Item	Name of Distributor	Location of Distributor
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______

Q3. Now I need some additional information about each of the after-market parts you handle. The questions will be very similar for each of the items but we'll talk about each item individually for the sake of simplicity. (USE ONE SHEET FOR EACH ITEM MENTIONED. ASK ALL QUESTIONS FOR 1980, THEN GO BACK TO Q3A, ETC. FOR 1979 AND THEN 1978.)

Name of Item ______________________________

Q3A. First, please estimate the total number of ____________ you sold in 19__. (RECORD ANSWER BELOW)

Q3B. Approximately how many of those, or what percentage, were likely to have been installed on California vehicles? This would include both street use and off-road or racing uses in 19__. (RECORD ANSWER BELOW)

Q3C. What % of the total California market in 19__ would you say that was? (RECORD ANSWER BELOW)

Q3D. Now I'd like to ask your ideas of the uses of the vehicles upon which this item was installed. That is, in 19__ what % of the _____ were installed upon vehicles intended for street use as opposed to racing or other off-road uses? (BE SURE THE TWO USES TOTAL 100%) (RECORD ANSWER BELOW.)

Q3E. And last, we're interested in which cars, street use only, you think these _____ were installed upon in 19__. Can you you tell me the make and engine size or type of vehicles receiving the most ______ in 19__? What year or years were most of these cars? Was there a prevalent model or models for that year(s)? What percent of 19__'s _____ sales were installed on those vehicles? (RECORD ANSWERS BELOW.)

Q3F. What was your major stock item(s) for that year? (hottest sales item)

(RETURN TO Q3A AND ASK Q3A-F FOR 1979 and THEN 1978)

	1980	1979	1978
Q3A. Total no. of items sold			
Q3B. No. or % sold for California use			
Q3C. % of total California market			
Q3D. Use of Item: Street use (%)			
Racing (%)			
Q3E. Major cars of installation			
Car #1: Make			
Engine size/type			
Year(s)			
Prevalent model			
% of sales			
Car #2: Make			
Engine size/type			
Year(s)			
Prevalent model			
% of sales			
Car #3: Make			
Engine size/type			
Year(s)			
Prevalent model			
% of sales			
Q3F. Major stock item			

Q4. Can you tell me your primary and secondary 4-digit Standard Industrial Classification, or SIC, codes? Please tell me your primary and secondary line of business, both product and function.

Primary SIC Code: ____________________

Secondary SIC Code: ____________________

Primary line of business: Function: ____________________

Product: ____________________

Secondary line of business: Function: ____________________

Product: ____________________

Q5. Do you have any (other) aftermarket parts facilities located in California? (IF YES) Where are they located and what are their major functions?

_____ No (other) facilities in California

_____ Yes, (other) facilities in California (LIST BELOW)

Name & Location	Function

Q6. Last question. Have you mailed a copy of your catalog and/or parts price list to us?

_____ Yes, in mail already

_____ No, but will do so soon

_____ No, will not send one/don't have one

Thank you very much for your time and cooperation.

INTERVIEWER'S COMMENTS:

____

____

____

____

____

APPENDIX C

LIST OF COMPANIES
FROM WHICH CATALOGS
WERE RECEIVED

COMPANIES FROM WHICH CATALOGS WERE RECEIVED

Accel, Branford, CN
Advance Adapters, Inc., Paso Robles, CA
Automotive Alliance, Santa Ynez, CA
Autotronic Controls Corporation, El Paso, TX
Keith Black Racing Engineers, South Gate, CA
Dick Cepek, South Gate, CA
Competition Cams, Memphis, TN
Crane Cams, Inc., Hallandale, FL
Discount Parts & Tires, Middleton, KY
Eagle Headers, Canoga Park, CA
Gratiot Auto Supply, Troy, MI
Don Hardy Race Cars, Inc., Floydada, TX
Ed Iskenderian Racing Cams, Gardena, CA
Jacobs Electrical Products, Inc., Los Angeles, CA
Midway Industries, Midway City, CA
Mitcom, Inc., North Hollywood, CA
Offenhauser Sales Corporation, Los Angeles, CA
Rapid Cool, A Division of Hayden, Inc., Corona, CA
S & S Headers, Costa Mesa, CA
Sanderson Headers, South San Francisco, CA
Turbo International, Garden Grove, CA
Web-Cam, Costa Mesa, CA

APPENDIX D

SURVEY MATERIALS FOR THE SURVEY OF HOUSEHOLDS

INTERVIEWER EXPLANATION
OF ARB AFTERMARKET PARTS SURVEY

The voters in California require the Air Resources Board to inventory all emissions of air pollutants -- including those from automobiles. The Board believes that aftermarket parts may affect emissions, but they need to know how large the effect is and how many aftermarket parts are installed. They will use this information to improve the emissions inventory, and the inventory can then be used to decide whether aftermarket parts make a significant difference.

I.D.# ______________

SURVEY OF USERS OF AFTERMARKET PARTS - #624

Hello. I'm calling long distance for a survey of automobile parts for the State of California. I would like to speak to that person in your household who would be most familiar with any automobile parts which were purchased by members of your household. (F RIGHT PERSON, CONTINUE. IF SOMEONE ELSE COMES TO THE PHONE, REPEAT INTRO BEFORE PROCEEDING.)

Q1. In the past three years, have you or anyone else in your household purchased any of the following items? (PROBE FOR THE NUMBER OF EACH ITEM PURCHASED.)

No.	Item	
_____	Exhaust headers (1)	A1)_____
_____	Modified intake manifolds (2)	A2)_____
_____	Turbo-chargers (3)	A3)_____
_____	Modified ignition distributors (4)	A4)_____
_____	Modified cam-shafts (5)	A5)_____
_____	Carburetors (6)	A6)_____

(IF NO ITEMS WERE PURCHASED, THANK RESPONDENT AND TERMINATE. IF ITEMS WERE PURCHASED, COMPLETE ONE GREEN EQUIPMENT FORM FOR EACH ITEM MENTIONED, INCLUDING MULTIPLES OF ANY ITEM. WRITE THE NAME OF THE ITEM AT THE TOP OF EACH FORM. USE EXTRA FORMS AS NEEDED AND STAPLE ALL FORMS TOGETHER WHEN FINISHED. COMPLETE ALL FORMS BEFORE PROCEEDING TO DEMOS.)

ID ____

Name of Item ______________________

Itm ____

Q2. When was the (name of item) purchased?

Month and year ______________ A1 ____

Q3. Who manufactured it? ______________________ DK 9 A2 ____

Q4. Who was it purchased from?

Name of Company ______________________ A3 ____

Q5. Was it purchased... 1 by mail order...

2 From a retail outlet, A4 ____

* Other (SPECIFY) ______________

Q6. Has it been installed? A5 ____

____ Yes (ASK:) When? ______________ (Month & Year) A6 ____

____ No (SKIP TO NEXT ITEM)

A7 ____

Q7. What is the make and model of the vehicle it is installed on? (IF CAR WAS PREVIOUSLY DESCRIBED, WRITE "SAME" FOR Q7 AND GO ON TO NEXT ITEM.) A8 ____

____ Make ____ Model ____ Year A9 ____

A10 ____

Q8. What is the engine type, size, year and number of cylinders?

____ Type ____ Size ____ Year ____ No. of cylinders A11 ____

A12 ____

Q9. Is the vehicle on which it is installed registered for street use? A13 ____

1 Yes (ASK Q7)

2 No (SKIP TO Q8) A14 ____

Q10. Is this vehicle your primary transportation?

1 Yes A15 ____

2 No

Q11. On the average, how many miles per year do you drive this vehicle?

______ Miles A16 ____

(GO TO NEXT ITEM. IF LAST ITEM, GO TO DEMOS.)

DEMOS

Q1. Now, to group your answers with those of others, I need to know what type of dwelling unit you live in. Is a single detached home, a building with multiple units, a mobile home, or what? (IF MULTIPLE UNIT, ASK:) How many units are attached together?

__1__ Single unit   __4__ 5 or more units

__2__ Mobile home   __5__ Other (dorm, etc.)   7) ______

__3__ 2 - 4 units   __9__ Refused

Q2. Do you rent or own your home?

__1__ Rent   __2__ Own   __9__ DK/Refused   8) ______

Q3. How many people 18 years of age or older are living in your household?

______ Persons 18 or older   9) ______

Q4. How many children below the age of 18 years are living in your household?

______ Children under 18 years of age   10) ______

Q5. Which of the following age groups includes your age? (READ LIST)

__1__ Under 18   __5__ 45 to 54

__2__ 18 to 24   __6__ 55 to 64   11) ______

__3__ 25 to 34   __7__ 65 and over

__4__ 35 to 44   __9__ Refused

Q6. And, is your household's total income, expected from all sources this year, likely to be $20,000 or more?

__*__ No (ASK:) Is it...   __*__ Yes (ASK:) Is it...

__1__ Under $10,000   __4__ $20,000 to $30,000

__2__ $10,000 to $15,000   __5__ $30,000 to $40,000   12) ______

__3__ $15,000 to $20,000   __6__ $40,000 or over

__9__ DK/Refused

(RECORD SEX OF RESPONDENT:)   __1__ Male   __2__ Female   13) ______

Thank you very much for your time and cooperation.

APPENDIX B

TEST DATA

Table B-1. 1979 CHEVROLET MALIBU - WORST CASE HEADERS AND INTAKE MANIFOLD EVALUATION (EGR, AIR INJECTION, CATALYST AND EARLY FUEL EVAPORATION REMOVED)

	BASELINE	HEADERS	MANIFOLD/ HEADERS	Δ HEADERS VS BASE	Δ MANIFOLD/ HEADERS VS BASE	Δ % HEADERS VS BASE	Δ % MANIFOLD/ HEADERS VS BASE
FTP							
HC (gm/mile)	0.523	2.337	1.913	1.814	1.290	346.8	265.8
CO "	12.365	15.534	12.692	3.169	0.327	25.6	2.6
NO_x "	1.064	1.450	2.205	0.386	1.141	36.3	107.2
CO_2 "	768.68	609.16	544.68	-159.52	-224.00	-20.8	-29.1
MPG	12.38	13.63	15.01	1.25	2.63	10.1	21.2
HFET-MPG	15.25	17.91	19.85	2.66	4.60	17.4	30.2
Combined MPG	13.53	15.27	16.86	1.74	3.33	12.9	24.6
Driveability							
Cold (demerits)	84	144	12	60	-72	71.4	-85.6
Hot "	48	48	0	0	-48	0.0	-100.0
Combined "	132	192	12	60	-120	45.3	-90.9
0-70 Acceleration (Seconds)	22	18	17	-4	-5	-18.2	-22.7
Steady State							
20 mph							
HC (gm/mile)	0.176	0.785	0.489	0.609	0.313	346.0	177.8
CO "	0.135	1.390	1.680	1.255	1.545	929.6	1144.4
NO_x "	0.196	0.148	0.238	-0.048	0.042	-24.5	21.4
Pi (in Hg.)	0.150	0.050	0.050	-0.10	-0.10	-66.7	-66.7
Po "	0.070	-	-	-	-	-	-
T #1 Cyl. (^{o}F)	1070	1038	1031	-32	-39	-3.0	-3.6
T Oil "	170	194	195	24	25	14.1	14.7
T CAT In "	810	350	355	-460	-455	-56.8	-56.2
T CAT Out "	650	-	-	-	-	-	-
T CAT Skin "	400	-	-	-	-	-	-

Table B-1. 1979 CHEVROLET MALIBU - WORST CASE HEADERS AND INTAKE MANIFOLD EVALUATION (EGR, AIR INJECTION, CATALYST AND EARLY FUEL EVAPORATION REMOVED) (CONTINUED)

	BASELINE	HEADERS	MANIFOLD/ HEADERS	Δ HEADERS VS BASE	Δ MANIFOLD/ HEADERS VS BASE	Δ % HEADERS VS BASE	Δ % MANIFOLD/ HEADERS VS BASE
30 mph							
HC (gm/mile)	0.046	0.467	0.627	0.421	0.581	915.2	1263.0
CO "	0.000	1.297	1.752	1.297	1.752	-	-
NO_x "	0.324	0.256	0.235	-0.068	-0.089	-21.0	-27.5
Pi (in. Hg.)	0.450	0.175	0.275	-0.275	-0.175	-61.1	-38.9
Po "	0.250	-	-	-	-	-	-
T #1 Cyl. (°F)	960	1140	1172	180	212	18.8	22.1
T Oil "	161	198	204	37	43	23.0	26.7
T CAT In "	575	455	510	-120	-65	-20.9	-11.3
T CAT Out "	445	-	-	-	-	-	-
T CAT Skin "	256	-	-	-	-	-	-
40 mph							
HC (gm/mile)	0.067	0.505	0.373	0.438	0.306	653.7	456.7
CO "	0.000	1.930	1.530	1.930	1.530	-	-
NO_x "	0.298	0.213	0.556	-0.085	0.258	-28.5	86.6
Pi (in Hg.)	1.450	0.550	0.550	0.900	0.900	-62.1	-62.1
Po "	0.600	-	-	-	-	-	-
T #1 Cyl. (°F)	1168	1298	1181	130	13	11.1	1.1
T Oil "	182	213	228	31	46	17.0	25.3
T CAT In "	980	695	600	-285	-380	-29.1	-38.8
T CAT Out "	830	-	-	-	-	-	-
T CAT Skin "	485	-	-	-	-	-	-

Table B-1. 1979 CHEVROLET MALIBU - WORST CASE HEADERS AND INTAKE MANIFOLD EVALUATION (EGR, AIR INJECTION, CATALYST AND EARLY FUEL EVAPORATION REMOVED) (CONTINUED)

		BASELINE	HEADERS	MANIFOLD/ HEADERS	Δ HEADERS VS BASE	Δ MANIFOLD/ HEADERS VS BASE	Δ% HEADERS VS BASE	Δ% MANIFOLD/ HEADERS VS BASE
50 mph								
HC	(gm/mile)	0.017	0.401	0.230	0.384	0.213	225.9	125.3
CO	"	0.000	1.977	1.412	1.977	1.412	-	-
NO_x	"	0.431	0.315	0.946	-0.116	0.515	-26.9	119.5
Pi	(in Hg.)	1.610	0.900	0.800	-0.710	-0.810	-44.1	-50.3
Po	"	0.930	-	-	-	-	-	-
T #1 Cyl.	(^{o}F)	1270	1348	1260	78	-10	6.1	-0.8
T Oil	"	210	220	254	10	44	4.8	21.0
T CAT In	"	1090	815	729	-275	-361	-25.2	-33.1
T CAT Out	"	980	-	-	-	-	-	-
T CAT Skin	"	575	-	-	-	-	-	-
60 mph								
HC	(gm/mile)	0.006	0.222	0.169	0.216	0.163	3600.0	2716.7
CO	"	0.000	1.771	1.424	1.771	1.424	-	-
NO_x	"	0.680	0.503	0.623	-0.177	-0.057	-26.0	-8.4
Pi	(in Hg.)	2.830	1.525	1.450	-1.305	-1.380	-46.1	-48.8
Po	"	2.00	-	-	-	-	-	-
T #1 Cyl.	(^{o}F)	1400	1400	1245	0	-155	0.0	-11.1
T Oil	"	220	230	256	10	36	4.5	16.4
T CAT In	"	1340	942	820	-398	-520	-29.7	-38.8
T CAT Out	"	1175	-	-	-	-	-	-
T CAT Skin	"	745	-	-	-	-	-	-

Table B-2. 1976 FORD GRANADA - BEST CASE HEADERS AND INTAKE MANIFOLD EVALUATION (NO EMISSION CONTROL COMPONENTS REMOVED)

	BASELINE	HEADERS	MANIFOLD/ HEADERS	Δ HEADERS VS BASE	Δ MANIFOLD/ HEADERS VS BASE	Δ% HEADERS VS BASE	Δ% MANIFOLD/ HEADERS VS BASE
FTP							
HC (gm/mile)	0.669	0.812	1.688	0.143	1.019	21.4	152.3
CO "	13.783	8.182	9.677	-5.601	-4.106	-40.6	-29.8
NO_x "	1.336	1.408	0.906	0.072	-0.430	5.4	-32.2
CO_2 "	885.87	626.64	720.59	-259.23	-165.28	-29.3	-18.7
MPG	9.77	13.73	11.99	3.96	2.22	40.5	22.7
HFET-MPG	14.23	19.25	18.50	5.02	4.27	35.3	30.0
Combined MPG	11.37	15.76	14.25	4.39	2.88	38.6	25.3
Driveability							
Cold (demerits)	30	33	71	3	41	10.0	136.7
Hot "	0	3	18	3	18	-	-
Combined "	30	36	89	6	59	20.0	196.7
0-70 Accel. (seconds)	22	17	20	-5	-2	-22.7	-9.1
Steady State							
20 mph							
HC (gm/mile)	0.734	0.273	1.680	-0.461	0.946	-62.8	128.9
CO "	0.135	0.241	0.367	0.106	0.232	78.5	171.9
NO_x "	0.358	0.406	0.417	0.048	0.059	13.4	16.5
Pi (in Hg.)	0.60	0.20	0.20	-0.40	-0.40	-66.7	-66.7
Po "	0.50	0.15	0.25	-0.35	-0.25	-70.0	-50.0
T #1 Cyl. (^oF)	1096	1082	1065	-14.0	-31.0	-1.3	-2.8
T Oil "	195	164	185	-31.0	-10.0	-15.9	-5.1
T Cat In "	915	651	552	-264.0	-363.0	-28.9	-39.7
T Cat Out "	825	632	615	-193.0	-210.0	-23.4	-25.5
T Cat Skin "	617	397	274	-220.0	-343.0	-35.7	-55.6
30 mph							
HC "	0.659	0.467	1.420	-0.192	0.761	-29.1	115.5
CO "	0.124	0.025	0.628	-0.099	0.504	-79.8	406.5
NO_x "	0.122	0.336	0.295	0.214	0.173	175.4	141.8
Pi (in Hg.)	0.50	0.30	0.40	-20.0	-10.0	-40.0	-20.0
Po "	0.70	0.40	0.60	-0.30	-0.10	-42.9	-14.3

Table B-2. 1976 FORD GRANADA - BEST CASE HEADERS AND INTAKE MANIFOLD EVALUATION (NO EMISSION CONTROL COMPONENTS REMOVED) (CONTINUED)

	BASELINE	HEADERS	MANIFOLD/ HEADERS	Δ HEADERS VS BASE	Δ MANIFOLD/ HEADERS VS BASE	Δ% HEADERS VS BASE	Δ% MANIFOLD/ HEADERS VS BASE
T #1 Cyl. (°F)	1094	1098	1140	4	46	0.4	4.2
T Oil "	187	161	179	-26	-8	-13.9	-4.3
T Cat In "	845	702	694	-143	-151	-16.9	-17.9
T Cat Out "	816	740	802	-76	-14	-9.3	-1.7
T Cat Skin "	529	429	378	-100	-151	-18.9	-28.5
40 mph							
HC (gm/mile)	0.156	0.168	0.548	0.012	0.392	7.7	251.3
CO "	0.154	0.043	0.222	-0.111	0.068	-72.1	44.2
NO_x "	0.442	0.596	0.461	0.154	0.019	34.8	4.3
Pi (in Hg.)	0.80	0.58	0.50	-0.22	-0.30	-27.5	-37.5
Po "	0.90	0.50	0.65	-0.40	-0.25	-44.4	-27.8
T #1 Cyl. (°F)	1134	1105	1137	-29	3	-2.5	0.3
T Oil "	188	164	177	-24	-11	-12.8	-5.9
T Cat In "	928	762	721	-166	-207	-17.9	-22.3
T Cat Out "	840	764	733	-76	-107	-9.0	-12.7
T Cat Skin "	582	488	385	-94	-197	-16.2	-33.8
50 mph							
HC (gm/mile)	0.103	0.125	0.178	0.022	0.075	21.4	72.8
CO "	0.410	0.113	0.400	-0.297	-0.010	-72.4	-2.4
NO_x "	0.594	1.093	0.689	0.499	0.095	84.0	16.0
Pi (in Hg.)	1.50	0.98	0.80	-0.52	-0.70	-34.7	-42.9
Po "	1.80	0.82	1.00	-0.98	-0.80	-54.4	-44.4
T #1 Cyl. (°F)	1264	1176	1201	-88	-63	-7.0	-5.0
T Oil "	191	166	189	-25	-2	-13.1	-1.0
T Cat In "	1044	847	867	-197	-177	-18.9	-17.0
T Cat Out "	957	843	870	-114	-87	-11.9	-9.1
T Cat Skin "	649	569	573	-80	-76	-12.3	-11.7

Table B-2. 1976 FORD GRANADA - BEST CASE HEADERS AND INTAKE MANIFOLD EVALUATION (NO EMISSION CONTROL COMPONENTS REMOVED) (CONTINUED)

	BASELINE	HEADERS	MANIFOLD/ HEADERS	△ HEADERS VS BASE	△ MANIFOLD/ HEADERS VS BASE	△% HEADERS VS BASE	△% MANIFOLD/ HEADERS VS BASE
Steady State							
60 mph							
HC (gm/mile)	0.069	0.132	0.157	0.063	0.088	91.3	127.5
CO "	1.511	0.341	0.497	-1.170	-1.014	-77.4	-67.1
No_x "	0.835	1.423	0.800	0.588	-0.035	70.4	-4.2
Pi (in Hg.)	2.80	1.50	1.60	-1.30	-1.20	-46.4	-42.9
Po "	3.40	1.63	1.90	-1.77	-1.50	-52.1	-44.1
T #1 Cyl. (°F)	1381	1252	1280	-129	-101	-9.3	-7.3
T Oil "	214	168	192	-46	-22	-21.5	-10.3
T Cat In "	1259	965	988	-294	-271	-23.4	-21.5
T Cat Out "	1198	970	993	-228	-205	-19.0	-17.1
T Cat Skin "	764	651	594	-113	-170	-14.8	-22.2

Table B-3. 1976 CHEVROLET CORVETTE - BEST CASE TURBOCHARGER EVALUATION
(NO EMISSION CONTROL COMPONENTS REMOVED)

		BASELINE		TURBOCHARGER		Δ		Δ %	
		RLHP	2XRLHP	RLHP	2XRLHP	RLHP	2xRLHP	RLHP	2XRLHP
FTP									
HC	(gm/mile)	0.692	0.753	0.772	0.907	+0.080	+0.154	+11.6	+20.5
CO	"	9.908	12.277	15.053	18.556	+5.145	+6.279	+51.9	+51.1
NO_x	"	1.987	2.407	1.464	2.126	-0.523	-0.281	-26.3	-11.7
CO_2	"	782.4	800.3	959.5	1008.4	+177.100	+208.100	+22.6	+26.0
MPG		12.92	12.02	10.11	9.51	-2.81	-2.51	-21.7	-20.9
HFET-MPG		15.29	12.77	13.02	10.53	-2.27	-2.24	-14.8	-17.5
Combined MPG		13.89	12.35	11.24	9.94	-2.65	-2.41	-19.1	-19.5
Steady States									
20 mph									
HC	(gm/mile)	0.097	0.170	0.139	0.333	0.042	0.163	+43.3	+95.9
CO	"	0.195	1.029	1.470	4.179	0.834	3.150	+427.7	+306.1
NO_x	"	0.322	0.248	0.411	0.453	0.089	0.205	+27.6	+82.1
Pi	(in Hg.)	0.15	0.10	0.15	0.20	0.00	0.10	0.0	100.0
Po	"	0.02	0.02	0.02	0.03	0.00	0.01	0.0	50.0
30 mph									
HC	(gm/mile)	0.180	0.176	0.020	0.020	-0.160	-0.156	-88.9	-88.6
CO	"	0.504	0.405	0.212	0.140	-0.292	-0.265	-57.9	-65.4
NO_x	"	0.273	0.287	0.447	0.583	0.174	0.296	63.7	102.1
Pi	(in Hg.)	0.25	0.25	0.40	0.40	0.15	0.15	60.0	60.0
Po	"	0.05	0.04	0.04	0.03	-0.01	-0.01	-20.0	-25.0
40 mph									
HC	(gm/mile)	0.031	0.034	0.012	0.015	-0.019	-0.019	-61.3	-55.9
CO	"	0.307	0.043	0.018	0.086	-0.289	0.043	-94.1	100.0
NO_x	"	0.754	0.948	0.699	1.043	-0.055	0.095	-7.3	10.0
Pi	(in Hg.)	0.56	0.68	0.62	0.75	0.06	0.07	10.7	10.3
Po	"	0.12	0.14	0.13	0.15	0.01	0.01	8.3	7.1

Table B-3. 1976 CHEVROLET CORVETTE - BEST CASE TURBOCHARGER EVALUATION (NO EMISSION CONTROL COMPONENTS REMOVED) (CONTINUED)

	BASELINE		TURBOCHARGER		Δ		Δ%	
	RLHP	2XRLHP	RLHP	2XRLHP	RLHP	2xRLHP	RLHP	2XRLHP
50 mph								
HC (gm/mile)	0.027	0.044	0.010	0.032	-0.017	-0.012	-63.0	-27.3
CO "	0.143	0.113	0.089	0.221	-0.054	0.108	-37.8	95.6
NO_x "	1.432	2.590	1.130	2.087	-0.302	-0.503	-21.1	-19.4
Pi (in Hg.)	1.02	1.20	1.02	1.30	0.0	0.1	0.0	8.3
Po "	0.23	0.30	0.25	0.30	0.02	0.0	8.7	0.0
60 mph								
HC (gm/mile)	0.030	0.035	0.043	0.189	0.013	0.154	43.3	440.0
CO "	0.126	0.156	0.431	1.459	0.305	1.303	42.6	835.2
NO_x "	2.967	3.749	3.570	2.405	0.603	-1.344	20.3	-35.8
Pi (in Hg.)	1.75	2.12	1.75	1.55	0	-0.57	0	-26.9
Po "	0.45	0.55	0.52	0.50	0.07	-0.05	15.5	-9.1

Table B-4. 1980 VW RABBIT - WORST CASE TURBOCHARGER EVALUATION (CATALYST REMOVED)

		BASELINE	TURBOCHARGER	Δ	Δ %
FTP					
HC	(gm/mile)	0.319	1.297	+0.88	+278.4
CO	"	3.781	14.254	+10.47	+277.0
NO_x	"	0.781	3.640	+2.86	+366.1
CO_2	"	435.9	387.7	-48.20	-11.1
MPG	"	22.66	23.95	+1.29	+5.7
HFET-MPG		25.46	24.98	-1.9	-0.48
Combined MPG		23.84	24.40	0.56	2.3
Steady States					
20 mph					
HC	(gm/mile)	0.170	0.448	0.278	163.5
CO	"	1.299	4.822	3.523	271.2
NO_x	"	0.045	0.390	0.345	766.7
Pi	(in Hg.)	0.10	0.0	0.10	-100.0
Po	"	0.05	-	-	-
30 mph					
HC	(gm/mile)	0.179	0.409	0.23	128.5
CO	"	1.277	4.251	2.974	232.9
NO_x	"	0.030	1.178	1.148	3826.7
Pi	(in Hg.)	0.24	0.0	-0.24	-100.0
Po	"	0.07	-	-	-
40 mph					
HC	(gm/mile)	0.134	0.459	0.325	242.5
CO	"	1.917	5.063	3.146	164.1
NO_x	"	0.113	1.858	1.745	1544.2
Pi	(in Hg.)	0.51	0.0	-0.51	-100.0
Po	"	0.15	-	-	-
50 mph					
HC	(gm/mile)	0.210	0.418	0.208	99.0
CO	"	4.772	7.182	2.41	5.05
NO_x	"	0.308	2.784	2.476	803.9
Pi	(in Hg.)	0.96	0.10	-0.86	-89.6
Po	"	0.35	-	-	-
60 mph					
HC	(gm/mile)	0.187	0.425	0.238	127.3
CO	"	3.512	9.787	6.275	178.7
NO_x	"	0.683	4.020	3.337	488.6
Pi	(in Hg.)	1.85	0.19	-1.66	-89.7
Po	"	0.79	-	-	-

Table B-5. CHEVROLET MALIBU TEMPERATURE READINGS (^{o}F) DURING FTP
(Taken Every 30 Seconds)

BASELINE			W/HEADERS		W/MANIFOLD & HEADERS	
#1 CYL	OIL	CAT SKIN	#1 CYL	OIL	#1 CYL	OIL
70	70	67	74	77	73	79
855	79	69	886	82	923	84
915	81	73	1079	88	981	91
1001	90	79	1115	95	1079	100
1000	108	85	1109	102	1082	106
773	108	91	1115	108	1056	111
992	111	97	1206	114	1224	118
141	119	113	1247	121	1317	125
1254	129	151	1227	134	1316	139
1261	139	232	1214	144	1207	148
1270	149	288	1065	152	991	155
1065	152	349	1125	160	1187	156
1174	159	408	993	161	1018	161
1172	166	448	1032	165	1022	163
1188	168	483	1127	168	1170	164
958	170	496	1085	171	1175	166
1185	169	502	1006	173	1067	168
993	171	519	1070	177	1023	170
1130	175	529	1020	178	1060	172
950	179	532	1088	180	1099	174
1084	180	528	952	180	900	175
880	181	717	1059	182	1060	177
1126	184	517	961	183	980	177
910	182	509	1047	184	985	179
1014	188	505	1103	185	1047	180
1130	186	502	1085	187	1023	181
1130	188	495	1101	189	1102	183
1175	190	490	1119	192	1115	185
1053	190	485	1109	192	1075	187
1080	191	480	1111	194	1073	190
1094	193	472	1093	195	1098	191
1064	192	469	1043	196	1085	192
944	192	461	1096	196	924	193
1057	195	457	934	197	1019	194
944	197	454	1061	198	981	198
845	197	449	1035	198	1083	198
1044	199	449	1096	200	1007	196
1037	199	446	980	200	1043	197
1081	200	444	1009	201	1024	197
934	200	441	1027	200	987	197
924	199	463	931	201	1043	198
990	201	434	1067	202	1126	197
835	201	429	963	202	891	198
1060	202	429	1033	203	1025	198
895	202	424	1025	202	1033	198
1024	204	422	927	203	1009	198
SOAK PERIOD			SOAK PERIOD		SOAK PERIOD	

Table B-5. CHEVROLET MALIBU TEMPERATURE READINGS (^{o}F) DURING FTP (Taken Every 30 Seconds). (Continued)

BASELINE			W/HEADERS		W/MANIFOLD & HEADERS	
#1 CYL	OIL	CAT SKIN	#1 CYL	OIL	#1 CYL	OIL
600	199	310	152	176	163	91
922	196	316	775	186	959	178
972	195	318	1006	190	1026	180
1045	194	325	1072	193	1092	183
840	193	327	1051	193	1012	186
769	193	328	933	193	872	188
1190	195	329	1045	196	1056	185
1270	197	336	1163	201	1236	190
1300	201	348	1227	207	1299	198
1281	205	379	1211	211	1286	204
1130	208	414	1197	214	1267	210
1000	209	433	1032	214	1035	210
1202	210	460	1098	215	1154	211
1104	210	479	1076	214	1062	211
950	209	490	1068	214	1061	212
1171	206	497	965	215	1094	211
1093	190	504	1108	215	1164	212
	END		END		END	

Table B-6. FORD GRANADA TEMPERATURE READINGS (^{o}F) DURING FTP
(Taken Every 30 Seconds)

BASELINE					W/HEADERS					W/MANIFOLD & HEADERS				
#1 CYL	OIL	CAT SKIN	BEFORE CAT	AFTER CAT	#1 CYL	OIL	CAT SKIN	BEFORE CAT	AFTER CAT	#1 CYL	OIL	CAT SKIN	BEFORE CAT	AFTER CAT
70	70	70	70	70	75	75	78	77	79	68	68	67	68	67
1015	73	115	653	676	917	76	136	435	373	1086	85	129	504	374
1111	75	148	1028	1069	925	81	158	498	438	1051	88	163	532	459
1124	79	212	726	1040	952	84	187	544	667	1030	88	208	608	679
1144	87	278	695	841	980	87	219	576	773	1039	89	268	673	828
1192	89	390	1023	1077	986	90	267	597	757	1100	96	305	823	660
928	94	430	1237	1296	1043	94	337	672	999	1032	107	336	655	750
1162	98	506	1340	1357	1085	105	427	844	1233	1175	105	423	758	1007
1400	111	550	1212	1298	1116	116	505	911	1246	1314	104	509	958	1041
1400	115	692	1305	1283	1125	125	557	894	1128	1314	111	576	1061	1102
1280	126	771	1034	1204	1237	133	596	927	1044	1255	119	620	1000	1040
1400	136	813	1268	1266	1085	140	602	793	929	1308	130	665	1042	1153
1003	145	826	1038	1166	1054	147	598	824	907	1268	142	675	902	1098
1304	151	820	1132	1223	1135	150	594	801	872	1210	149	679	890	1009
1196	156	820	1143	1267	1134	156	585	781	893	1060	157	680	821	1007
1271	161	817	1067	1148	890	150	938	719	905	1074	161	667	790	1035
950	167	805	974	1104	1166	147	580	792	890	1144	158	675	948	1038
1265	167	822	1038	1086	920	155	575	724	837	1183	154	674	849	988
989	175	815	1057	1097	1110	153	563	743	805	1087	163	663	766	947
1216	175	796	1006	1083	914	160	556	662	778	1127	160	654	817	964
940	179	784	897	1050	1066	157	546	700	813	991	171	637	710	947
1168	180	758	997	1049	1112	159	541	721	776	1123	166	628	777	965
978	184	748	857	984	881	162	533	632	768	1091	168	613	713	906
1202	183	727	964	1054	1069	156	526	698	789	947	175	603	668	877
956	187	719	932	1090	972	163	520	627	755	1155	166	595	740	897
1197	186	702	1092	1131	1097	160	514	688	777	945	172	585	745	889
1243	188	767	1048	1107	1064	161	510	709	782	1100	170	580	693	900
1214	188	709	1038	1103	986	160	508	645	752	1157	164	578	765	889
1246	190	713	1022	1055	1087	161	507	717	781	1138	164	577	794	888
1202	191	720	997	1044	1122	162	506	714	751	1174	164	582	816	881
1205	193	721	1001	1046	1069	161	505	725	768	1190	162	581	780	927
1198	194	722	1049	1110	1078	166	505	718	761	1117	163	584	778	917
1189	196	714	990	841	1113	164	503	714	742	1138	165	587	786	914

Table B-6. FORD GRANADA TEMPERATURE READINGS (^{o}F) DURING FTP
(Taken Every 30 Seconds) (CONTINUED)

BASELINE					W/HEADERS					W/MANIFOLD & HEADERS				
#1 CYL	OIL	CAT SKIN	BEFORE CAT	AFTER CAT	#1 CYL	OIL	CAT SKIN	BEFORE CAT	AFTER CAT	#1 CYL	OIL	CAT SKIN	BEFORE CAT	AFTER CAT
1005	196	714	990	841	1103	167	504	717	752	1177	165	587	773	951
1164	197	718	896	1020	1020	167	505	676	749	1146	167	586	768	946
1049	198	711	897	1066	1118	164	507	732	813	1167	169	588	725	908
935	203	702	904	1038	1098	166	505	719	771	1158	166	582	789	921
1155	197	692	973	1025	907	168	503	640	748	1122	168	584	770	892
979	200	684	955	997	851	167	498	649	785	994	177	568	681	848
1210	200	687	976	1018	1031	165	496	648	761	1043	173	567	770	875
941	202	680	956	1040	984	170	492	661	746	1038	178	557	666	867
956	200	680	939	994	1091	166	488	686	738	1142	170	561	753	888
1114	200	677	912	966	917	170	485	618	715	1168	170	556	703	891
999	202	665	991	1058	1051	165	484	658	752	943	176	553	780	869
1188	201	667	851	985	1018	164	483	642	772	974	179	551	717	889
980	202	658	917	986	1053	166	481	653	735	1114	174	548	711	889
1176	200	646	985	1009	876	170	477	593	711	968	181	543	630	914
859	197	638	990	1062	1094	167	476	687	769	1131	172	549	715	938
SOAK PERIOD					SOAK PERIOD					SOAK PERIOD				
305	191	300	127	184	179	130	186	152	251	544	141	220	228	258
1150	191	344	687	75	914	142	201	456	371	1018	145	229	377	339
1164	194	360	743	73	1054	147	224	525	497	1078	145	251	529	489
1200	192	447	806	862	1097	151	244	578	546	1092	146	282	592	664
1015	196	465	746	853	863	158	262	497	582	1136	150	307	595	717
910	196	503	667	814	1074	157	285	620	677	932	162	217	542	709
1349	193	538	982	957	1087	159	342	849	887	912	165	340	567	731
1400	193	670	1086	1160	1200	158	406	876	880	1120	162	402	819	911
1345	196	723	1154	1183	1227	158	462	867	888	1290	159	463	898	950
1312	199	741	1143	1208	1208	168	507	919	916	1313	161	523	971	989
1297	202	816	1028	1146	1193	161	530	833	901	1239	162	568	935	956
980	210	811	946	1121	987	170	528	742	871	1343	163	607	902	1045
1230	204	816	1076	1153	1130	171	534	807	882	1082	179	601	786	782
1015	210	815	943	1051	1124	167	537	765	826	1174	176	618	901	993
1045	210	817	1000	1141	1037	171	537	824	873	1217	174	617	793	962
1303	207	819	1127	1176	952	173	534	695	867	1243	175	624	832	999
1242	211	827	990	1065	1180	172	540	827	877	992	182	624	764	964
END					END					END				

APPENDIX C

TEST LABORATORY

TEST LABORATORY

The Custom Engineering Laboratory is located within the metropolitan Los Angeles area at an elevation well below the 1500 foot limit for low altitude testing. The laboratory is recognized by the Environmental Protection Agency (EPA) as being capable of accurately performing light duty vehicle emission tests in accordance with the procedures specified in Title 40 of the Code of Federal Regulations, Part 86, Subparts A and B (40 CFR 86). The facility occupies approximately 8,000 square feet divided into the following areas:

- Soak room (50 x 40 feet)
- CVS control room housing console and computer (10 by 30 feet)
- CVS dyno room housing CVS (20 x 30 feet)
- Engine dyno testing room (20 x 20 feet)
- Engine dyno control room (20 x 20 feet)
- Inspection, maintenance and raw exhaust emissions dyno testing room (20 x 40 feet)
- Engine and parts rebuilding room (20 x 30 feet)
- Vehicle storage, maintenance, and refueling room (50 x 50 feet)
- Offices
- Miscellaneous storage area

C.1 Soak and Test Areas

The soak area in the Custom Engineering Laboratory is equipped with heating and air conditioning to maintain temperatures between 68^{o}F and 86^{o}F at all times. Soak area temperatures are monitored and continuously recorded. The soak area is isolated from outside entrances which eliminates the impact of the sudden introduction of hot or cold outside air.

The test area is adjacent to the soak area. The test area has its own five ton air conditioning and heating system to keep the temperature of the air in front of the vehicle between 68^{o}F and 86^{o}F. The wet and dry bulb temperatures are periodically recorded during tests. There is one emission test cell within the facility which is fully equipped with a dynamometer, constant volume sampler (CVS), and exhaust gas analysis system which are described

Table C-1. Custom Engineering Laboratory Equipment

Manufacturer - Description	Model	Serial No.
Western - Vehicle Cooling Fan	MCW-24-R11	71-5
AESI CVS	1000	770417
AESI Exhaust Analysis Console with:	2500	770416
Beckman O_2 Analyzer	OM11	
Horiba FID	FIA-21	
Horiba Low CO NDIR	AIA-21	
Horiba High CO NDIR	AIA-21	
Horiba CO_2 NDIR	AIA-21	
Texas Instruments 10" 2 pen recorders	FS01W6D	
AESI Data Acquisition & Control Computer (DACC)	3000	
Clayton ECE-50 DDVIF with automatic road load	ELE-50	DN679R
Clayton dyno with 5500 pound inertia flywheels in 125 pound increments	CT-200	01-1967-R
Horiba Raw Exhaust Analyzer CO 0-2/10%, CO_2 0-16% HC 0-400/2000 ppm, NO 0-1000/4000 ppm	D-500	
Sun Engine Performance Tester	SS400	25A-15489
Horiba - Garage Analyzer	GSM 300	
Heenan & Froude Ltd Engine Dyno with 2000 Hp Capacity	HS2809	
Custom Engineering Fuel Conditioning Cart		78-03
Sun Distributor Tester	506	25A-122
Texas Instrument 10" 2 pen Temperature Recorders	FS02W6D	10560-2
Texas Instrument 2 pen 10" pressure (0-3psi), Vacuum (0-15 in Hg) recorder	FS02W6D	10487-2
Bendix Hygrothermograph	594	12-77-15
Bendix wet bulb/dry bulb thermometer	566	
AESI CVS Calibration Kit including:		
Meriam LFE	50MC2-6F	1-11681
Well Manometer		
Inclined Manometer		
Eberbach Barometer		
AESI Propane Recovery Kit including:		
Sartorius Balance	2354	2612212

below. In addition to the emission test cell, there is a vehicle preparation area with dynamometer, HC/CO infrared exhaust gas analyzers, and an engine diagnostic tester.

C.2 Laboratory Equipment

Table C-1 summarizes the laboratory test equipment. All mass emissions measurement equipment conform to the requirements of 40 CFR 86.

C.2.1 Chassis Dynamometer

The test cell is equipped with a Clayton Model ECE-50 direct drive variable inertia flywheel dynamometer with 125 pound inertia weight increments. The dynamometer is equipped with automatic road load control and a distance travelled meter based on roll circumference and a revolution counter.

The driver's aid is a a 10 inch dual pen laboratory grade recorder. The target driving race is generated by the emission measurement system computer during each test. The driver's performance is recorded on each trace from the dynamometer's rear roll speed signal. The driver's aid strip chart becomes a part of the data packet for each test.

The dynamometer was calibrated at the beginning of the test program. The calibration included a speed check, dead weight torque transducer calibration at four weights and coast downs for all inertia weights specified by EPA. Bi-weekly calibration checks of the speed transducer and nominal inidicated horsepower (IHP) at 50 miles per hour (mph) were performed for each calibrated weight.

C.2.2 Mass Emission Sampling Equipment

The Custom Engineering sampling system meets or exceeds all specifications contained in 40 CFR 86. All plumbing is teflon or stainless steel, including the convoluted tubing which connects the analytical system and the vehicle tail pipe to the CVS. Silicon rubber/fiberglass connectors were used to seal the convoluted tubing to the vehicle tailpipe. The CVS pump inlet temperature was maintained within ±10^{o}F of the nominal set point (110^{o}F). Filling of the bags was controlled by the test cell computer.

The CVS was calibrated prior to testing in accordance with procedures specified in 40 CFR 86. The calibration was verified daily by the propane recovery procedure. The laminar flow element used for calibrating the CVS has a calibration traceable to the National Bureau of Standards which is on file at Custom Engineering.

C.2.3 Mass Emission Analytical System

The Custom Engineering analytical system conforms to the requirements of 40 CFR 86. The system is computer operated including analysis of background and sample bags and calculation of grams per mile emission results. The instruments of the analytical system were calibrated prior to testing and weekly during the test program. The best fit equation coefficients were entered into the computer to enable direct computer calculation of test results. The analytical system and instruments were leak checked daily. All calibrations were performed in accordance with procedures specified in 40 CFR 86. All instrument ranges were calibrated with six points plus zero speed as evenly as possible over each range. All instruments except the FID used zero grade N_2.

The FID used zero grade air. All sample handling components are either of stainless steel or teflon. The instrument system contains the following instruments:

- o Horiba Model FIA-21 flame ionization detector (FID) with ranges of 0-100 ppmC, 0-300 ppmC, and 0-1,000 ppmC.
- o Horiba Model AIA-21 (A.S) infrared carbon monoxide analyzer with ranges of 0-100 ppmCO and 0-500 ppmCO.
- o Horiba Model AIA-21 infrared carbon monoxide analyzer with range of 0-3000 ppm CO.

- Horiba Model A1A-21 infrared carbon dioxide analyzer with range of 0-5% CO_2

- TECO Model 10 chemiluminescent nitrogen oxides analyzer with ranges of 0-100 ppm NO_x and 0-250 ppm NO_x.

All calibrations and checks were recorded in a log book. Each entry contained the date, results, and signature of the person performing the work. The zero, tune and gain settings of the NDIR's were recorded daily along with the chemiluminescent vacuum and FID pressures (fuel, air, and sample). A span gas log book was also maintained showing the date, cylinder number, pressure, component, concentration, deflection, range of use, and initials of person making the entry. Any calibration and maintenance actions were documented in a maintenance log which contained the initials of the person doing the maintenance and calibration work, the date, and a statement of the work performed.

Custom Engineering maintains a complete set of calibration, span and zero gases. The calibration gas concentrations are traceable through the gas supplier to within ±1% of National Bureau of Standards reference gases. Custom Engineering names the concentrations of span gases using the calibration curve which is accurate to ±2%. The gases are stored at an ambient temperature beteeen $15^{o}C$ and $30^{o}C$.

C.3 Procedural Precautions

The analyzers were zeroed and spanned before and after each bag analysis with the strip charts running continuously from the first zero through the final span gas check. The maximum drift allowed was ±1 deflection.

All vehicles operated within the test facility had their exhausts vented to the outside.

A rubber stamp was used to give the technicians a list of all the items to be recorded on each strip chart.

The test drivers were experienced in driving the test. Drivers used one foot for brake and accelerator except as allowed immediately following the cold start. The test vehicle was attached to a cable restraint whenever the vehicle was operated on the dynamometer. The restraint was adjusted so as to not raise the vehicle up on the rear roll.

The CVS bags were purged with nitrogen after every use. They were evacuated and leak checked after each purging. The sequence was evacuate and purge, evacuate and leak check. All of the bags were made of Tedlar and had sufficient volume to prevent back pressure during the tests.

The dynamometer was always warmed up before use by operating at 30 mph for 15 minutes using a non-test vehicle (one not scheduled for testing in the following 24 hours). This was repeated if the dynamometer was not used for 1 hour. All test vehicle accessories were turned off during testing including air conditioning, lights and radio.

The test vehicle starting and shifting were done according to manufacturer's specification. As soon as the vehicle started, the trace was begun by the computer. If the engine false started, the driver repeated the recommended starting procedure. Automatic choke setting and, if needed, kick-down were done according to owner's manual instructions.

The driver's aid was calibrated at 0 mph and 50 mph before each test series and checked immediately following each test series. The maximum allowable drift is ± 1 mph. The results of these checks were recorded on the driver's aid strip chart.

Soak time was 12-24 hours. If the 24 hours were exceeded the vehicle was re-preconditioned with a "hot" 505 or 10 minutes on the road driving. The vehicle then began soaking again.

The driving speed tolerances were monitored by the computer. The driver trace was required to be within ± 2 mph of the highest or lowest speed of the target trace occurring within ± 1 second of the target time. These tolerances could be exceeded for manual shifting provided they occurred for less than 2 seconds. Lower acceleration rates were allowed if the vehicle was operated at maximum available power. Such occurances were noted on the driver's trace.

C.4 Fuel Storage and Handling

The test fuel (Indolene Clear) used by Custom Engineering meets the specifications in 86.177-6. The fuel handling procedures used ensured that fuel specifications would not be degraded due to improper procedures. Fuel was stored in sealed drums in a separate building located at the rear of the parking lot. The fuel was purchased in bulk and an analysis was performed for each batch by the supplier.