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EFFECT OF AUTOMOTIVE PARTS ON VEHICLE AND ENGINE EMISSIONS

PHASE II - AFTER-MARKET PARTS

U.S. Environmental Protection Agency
Mobile Source Enforcement Division
Technical Support Branch
Washington, D.C. 20460

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PHASE II - AFTER-MARKET PARTS

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REPORT AVAILABILITY

Copies of this report are available from the Air Pollution Technical Information Center, Environmental Protection Agency, Research Triangle Park, North Carolina 27711, or may be obtained at a nominal cost from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

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FOREWORD

The Clean Air Act requires that new vehicles and vehicle engines are to be warranteed by their manufacturer to be designed, built, and equipped so as to conform with applicable emission standards for their useful life. The Environmental Protection Agency, Office of Enforcement, Mobile Source Enforcement Division, is charged with enforcing compliance with applicable emission standards. Classes of vehicles or engines which are found to violate applicable standards during their useful life are subject to recall and corrective maintenance at the manufacturer's cost, providing that recommended maintenance and operating procedures had been followed by the vehicle owner.

Strict interpretation of the Clean Air Act warranty requirements could, however, lead to voiding of the emissions warranty if non-OEM components were installed. The EPA, in the interest of maintaining a viable after-market parts industry and maximizing consumer choice, elected to sanction a voluntary program for self-certification of after-market parts critical to vehicle or engine emissions performance. Although the major activity under this program would be performed by the after-market parts industry, the EPA determined that an independent evaluation of after-market part criticality was advisable in the interest of advancing the program.

The objective of this study, therefore, was to assess the relative importance of after-market engine and emission control components in causing excessive emissions in the in-service vehicle population. The importance of each component was measured by a criticality index based on factors representing:

- Impact on emissions of a single vehicle with a defective component
- Probability of defect occurrence
- Duration of defect occurrence
- Relative usage of each component.

ABSTRACT

This final report documents the methodology and results of Phase II of the Investigation of the Effect of Automotive Parts on Vehicle and Engine Emissions. This study was performed for the Environmental Protection Agency, Office of Mobile Source Enforcement, under Contract No. 68-01-1957. The primary objective of this study was to identify engine and emission control system components which are critical in causing excessive emissions of one or more regulated pollutants. Phase II of the study investigated the emission-criticality of after-market equipment not installed or distributed by the original engine or vehicle manufacturers.

A computer model was developed to calculate and rank-order an index representing the criticality of each component type. Separate rankings were developed for HC, CO, NO_x and smoke (heavy-duty diesel engines) emissions using three independent sets of input data. The index for each component type was calculated from the product of four factors representing the emission increase resulting from a component failure, the probability of component failure, the probability of component repair, and the sales volume of the component.

The values of these factors were established based on data obtained from a search of technical literature and engineering analysis of system and component design or operating characteristics. The study was performed without emission or performance testing. However, a series of tests on 25 of the most emission-critical components was recommended to develop or refine data on emission increases and symptoms of failure.

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Section 1

INTRODUCTION AND SUMMARY

This report documents the results of Phase II of the Investigation of the Effect of Automotive Parts on Vehicle and Engine Emissions, EPA Contract 68-01-1957. Phase II of this study included all equipment not installed by or for the original vehicle or engine (OEM) manufacturers. For purposes of this study, after-market equipment also excluded replacement components distributed through the OEM dealer/service center network.

This section contains a summary of major findings, a statement of the problem, and a description of the study objectives, scope, and study plan. Section 2 discusses the literature search performed to obtain pertinent data and information. Section 3 describes emissions-related after-market components and systems. Section 4 discusses the emission-critical after-market components and the methodology used to rank them in order of their criticality. Section 5 discusses the critical parameters or specifications of the most critical after-market components. Section 6 concludes this report with a recommended test protocol for 25 of the most critical after-market components.

1.1 SUMMARY OF MAJOR FINDINGS

The major findings of Phase II of this study for after-market components are the following:

- Literature clearly defining the effect on FTP emissions from after-market components exists for only a few specific components.
- The ranking of emission-critical components is sensitive to changes in the values of the input parameters particularly the sales volume. (See Tables 1-1 through 1-3 for criticality lists using various values of input parameters.)
- The most emission-critical after-market components for HC are typically ignition tune-up components.
- The most emission-critical after-market components for CO are carburetors or carburetor rebuilding components.
- The most emission-critical after-market components for NO_x are typically components which affect vacuum signals controlling ignition timing and EGR valve operation.
- The most emission-critical after-market components for smoke are typically mechanical components of the engine.

Based on the criticality rankings shown in Tables 1-1 to 1-3, the critical performance parameters for the 5 components most critical to each pollutant were identified and are summarized in Table 1-4.

A series of tests were recommended on 25 after-market components to develop or refine data on emissions increases and symptoms of failure. These components are summarized in Table 1-5.

Table 1-1. AFTER-MARKET PART CRITICALITY RANKING
(Automotive Parts Study - EPA Contract No. 68-01-1957)
GARAGE SALES VOLUME AND EARLY MODEL EMISSION FACTORS

HC	CO	NO_x	SMOKE (Diesel)	COMPOSITE
Spark Plugs	Rebuilding Kits	Exhaust Manifold	Valve Lifter/Spring	Spark Plugs
Ignition Wires	Float and Valve	Rebuilt Carburetor	Exhaust Valves	Ignition Wires
Cap	Air Cleaner Element	Specialty Carburetor	Air Cleaner Element	Rebuilding Kits
Rotor	PCV Valve	New Carburetor	Valve Seals	Float and Valve
Rebuilding Kits	Valve Lifter/Spring	High Perf Exhaust	Piston Rings	Cap
Float and Valve	Rebuilt Carburetor		Valve Guides	Rotor
Points	Exhaust Valves		Head Gaskets	Air Cleaner Element
Valve Lifter/Springs	Valve Seals		Valve Cam Lobes	PCV Valve
Exhaust Valves	New Carburetor		Camshafts	Points
Rebuilt Carburetor	Piston Rings		FI Hi Pres Pump	Valve Lifter/Springs
Valve Seals	Exhaust Manifold			Rebuilt Carburetor
Condenser	Valve Guides			Exhaust Valves
Mag/Opt Triggers	Specialty Carburetor			Valve Seals
EI Control Circuit	Head Gasket			New Carburetor
New Carburetor	Valve Cam Lobes			Condenser
PCV Valve	Camshafts			Mag/Opt Triggers
Piston Rings	High Perf Exhaust			EI Control Circuit
Air Cleaner Element	FI Hi Pres Pump			Piston Rings
Exhaust Manifold	Idle Stop Solenoid			Exhaust Manifold
Fuel Filter	Throttle Dashpot			Fuel Filter
Valve Guides	Throttle Positioner			Valve Guides
Specialty Carburetor	Metering Jets			Specialty Carburetor
Head Gaskets	Metering Rods			Head Gaskets
Valve Cam Lobes	Vacuum Break Valve			Valve Cam Lobes
Camshafts	Choke Mechanism			Camshafts

Table 1-2. AFTER-MARKET PART CRITICALITY RANKING
(Automotive Parts Study - EPA Contract 68-01-1957)
WAREHOUSE SALES VOLUME AND EARLY MODEL EMISSION FACTORS

HC	CO	NO_x	SMOKE (Diesel)	COMPOSITE
Spark Plugs	Rebuilding Kits	Thermal Vac Valve	Valve Lifter/Spring	Spark Plugs
Ignition Wires	Choke Mechanism	Spark Delay Valve	Valve Seals	Rebuilding Kits
Rebuilding Kits	Rebuilt Carburetor	EGR Valves	Exhaust Valves	Ignition Wires
Rebuilt Carburetor	New Carburetor	Rebuilt Carburetor	Air Cleaner Element	Choke Mechanism
Rotor	Air Cleaner Element	Specialty Carburetor	FI Throttle Valve	Rebuilt Carburetor
Cap	Valve Lifter/Spring	New Carburetor	Valve Guides	New Carburetor
Choke Mechanism	PCV Valve	EGR Vacuum Amplifier	Head Gaskets	Rotor
New Carburetor	Valve Seals	TCS Vacuum Solenoid	Piston Rings	Cap
Valve Lifter/Spring	Exhaust Valves	TCS Temp Switch	Camshafts	Air Cleaner Element
Points	Specialty Carburetor	Mechanical Advance	Valve Cam Lobes	Valve Lifter/Springs
Valve Seals	Vacuum Break Valve	Exhaust Manifold	FI Hi Pres Pump	Thermal Vacuum Valve
Exhaust Valves	PCV Freshair Filter	High Perf Exhaust		PCV Valve
Specialty Carburetor	Idle Stop Solenoid			Spark Delay Valve
Coil	Throttle Dashpot			Points
Condenser	Decel Valve			EGR Valves
PCV Valve	AI Hoses			Valve Seals
Air Cleaner Element	Valve Guides			Exhaust Valves
Spark Delay Valve	Head Gaskets			Specialty Carburetor
Fuel Filter	Piston Rings			Vacuum Break Valves
Distributor Drive	Camshafts			PCV Fresh Air Filter
EVAP Fresh Air	Vacuum Advance			Coil
AI Hoses	AI Pump/Belts			Idle Stop Solenoid
Valve Guides	Intake Manifold			Condenser
Head Gaskets	Mechanical Advance			EGR Vacuum Amplifier
Piston Rings	Valve Cam Lobes			Throttle Dashpot

Table 1-3. AFTER-MARKET PART CRITICALITY RANKING
(Automotive Parts Study - EPA Contract 68-01-1957)
OEM SALES VOLUME AND LATE MODEL EMISSION FACTORS

HC	CO	NO_x	SMOKE (Diesel)	COMPOSITE
Spark Plugs	Rebuilding Kits	EGR Valves	Valve Lifter/Springs	Spark Plugs
Ignition Wires	Float and Valve	EGR Thermal Valve	Valve Seals	Ignition Wires
Rebuilding Kits	Choke Mechanism	Spark Delay Valve	Exhaust Valves	Rebuilding Kits
Float and Valve	Power Valves	EGR Vacuum Amplifier	Air Cleaner Element	Float and Valve
Choke Mechanism	Rebuilt Carburetor	Thermal Vacuum Valve	MFI Valves	Choke Mechanism
Power Valves	New Carburetor	EGR Hoses/Seals	Valve Guides	Power Valves
EVAP Canister	Accelerator Pump	TCS Temp Switch	Piston Rings	Valve Lifter/Springs
Rebuilt Carburetor	Metering Rods	TCS Trans Switch	Head Gaskets	Rebuilt Carburetor
Heat Riser	Air Cleaner Element	TCS Vacuum Solenoid	FI Throttle Valve	EGR Valves
PCV Valve	Metering Jets	EGR Solenoid Valve	Valve Cam Lobes	Valve Seals
Rotor	PCV Valve	Rebuilt Carburetor	FI Pres Sens/Reg	Exhaust Valves
Cap	Spark Plugs	TCS Time Delay	Supercharger	New Carburetor
New Carburetor	Vacuum Break Valve	OSAC Vacuum Orifice	PCV Oil Separator	Accelerator Pumps
Vacuum Break Valve	AI Hoses	Specialty Carburetor	Camshafts	EVAP Canister
TAC Vacuum Motor	AI Pump/Belts	EGR Carb Spacer	Turbocharger	Heat Riser
TAC Vacuum Hoses	PCV Fresh Air Filter	TCS Thermal Valve	FI Dist Manifold	Metering Rods
PCV Fresh/Air Filter	Specialty Carburetor	New Carburetor	FI Hi Pres Pump	Air Cleaner Element
PCV Hoses	Vacuum Advance	EGR Backpres Sensor		EGR Thermal Vac Valve
EVAP Hoses	AI Bypass/Diverter	EGR Temp Switch		Metering Jets
Valve Lifter/Springs	Valve Lifter/Springs	EGR Time Delay		PCV Valve
Idle Stop Solenoid	Idle Stop Solenoid	EGR Speed/Trans Sen		Rotor
EVAP Fresh Air Filter	Ignition Wires	OSAC Vacuum Bypass		Cap
TAC Shroud	Valve Seals	ESC Speed Switch		Vacuum Break Valve
TAC Thermostat	Exhaust Valves	ESC Elec Module		TAC Vacuum Motor
AI Hoses	AI Manifold	Exhaust Manifold		TAC Vacuum Hoses

Table 1-4. SUMMARY OF CRITICAL PARAMETERS OF EMISSION-CRITICAL AFTER-MARKET PARTS

SYSTEM/COMPONENT	CRITICAL PARAMETERS					
	Dimensions	Materials	Flow Curve	Movement	Electrical	Thermodynamic
Carburetion System						
Rebuilding Kits	x	x				
Rebuilt Carburetors	x		x			
New Carburetors	x		x			
Specialty Carburetors	x		x			
Choke Thermostats	x	x		x		x
Float and Valves	x		x	x		
Power Valves	x	x	x	x		
Ignition System						
Spark Plugs	x	x			x	x
Wires		x			x	x
Rotors	x	x			x	
Caps	x	x			x	
Induction System						
Air Cleaner Elements	x	x	x			
Mechanical System						
Exhaust Manifolds	x	x	x			x
Headers	x		x			x
Valve Lifters/Springs	x	x		x		
Exhaust Valves	x	x				x
Valve Seals	x	x				x
Piston Rings	x	x				x
Fuel Injection System						
MFI Valves	x		x	x		
FI Throttle Valves	x		x	x		
Emission Control System						
EGR Valves	x	x	x	x		x
Thermal Vacuum Valves	x	x	x	x		x
EGR Vacuum Amplifiers			x	x		
Spark Delay Valves			x	x		

Table 1-5. AFTER-MARKET COMPONENTS RECOMMENDED FOR TESTING

COMPONENT	TEST CONDITIONS
Carburetion System	
New Carburetor	OEM - After-market
Rebuilt Carburetor	OEM - After-market
Specialty Carburetor	OEM - After-market
Carburetor Rebuilding Kit	OEM - Rebuilding Kit
Choke Thermostat	OEM - After-market
Float and Valve	OEM - After-market
Metering Jet	Lean - OEM - Rich
Dashpot	OEM - After-market
Ignition System	
Spark Plugs	OEM - After-market
Ignition Wires	OEM - After-market
Points	OEM - After-market
Condenser	OEM - After-market
Coil	OEM - After-market
Distributor Cap	OEM - After-market
Distributor Rotor	OEM - After-market
Vacuum Advance Unit	OEM - After-market
Retrofit CD Electronic Ignition	OEM - After-market
Optical/Magnetic Retrofit EI Distributor System	OEM - After-market
Replacement Distributor	OEM - After-market
Engine System	
Valve Lifters/Springs	OEM - After-market
Intake Manifold/Headers	OEM - After-market
Emission Control System	
PCV Valve	OEM - After-market
Decel Valve	OEM - After-market
Spark Delay Valve	OEM - After-market
Thermal Vacuum Valve	OEM - After-market

1.2 STATEMENT OF THE PROBLEM

The Clean Air Act (Section 207c) requires that all new vehicles and vehicle engines are to be warranteed by the manufacturer to be designed, built, and equipped so as to conform with applicable emission standards for 50,000 miles providing that they are maintained, serviced, and operated in accordance with written instructions provided to the vehicle owner. Classes (i.e., engine families of vehicles or vehicle engines) which are found to violate the applicable emission standards during the 50,000-mile warranty period are subject to recall and corrective repair at the manufacturer's cost in accordance with Section 207e of the Clean Air Act. As a result of the warranty provisions of the Clean Air Act, manufacturers have issued specific maintenance schedules covering those adjustments and component replacements which the manufacturers have found to be important in maintaining compliance with the emission standards for 50,000 miles.

Strict interpretation of the Clean Air Act warranty requirements could, however, lead to voiding of the emissions warranty if non-OEM components were installed. The EPA, in the interest of maintaining a viable after-market parts industry and maximizing consumer choice, elected to sanction a voluntary program for self-certification of after-market parts critical to vehicle or engine emissions performance. Although the major activity under this program would be performed by the after-market parts industry, the EPA determined that an independent evaluation of after-market part criticality was advisable in the interest of advancing the program.

1.3 STUDY OBJECTIVES

The objective of this phase of the study was to assess the relative importance of after-market parts in causing excessive emissions in the in-service vehicle population. The importance of each component was measured by a criticality index based on factors representing:

- Impact on emissions of a single vehicle with a defective component
- Probability and duration of defect occurrence
- Relative usage of each component.

Additional objectives included determining critical performance parameters for the most critical after-market components, and recommending test protocols for 25 of the most critical after-market components.

1.4 STUDY SCOPE

This study was conducted in two phases. Phase I consisted of an assessment of the criticality of original factory installed (OEM) equipment. Phase II consisted of an assessment of the criticality of after-market equipment including both high performance equipment and OEM equivalent replacement components. This study was accomplished without testing but was supported by a literature search and engineering analysis.

The emission-criticality of parts, components and systems was determined separately for the following regulated emissions: hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x) and smoke (percent opacity). All engines subject to regulation were within the nominal scope of the study; however, as a practical matter, diesel engine and heavy duty gasoline engine components were not included in the criticality ranking of HC, CO, and NO_x because of the relatively low occurrence of these engines in the population. The emission-criticality of after-market components for smoke was based on the most popular heavy duty diesel engines.

Because of the very large number of individual components used by engine and vehicle manufacturers, it was impossible to assign individual parameters to each component. Rather, components were grouped into classes having similar function and configuration. Each class or category of components was then assigned parameter values which were applied to all individual components within each category.

1.5 STUDY PLAN

Figure 1-1 illustrates the sequence and interrelationship of the tasks of both phases of the study. The initial effort was directed towards the literature search and acquisition of pertinent data. Simultaneously, the criticality index model was formulated, coded, and checked out. Subsequent Phase I activity included the following tasks which were documented in the Final Report for Phase I (Ref. 107):

- Identify emissions-related systems and components.
- Determine characteristic failure mode of each component.
- Determine effect on emissions of each defect.
- Determine probability of defect occurring and probability of defect being corrected before the end of component design life.

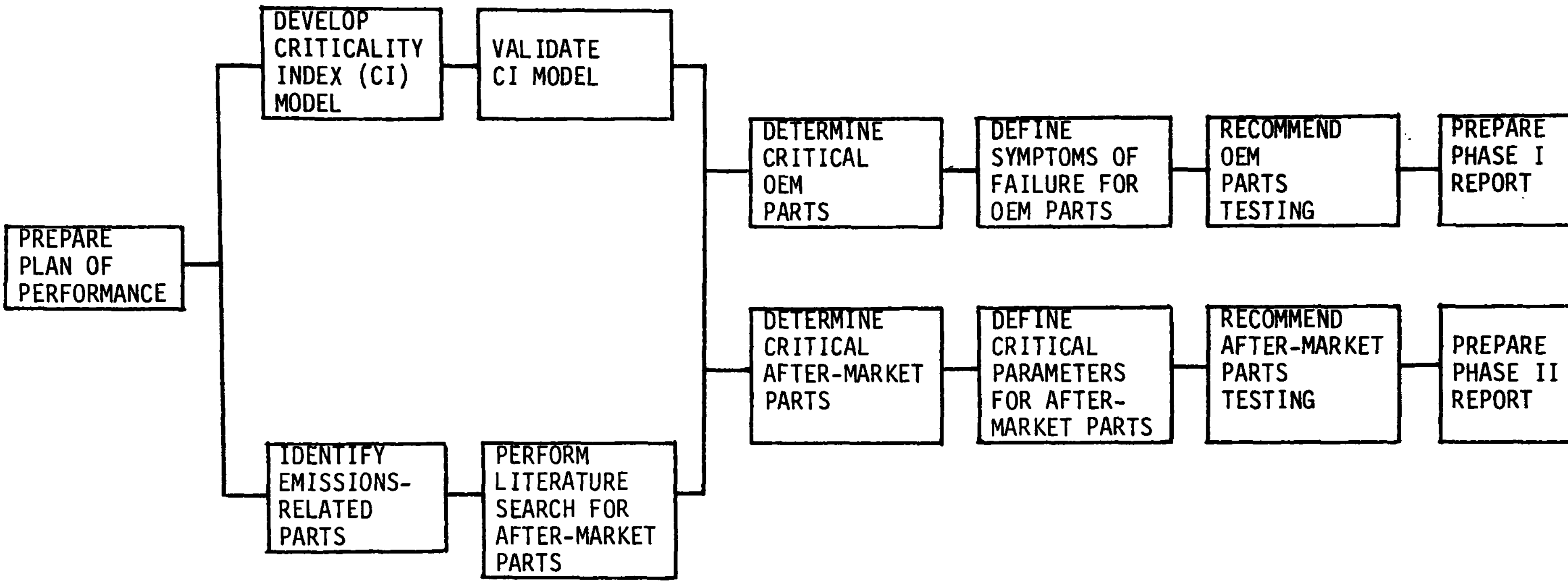


Figure 1-1. STUDY APPROACH

- Determine relative usage (sales volume) of each OEM component.
- Use the factors defined above to calculate a criticality index for each OEM component for each pollutant.
- Rank the components by criticality index.
- Describe symptoms of failure and appropriate diagnostic techniques for the 25 most critical components for each pollutant.
- Recommend a series of tests for 25 of the most critical OEM components to provide supportive data not available in the literature.

Phase II activity included the following tasks relative to after-market components, parts, and systems:

- Redefine the values of the criticality index input parameters for after-market components.
- Execute the criticality model to select the most emission-critical after-market components for each pollutant.
- Determine the critical parameters (specifications or design characteristics) of each of the five most critical after-market components for each pollutant.
- Recommend a series of tests for 25 of the most critical after-market components.

The above analyses and subsequent findings, conclusions, and recommendations formed the basis of this Final Report on Phase II of the Investigation of the Effect on Automotive Parts on Vehicle and Engine Emissions.

Section 2

LITERATURE SEARCH

An extensive search was conducted during the study to identify all potential sources of information. The literature search was intended to obtain information for each component which would support the following parameters of the criticality index:

- Typical failure or defect modes.
- Probability and duration of failure.
- Consequence of the failure on emissions and performance.
- Sales volume of vehicles, engines, and components.

The literature search was performed by a professional search organization and included the following data bases:

- National Technical Information Service (NTIS)
- Chemical Abstracts
- Engineering Index
- Pollution Abstracts

The formal literature search was directed chiefly toward evaluating the effect of component defects on emissions. The literature search was conducted using the key words shown in Table 2-1. Unfortunately, the search was extremely broad, resulting in approximately 600 citations of potentially applicable reports. Review of the cited titles and descriptors reduced to approximately 100 the number of reports which appeared to deserve detailed review.

Table 2-1. KEY WORDS USED FOR LITERATURE SEARCH

Automobile(s)	Fuel Economy
Automotive	Hydrocarbon(s)
Carbon Monoxide	Ignition
Carburetion	Internal Combustion
Carburetor(s)	Maintainability
Catalyst(s)	Mileage
Component(s)	Mobile Source(s)
Diesel	Nitric Oxide
Durability	Oxide(s) of Nitrogen
Electrical	Parts
Emission(s)	Reactor
Engine(s)	Smoke
Exhaust	Spark Ignition
Expected Life	Vehicle

In addition to the formalized literature search, extensive research was performed to define the type, quality, and availability of data on performance and production of engines, components, and systems. This research involved discussions with industry and government representatives to evaluate the applicability and accessibility of unpublished data. This evaluation indicated that, in general, data of the detail required by this study did not exist except for a few specific components.

The discussion of the literature search is divided into the following subject areas:

- Component usage.
- Effect of component failure on emissions.
- Probability and duration of component failure.
- Sales volume.

2.1 AFTER-MARKET COMPONENT USAGE

In order to identify emissions-related after-market components, it was necessary to determine which components and systems were available through after-market sources. For purposes of this study, after-market components were defined to include all components not built by or for the vehicle or engine manufacturers. This definition excluded replacement components distributed by the vehicle or engine manufacturers through their authorized service centers and parts divisions. In general, the after-market component sources considered in this study included the following:

- Nationally advertised name brand components sold as OEM component replacements (plugs, wires, points, condensers, air filters, PCV valves, etc.).

- Private brand components distributed by major retail chains and sold as OEM component replacements (same components as above).

- Rebuilders selling components rebuilt and restored to OEM specifications (primarily carburetors, air injection pumps, and mechanical components such as heads, engine blocks, crankshafts, pistons, valves and valve train components).

- Add-on specialty components not intended to be OEM replacements. Add-on components fall into the following four major system categories: ignition, air induction, carburetion, and exhaust system.

After-market parts can be generally characterized as replacement or specialty components. Most after-market parts are sold as OEM replacement parts with only 1 percent to 3 percent of sales volume for most categories attributable to specialty components (Ref. 105). Furthermore, most after-market parts, whether replacement or specialty, are sold for vehicles which are at least 2 to 3 years old. This is because of the longer maintenance intervals on newer vehicles, the higher frequency of component failure on older vehicles, and the common consumer practice of returning to the dealer for repairs or service during the major mechanical engine warranty period.

In general, nearly all standard ignition, carburetion, and mechanical components used on vehicles are available through the after-market. Certain special purpose and/or low production volume components, however, are available only through the original engine or vehicle manufacturer's parts and service centers. These components, therefore, are not readily available to the after-market. In general, as a vehicle becomes older, after-market sources of supply gradually become available to satisfy demand from independent jobbers and garages who perform the majority of repairs on older vehicles.

2.2 EFFECT OF COMPONENT FAILURE ON EMISSIONS

The literature search was mainly conducted during Phase I, the original equipment portion of the study. Very little technical literature explicitly concerned after-market parts. For replacement components, this was not a serious problem since they are nominally identical in design and performance characteristics to the OEM components which they replace. They would be expected to have similar failure modes and affects on emissions as the corresponding OEM component. The literature on OEM components, therefore, is applicable to these after-market components and provides the best available information.

Twenty-seven papers were reviewed which described the influence of engine and control system design on emissions. These papers generally were based on prototype tests using nonstandard systems (CFR engines) or operating conditions (steady states). Unfortunately, none of these papers provided pertinent data on the probability or effect on emissions of malfunctions in the engine or system being evaluated. Several of these papers also discussed systems which have not been produced for sale. Table 2-2 summarizes the design and development papers which were reviewed but which did not provide useful data or information.

Several papers (Ref. 19, 22, 37, 38, 40, 46, 48, 58, and 60) and books (Ref. 2 and 3) were used to help define the operating principles and design characteristics of engine or emission control systems. In general, these documents did not provide data on the probability of component failure or the effect of defects on FTP emissions. They did, however, provide a basis for establishing probable modes of failure.

Several papers (Ref. 35, 47, 72, 73, and 82) reported durability test results on production prototype vehicles. These papers, generally, did not describe specific defects and their effect on emission levels. The papers, however, did give some insight into the probability of failures and some typical system problems. Presumably, characteristic failures detected during durability testing were corrected prior to production.

Table 2-2. ENGINE DEVELOPMENT LITERATURE NOT APPLICABLE TO AUTOMOTIVE PARTS STUDY

REFERENCE NO.	TITLE	SOURCE
1	Extension of the Lean Misfire Limit and Reduction of Exhaust Emissions of an SI Engine by Modification of the Ignition and Intake Systems.	SAE 740105
4	Questor Reverter Emission Control System Total Vehicle Concept.	SAE 730227
6	Control of Refueling Emissions with an Activated Carbon Canister on the Vehicle.	SAE 751181
8	EFI Prechamber Torch Ignition of Lean Mixtures.	SAE 750351
9	Emissions Study of a Single-Cylinder Diesel	SAE 740123
10	Factors Affecting Dual Catalyst System Performance	SAE 740252
11	A Study of Ignition System Effects on Power, Emissions, Lean Misfire Limit, and EGR Tolerance of a Single-Cylinder Engine - Multiple Spark Versus Conventional Single Spark Ignition.	SAE 740188
18	Efficient and Clean Diesel Combustion.	SAE 750787
21	Trade-Offs between Engine Emission Control Variables, Fuel Economy, and Octane.	SAE SP-395
23	Emissions Control of a Stationary Two-Stroke Spark-Gas Engine by Modification of Operating Conditions.	Inst. of Gas Technol, Chicago 6/5-7/72

Table 2-2. ENGINE DEVELOPMENT LITERATURE NOT APPLICABLE TO AUTOMOTIVE PARTS STUDY (Continued)

REFERENCE NO.	TITLE	SOURCE
25	Closed Loop Carburetor Emission Control System	SAE 750371
30	Teledyne Continental Motors Red Seal Engines First CPCS Application.	SAE 750017
31	New Concept in Automotive Ignition.	Automot. Eng.,v 84, n3, 3/75
32	Divided Combustion Chamber Gasoline Engines - A Review for Emission and Efficiency.	APCA 73-74 6/24-28/73
34	Exhaust Purifiers for Compression Ignition Engines.	Platinum Met Rev, v 19 n1, 1/75
36	Lean Combustion and the Misfire Limit in Spark Ignition Engines.	SAE 741055
39	Electronic Closed Loop Controls for the Automobile.	SAE 740014
41	Physical and Chemical Characteristics of Particulates in Spark Ignition Engine Exhaust.	Environ. Sci. Technol, v 8, n4, 4/75
44	Initial Performance of Supported NO_x Reduction Catalysts in a Dual-Catalyst System.	SAE 740251
45	Texaco Controlled Combustion System Multifuel, Efficient, Clean and Practical	Combust. Sci. Technol, v 8, n
50	Mechanisms of Polynuclear Aromatic Hydrocarbon Emissions from Automotive Engines.	SAE 730835

Table 2-2. ENGINE DEVELOPMENT LITERATURE NOT APPLICABLE TO AUTOMOTIVE PARTS STUDY (Continued)

REFERENCE NO.	TITLE	SOURCE
55	Simulated Road Test Evaluation of the Effect of Gasoline Additives on Exhaust Gas Emissions.	SAE 720942
61	Control of Exhaust Pollution through a Mixture Optimizer.	SAE 720254
62	Closed Loop Control of Internal Combustion Engine Exhaust Emissions.	PB-239 850/1ST DOT-OS-30 111 2/74
77	Emissions Control Technology of Heavy Duty Vehicle Engines.	PB-236 899/1ST EPA-68-01-0472 12/73
76	Experiments with a Catalytic Cleaner for Car Engine Exhaust Gases.	N75-12455/2ST FOA-1-C-1492-H3 12/72
88	An Evaluation of the Emissions Characteristics of the Exxon Well Mixed Thermal Reactor.	PB-220 034/3 APTD-1387, 72-3

Weaver, et al (Ref. 35), reported data on a fleet of 450 prototype catalyst vehicles. In general, they found that maintenance performed in accordance with the manufacturer's recommended schedule enabled the vehicles to maintain emission levels within 1975 statuatory standards for the 50,000-mile certification period. Furthermore, the maintenance actions did not affect HC emissions, decreased CO emissions and increased NO_x emissions. Unfortunately, the report did not relate specific maintenance actions or defects to changes in emissions of individual vehicles.

The Weaver study also indicated that overtemperature operation caused the greatest number of catalyst failures. However, partially melted catalysts were found to have residual activity although the 1975 HC and CO statuatory standards were exceeded slightly. Examination of the vehicles with melted catalysts showed that 14 catalysts were damaged by intermittent or total ignition loss occurring within 10,000 miles. The ignition failure was traced to defective breaker points (five cases), primary coil wires (seven cases), or ignition coil failure (two cases). In addition, two catalysts were damaged by intermittent ignition misfire occurring at greater than 10,000 miles. One each of these failures was attributed to a loose primary coil wire and a faulty coil. There were no cases of catalyst melting caused by rich carburetion or other emission control system defects. Although all catalyst failures were caused by ignition failures, the incidence of ignition failure was small relative to the fleet size (3.5 percent) which is characteristic of the in-service noncatalyst vehicle population.

Miles, et al (Ref. 47), described a durability program of approximately 250 catalyst vehicles. Several alternative design configurations and prototype components were evaluated to establish performance data. In general, catalyst systems performed within their design emission standard for the 50,000-mile durability test. Specific data on the effect of component failure were not presented, although some vehicles did exceed one or more of the standards and some catalysts failed. Difficulty was reported with prototype high energy ignition components which resulted in misfire attributed partly to plug fouling. Ignition misfire was believed to have caused the catalyst failures. However, converter failures occurred when at least two cylinders were misfiring. More rapid deterioration of HC than CO emissions generally occurred, with NO_x emissions showing little deterioration.

A review of catalyst technology was prepared by the National Academy of Sciences (Ref. 15, 69, 72, 73, and 74). Deactivation of catalysts was determined to be due to thermal cycling and excessive temperatures (Ref. 72). The catalytic media was sintered and agglomerated resulting in increased void (pore) size and decreased surface area. Severe thermal stress lead to structural deformation (melting and collapse).

The following specific defects leading to catalyst failure were identified from surveys of catalyst development and durability testing (Ref. 72, 73, and 82):

- Severe dieseling after ignition shut-off.
- Running out of fuel at high speed.
- Failure of coasting protection (deceleration controls).
- Misfire caused by ignition failure.
- Complete ignition failure at moderate to high speed.
- Stuck choke.
- Fuel which causes plug fouling.

The frequency and duration of failure and the effectiveness of protective devices (air injection dump) determined the degree to which the catalyst was degraded or destroyed. If the catalyst was to become essentially deactivated and all other defects were corrected, the average emission level from catalyst-equipped vehicles was estimated at 2.5 gm/mi HC and 18.0 gm/mi CO.

A summary NAS report (Ref. 70) presented a compilation of emission-critical components which has been abstracted and is shown in Table 2-3. These data represented the opinion of the NAS committee based on data available prior to 1973.

Matsumoto, et al (Ref. 7), described an analysis of catalyst reliability based on empirical data. The analysis was performed to rank various component defects in order of their criticality in causing catalyst failure. Catalyst failure was found to be critically-related to high temperature. Factors causing high catalyst temperature included hydrocarbon concentration (misfire), exhaust gas temperature at the inlet to the catalyst, and flow rate of the exhaust gas. Criticality of each defect was determined by the product of a damage intensity factor and probability of repair factor. The criticality ranking of the components was as follows:

- Two cylinders misfiring.
- One cylinder continuously misfiring.
- One cylinder intermittently misfiring.
- One cylinder occasionally misfiring.
- Choke valve stuck.
- Fuel restriction (lean operation).
- Plugged air bleed.
- Main jet fell out.
- Carburetor flooding.
- Primary jet fell out.

A study (Ref. 17) for the California Air Resources Board (CARB) investigated the sensitivity of FTP emissions

Table 2-3. EFFECT ON EMISSIONS OF VARIOUS COMPONENTS[1]

NO.	ITEM	HC	CO	NO_x	MEAN TIME TO FAILURE, YEARS	SERVICE INTERVAL, YEARS
Major Control Equipment						
1*	3-way catalyst (HC, CO, NO_x)	H	H	H	2	1
2*	Reduction catalyst (NO_x)			H	2	1
3*	Oxidation catalyst (HC, CO)	H	H		2	1
4*	Exhaust manifold reactor	M	M		10	5
5	Exhaust gas recirculation valve			H	5	1
6	Air injection pump	M	M	L	5	1
These Can Cause A Catalyst Failure						
7*	Catalyst bypass	H	H		5	1
8*	Catalyst thermocouple	H	H		2	1
9*	Exhaust manifold reactor bypass	M	M		5	1
10*	Exhaust air diverter valve	M	M	H	8	1
11*	Oxygen sensor for 3-way catalyst	M	M	M	2	1
12*	Electronic feedback control	M	M	M	8	1
13*	Electronic fuel injection	M	M	M	8	1
14*	Fast acting choke	H	H	L	5	1
15	Float valve	M	H	L	5	5
16	Power jet	L	L	L	10	5
17	Fuel pump	L	L	L	5	5
18	Spark plugs	H		M	2	1
19	Plug wires	H		M	3	1
20	Electronic ignition	L	L		10	1
21	Exhaust valve leaks	H		M	10	2

[1]Table 12 from Reference 70.
*Components not in production prior to 1973.

Table 2-3. EFFECT ON EMISSIONS OF VARIOUS COMPONENTS[1] (Continued)

NO.	ITEM	HC	CO	NO_x	MEAN TIME TO FAILURE, YEARS	SERVICE INTERVAL, YEARS
These Can Have A Major Effect on Emissions						
22	Idle mixture screw	H	H	L	10	1
23	Idle speed screw	L	L		10	1
24	Fast idle speed screw	L	L		10	1
25	Heat riser valve	M	M		8	1
26	Air filter	L	M		2	1
27	PCV valve	M	M		3	1
28	PCV fittings and hoses	L	L		5	1
29	Distributor cap	M			5	1
30	Points	H			4	1
31	Coil wire	H			5	1
32	Air pump belt	H		L	5	1
33	Transmission controlled spark switch			M	5	1
These Can Have Effect on Emissions						
34	Coolant thermostat			L	5	5
35	Vacuum advance	M		M	5	2
36	Battery	L		M	3	2
37	Battery cables	L			5	2
38	Voltage regulator	L			5	5
39	Distributor rotor	M			5	1
40	Ignition condenser	M			8	1
41	Coil	H			10	1
42	Centrifugal advance	M		M	10	1

[1]Table 12 from Reference 70.

Table 2-3. EFFECT ON EMISSIONS OF VARIOUS COMPONENTS[1] (Continued)

NO.	ITEM	HC	CO	NO_x	MEAN TIME TO FAILURE, YEARS	SERVICE INTERVAL, YEARS
43	Intake manifold leaks	M	L		5	2
44	Carburetor metering rods	M	M	L	8	2
45	Carburetor internal vents	L	M	L	10	1
46	Carburetor float	M	M	L	10	10
47	Fuel filter	L	L		2	2
48	Carburetor accelerator pump	L	L		5	5
49*	Quick heat manifold	L	M		10	10
50*	PCV delay solenoid	L	L		5	2
51*	Thermistor to sense coolant	L	L		5	5
52*	Solenoid to activate EGR			M	5	1
53*	Solenoid to activate evap. CS	L			5	1
54	Activated carbon ECS	L			5	5
55	Anti dieseling solenoid valve	L			3	3
56	CAP vacuum advance valve	M			8	5
57	Air injection check valve	M			5	5
58	Air cleaner thermostat	M	M	L	5	5
59	Distributor vacuum control valve	M		M	5	5
60	Gulp valve				5	5
61	Vacuum lines				3	2

[1]Table 12 Reference 70.
*Components not in production prior to 1973.

to various changes in test conditions and engine adjustments. Tests were performed on catalyst- and noncatalyst-equipped vehicles. Pertinent parameters investigated included idle speed, basic timing, and idle mixture. Unfortunately, the emissions were tested using the hot start 1972 FTP. Therefore, results using cold start FTP tests may be somewhat different. The results are summarized in Table 2-4 in percent change relative to a hot start 1972 FTP baseline test.

Table 2-4. EFFECT OF IDLE PARAMETERS ON HOT FTP EMISSIONS (REF. 17)

	PRE-CATALYST			CATALYST-EQUIPPED		
	HC	CO	NO_x	HC	CO	NO_x
Timing $+5^o$	+10%	-	+15%	-	-30%	+20%
Idle CO +1%	-	+15%	-	+100%*	+100%*	-
Idle Speed -100 rpm	+10%	+10%	-	-	-25%	-

*Baseline emissions approximately 1/3 of standard.

The California Air Resources Board (CARB) performed two studies (Ref. 92 and 93) of defects in catalyst-equipped vehicles. Table 2-5 summarizes these results in terms of the increase (decrease) on emissions attributable to specific component defects. The results of these studies show that misfire due to faulty plugs or wires was the most critical HC-related defect. Other critical defects included choke malfunctions, air injection failure, lean misfire caused by vacuum leaks and incorrect timing (10^o retarded). The most critical CO-related defects were air injection failure, choke malfunction, retarded timing, and misfire. The most critical NO_x-related defects were clearly disabled EGR systems and advanced basic timing.

Table 2-5. CHANGES IN 1975 FTP EMISSIONS CAUSED BY SPECIFIC DEFECTS (PERCENT INCREASE FROM BASELINE EMISSIONS)

DEFECT	INDUCED DEFECTS[a]				DIAGNOSED DEFECTS[b]			
	Number of Vehicles	HC	CO	NO_x	Number of Vehicles	HC	CO	NO_x
No EGR	6	33	33	65	3	0	12	65
Plugs/Wires	6	833	252	41	3	731	14	35
Vacuum Leak	6	83	73	0	1	150	-32	11
Timing (advanced)	6	17	2	35	1	-23	-47	64
Timing (retarded)	6	133	355	-12	0	-	-	-
Air Failure	0	-	-	-	6	160	365	-9
Choke Stuck	6	433	298	-12	3	60	170	-15
Carburetor Mixture	0	-	-	-	3	33	26	4
Idle Stop Solenoid	0	-	-	-	1	150	33	15
Dirty Air Filter	6	50	62	0	0	-	-	-

[a]Defects induced in low mileage catalyst vehicles (Ref. 92).

[b]Defects diagnosed in low mileage catalyst vehicles which failed an idle HC screening standard of 200 ppm Hexane (Ref. 93).

Maugh (Ref. 100) presented data, shown in Table 2-6, on defect testing of the three different 1976 Federal certification vehicles. These data and other information discussed in the paper led to the following conclusions:

- Restricted air cleaner or timing variations of $\pm 10^{\circ}$ did not significantly affect FTP emissions.

- Disconnected air injection caused significant increases in HC and CO emissions but reduced NO_x emissions.

- A stuck choke increased HC and CO emissions on large engines but not necessarily on small engines. NO_x emissions were reduced, significantly on large engines.

- Total misfire caused significantly higher HC emissions particularly on small engines. CO and NO_x emissions also increased although not as much as HC emissions.

Two EPA studies investigated tampering and maladjustments of 1973-1975 model-year vehicles. Timing maladjustments of up to $\pm 5^{\circ}$ alone resulted in 10 percent to 20 percent increases in FTP emissions of HC and CO from 1975 model-year vehicles. Emissions of NO_x were increased 20 percent by a 5° advance in timing and reduced 20 percent by retarding timing 5° (Ref. 98). Several 1973-1974 model-year vehicles were sent to commercial garages to have their fuel economy improved. Although most adjustments did not improve fuel economy, emissions of all three pollutants were increased with NO_x and CO receiving the greatest increase (Ref. 97). These data indicated that intentional maladjustment or

Table 2-6. EFFECT OF COMPONENT DEFECTS ON 1975 FTP EMISSIONS
(EXHIBIT V OF REF. 101)

	2.3L 4-CYLINDER			351 CID 8-CYLINDER			460 CID 8-CYLINDER		
	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
Baseline	0.51	2.31	1.76	0.62	4.97	1.24	0.51	3.04	1.46
Air Cleaner Restricted 75%	0.47	2.14	2.18	0.60	5.06	1.08	0.40	1.70	1.41
Timing +10^{o}	0.60	3.52	3.12	0.63	3.75	1.65	0.51	2.13	1.81
Timing -10^{o}	0.49	2.34	1.19	0.55	5.02	0.93	0.32	3.22	1.23
EGR Line Off	0.43	1.56	6.44	0.44	2.69	4.25	0.33	1.55	5.60
Thermactor Disconnected	0.68	11.10	1.32	2.23	69.30	0.93	2.46	66.10	1.24
Choke Restricted 50% Travel	0.50	3.95	1.45	0.57	6.84	0.85	17.80	322.00	0.35
Spark Plug Wire Grounded	10.20	7.57	2.84	4.11	4.65	1.69	2.61	8.57	2.55

defeat of emission controls resulted in significant emissions increases without actual component failures.

The EPA/CRC CAPE-13-68 study (Ref. 16) included an analysis of several common adjustment and component defects in pre-1972 model-year vehicles. Variables studied in the controlled experiment included timing, idle speed, idle mixture, air cleaner restriction, PCV restriction, and NO_x TCS defeat. Emissions were reported in grams per mile and were measured using hot start 1972 FTP tests. The data in Table 2-7 was reported for 1971 NO_x controlled vehicles.

Table 2-7. EFFECT OF COMPONENT DEFECTS ON HOT FTP EMISSIONS (Ref. 16)

	HC	CO	NO_x
Timing (gm/mi/degree advance)	0.08	-0.90	0.15
Idle Speed (gm/mi/100 rpm)	-0.15	2.80	0.07
Idle Mixture (gm/mi/% CO)	-0.07	6.53	-0.03
½ Blocked Air Cleaner (gm/mi)	0.18	12.42	-0.48
PCV Blocked (gm/mi)	0.36	18.03	-0.33
TCS Defeat (gm/mi)	0.55	-6.30	0.99

All changes were relatively small with respect to the effective emission standards of 1971 model-year vehicles. Direct comparison to 1972 and later model-year vehicles is difficult, however, because these data were based on hot start tests and did not reflect changes in engine and emission control system design applicable to recent model years.

Panzer (Ref. 12 and 96) discussed the idle emission test program performed by Exxon. The first paper included a survey of 23 previous papers relating component defects to qualitative steady-state emissions (Table 2-8). No quantitative data based on FTP emissions were presented. However, substantial HC and CO emission reductions were achieved by performing adjustments and repairs to correct idle mixture, engine speed, timing, PCV system restriction, ignition and carburetor malfunctions, vacuum leaks and valve leaks.

Several reports (Ref. 16, 33, 42, 43, 49, 51, 54, 60, 74, 78, 84, 94, 95, and 99) discussed various Inspection and Maintenance (I/M) studies. These reports indicated that I/M was effective in reducing emissions of HC and CO. Unfortunately, only a few of these studies were performed on catalyst-equipped vehicles and none associated emissions increases or decreases to individual component defects. Data on the source of parts used in repairing vehicles which failed the emission inspection was not reported in these references. However, use of after-market parts is common practice by the independent service industry which performs many of the repairs required in these studies. Therefore, since reasonable emission reductions were achieved in most of these studies, they imply that after-market replacement components do not adversely affect emissions.

An EPA study (Ref. 104) evaluated the effect of high performance centrifugal advance springs which provided more advance at low and moderate engine speed than OEM springs. The special springs were found to increase emissions of all three pollutants without substantially improving fuel economy. These tests were run on a 1974 Chevrolet with 350-CID engine.

A report by the Specialty Equipment Manufacturers Association (Ref. 105) showed that off-the-shelf performance components could either improve or degrade emissions relative to the OEM components, depending on the OEM system configuration and calibration, and the amount of optimizing adjustments performed. However, the average emission reduction measured

Table 2-8. EFFECT OF ENGINE VARIABLES ON STEADY STATE EMISSIONS FROM PRE-1973 VEHICLES (TABLES 3 AND 4, REF. 12)

VARIABLE	IDLE		LOADED	
	CO	HC	CO	HC
Increased A/F	Decrease	Decrease to Stoichiometric	Decrease	Decrease to Stoichiometric
Increased RPM	Decrease	-	None	Decrease
Restricted PVC	Increase	-	Increase	Increase
Restricted Air Cleaner	Increase	-	Increase	Increase
Stuck Choke	Increase	-	Increase	Increase
Carburetor Malfunction	Increase	-	Large Increase	Increase
Ignition Malfunction	-	Increase	-	Increase
Retarded Timing	-	Increase	None	Decrease
Stuck Heat Riser	Increase	-	-	-
Excessive Fuel Pressure	Increase	-	-	-
Exhaust Valve Leaks	-	Increase	-	Increase
Vacuum Leaks	Increase	Increase	-	Increase
Decel Device Failure	-	-	-	Increase
Spark Advance Failure	-	-	-	Increase
Air Pump	-	-	Increase	Increase
Air Inlet Temp. Increase	-	Slight Increase	-	-

by the 1975 FTP was approximately 25 percent for HC, 30 percent for CO and 40 percent for NO_x from four typical 1969 model-year vehicles. Data on more recent vehicles is currently being developed.

The California Air Resources Board (Ref. 106) conducted a preliminary test program to investigate the effect of certain after-market components on emissions. In general, ignition components did not affect emissions unless ignition timing was modified. Carburetion intake manifold or exhaust system modifications could either increase or decrease emissions depending on the component, base engine, and degree of optimizing adjustments performed.

Springer (Ref. 63) reported extensively on smoke emissions from diesels. Control of smoke emissions were primarily due to modifications to injector pumps, injector tips, spray pattern, duration and timing. In some applications, introduction or modification of turbochargers reduced smoke. Control requirements for NO_x, however, tend to increase smoke emissions due to premature flame quenching in the cooler combustion gases. Control of smoke from in-use vehicles, however, is more related to engine power derating, retrofit components, or modified driver operating procedures. Except in severe conditions, normal maintenance generally did not make significant changes in smoke emissions, providing that basic adjustments of the fuel injection system were made to manufacturer's specification.

2.3 PROBABILITY AND DURATION OF COMPONENT FAILURE

Several of the references describing emissions characteristics of defective components also provided data on failure rates of components or systems. No data, however, was obtained regarding probable duration of failure, although most sources implied a strong relationship between performance degradation and corrective repair. However, in practice, driver sensitivity to, and tolerance of, performance degradation varies and depends, in part, on the nature and severity of degraded performance, vehicle age, and the imagined or real cost of repair.

Inspection and Maintenance (I/M) studies provided some data on the incidence of system failures in the vehicle population. Unfortunately, the failure criteria and the observed failure rates varied considerably. Most studies related failure criteria to modal emission characteristics (Ref. 33, 42, 43, 49, 60, 79, 84, 94, 95, and 99). These studies identified high incidences of incorrect basic idle adjustments. Other studies which involved parameter inspection or performance criteria generally detected more component failures than the emission inspection studies (Ref. 16, 78, 101, and 102). None of the studies suggested that aftermarket components had higher failure rates than the equivalent OEM component. However, errors in component installation or adjustment by service personnel may result in excessive emissions. This has been reported for rebuilt carburetors (Ref. 33).

The observed failure rates, regardless of the inspection criteria and methodology, reflect an average of continually occurring component failures and repairs. Therefore, using inspection data to define component failures, may not truly reflect the probability of an individual component failing. It only represents the probability of finding defects at any one time in a vehicle population. The true failure rate is, therefore, likely to be higher than detected for components which are likely to be repaired. The failure rate is likely to be about the same as indicated for components which are not likely to fail or be repaired.

Panzer (Ref. 12) summarized several prior studies in addition to data from the Exxon Research idle fleet. This data is presented in Table 2-9.

Table 2-9. INCIDENCE OF MALFUNCTIONS
(ABSTRACTED FROM TABLES 7 AND 8 OF REF. 12)

DESCRIPTION	ALL VEHICLES Survey (Percent)	ALL VEHICLES Exxon (Percent)	REJECTED VEHICLES Survey (Percent)	REJECTED VEHICLES Exxon (Percent)
Ignition	4 - 78	12 - 18	12 - 30	51
Mixture	60	26 - 40	-	28
Engine RPM	70	38 - 55	-	38
Carburetor	24	4 - 10	15 - 20	17
Choke	-	1 - 4	-	13
Timing	76	4 - 27	-	10
PCV Valve	-	1 - 4	-	7
Air Filter	-	1 - 5	-	6
Vacuum Leak	-	1 - 2	-	6
Heat Riser	9	11 - 3	-	0
Vacuum Advance	-	1 - 4	-	1
Air Pump	11	-	-	-

Catalyst durability studies provided some data on component failure as described in Section 2.2. The NAS summary document (Ref. 70) provided preliminary data on mean time to failure or suggested maintenance intervals for some selected components. These data are shown in Table 2-10.

Catalyst durability studies also showed that ignition defects severe enough to cause catalyst malfunction occurred on only 3 to 5 percent of the vehicles. Other component failures were not described because they generally did not occur or they did not adversely affect catalyst life.

A consultant report to the NAS (Ref. 73) described some probable maintainability and reliability data for 1975-1976 configuration vehicles:

- EGR maintenance should be reduced by lead-free fuel because particulate (deposits) emissions are reduced.
- Spark plug life should be increased by lead-free fuel and high energy ignition systems.
- Ignition wire life should be increased by improved insulation and conductor materials.
- Heat riser service interval should be extended four to five times due to lead-free fuel.
- Electronic ignition should minimize changes in spark timing and firing due to point failure, thereby reducing misfire.
- Vacuum line, vacuum motor, vacuum diaphragm, and exhaust pressure diaphragm malfunction should be low (fraction of 1 percent in the vehicle population).

Table 2-10. ESTIMATED DURABILITY OF AUTOMOTIVE PARTS
(TABLE 13 OF REF. 70)

SYSTEM PARAMETERS	MEAN TIME-TO FAILURE (MI) Scott Labs.	MEAN TIME-TO FAILURE (MI) American Motors	SERVICE INTERVAL (MI) Chrysler
Carburetion			
A/F at idle	15,000	25,000	12,000
A/F at main jet	30,000	--	12,000
A/F power jet	--	--	12,000
Choke	25,000	25,000	6 months
Heat Riser valve	25,000	5,000	6 months
Altitude compensation	--	--	--
Leaks intake manifold	50,000	50,000	--
Leaks vacuum line	35,000	50,000	Infrequent
Air cleaner - plugged	20,000	15,000	12,000
Ignition			
Misfire--plugs	20,000	15-30,000	18,000
Misfire--wiring	25,000	50,000	Infrequent
Misfire--cap and rotor	30,000	50,000	Infrequent
Basic timing	15,000	15,000	12,000
Automatic spark advance	25,000	100,000	12,000
Devices			
PCV system	30,000	15,000	12,000
EGR system	--	12-50,000	12,000
Air pump system	40,000	100,000	12,000
Oxidation catalyst	25,000	12,000	--
Reduction catalyst	25,000	--	--
Evaporative control system	70,000	50,000	12,000
Other			
Idle speed	15,000	15,000	12,000
Burned exhaust valve	90,000	100,000	Infrequent
Low compression	60,000	100,000	Infrequent

The California Bureau of Automotive Repair reported the failure incidences at the Vehicle Inspection Facilities in Riverside (Ref. 94). These data are reported in Table 2-11 and include about 900 failed vehicles. The decision on whether repairs were required were based on an engineering evaluation of ignition and emission data before and after maintenance. In general, a low incidence of ignition malfunctions were found with most failures due to idle adjustments and off idle carburetion problems.

The CARB reported on the incidence of failures found in low mileage catalyst vehicles which failed an idle HC screening standard (Ref. 93). These data are reported in Table 2-12. The determination of whether a defect existed or not was based on a diagnosis performed by CARB technicians.

Table 2-12. INCIDENCE OF DEFECTS IN LOW MILEAGE CATALYST VEHICLES (REF. 93)

DEFECTS	PERCENT OF FAILED VEHICLES	PERCENT OF ALL VEHICLES
Ignition Misfire	12	0.8
Mixture	15	1.0
Engine Speed	9	0.6
Carburetor	3	0.2
Choke	9	0.6
Timing	15	1.0
PCV Valve	3	0.2
Air Filter	30	2.0
Vacuum Leak	12	0.8
Heat Riser	0	0
Vacuum Advance	3	0.2
Air Pump/Hose	15	1.0
EGR Failed/Defeated	15	1.0
Thermal Air Cleaner	6	0.4
Catalyst	3	0.2
Other Defects	18	1.2

Table 2-11. REPAIRS PERFORMED DURING CALIFORNIA VEHICLE EMISSION INSPECTION PROGRAM (ABSTRACTED FROM TABLES 13 THROUGH 21, Ref. 94)

DESCRIPTION	PERCENT OF FAILED VEHICLES RECEIVING REPAIR	PERCENT OF FAILED VEHICLES REQUIRING REPAIR
Idle Adjustment	100	82
PCV Filter Replacement	2	2
Choke Adjustment Repair	3	3
Carburetor Overhaul (Kit)	16	8
Carburetor Replacement (New or Rebuilt)	4	1
Air Filter Replacement	13	3
Spark Plug Replacement	12	3
Point Replacement	12	2
Condenser Replacement	10	2
Rotor Replacement	4	1
Ignition Wire Replacement	5	3
Heat Riser Repair	1	1
Heated Air Inlet Repair	<1	<1
Air Injection System Repair	<1	<1
Compression Check for Engine Defects	1	1
Other Misc. Repairs (Mechanical, Ignition, Vacuum)	4	1

2.4 SALES VOLUME OF AFTER-MARKET COMPONENTS

Data on the sales volume of after-market components was not compiled in a form suitable for this study. The data available was applicable only to certain component categories and did not distinguish between model-years. A major limitation of the available data was the fact that many component manufacturers distributed parts to both OEM and after-market customers. In these cases, it was impossible to determine the faction of sales attributable to the after-market.

A further limitation in the data involved the changing component mix in the after-market. After-market sales lag behind OEM sales by several years. Therefore, emission control system parts which are now exclusively OEM-distributed may become readily available in the after-market within several years. This has already occurred with PCV valves and air injection components which have been standardized and installed on vehicles for many years.

In an effort to estimate sales of after-market parts, two approaches were employed. First, the actual sales level of components was solicited from several sources. Members of the Automotive Warehouse Distributors Association (AWDA) were surveyed to acertain their sales volume of emissions-related parts. Unfortunately, only a few responses were received with the majority of the respondents indicating that the requested data was not accessible without explicitly identifying all the desired components by part number. Several respondents did, however, provide estimates of their sales volumes. The gross annual sales volume for those AWDA members responding is summarized in Table 2-13.

In addition to AWDA, the Automotive Liaison Council (ALC) was approached for information on sales volume. However, the ALC itself had not been able to quantify component sales volumes of its own members.

Table 2-13. GROSS ANNUAL AFTER-MARKET SALES VOLUME FROM WAREHOUSE DISTRIBUTORS RESPONDING TO SURVEY

CARBURETION SYSTEM COMPONENTS	
New Carburetors	83,164
Rebuilt Carburetors	80,112
Carburetor Rebuilding Kits	82,236
Vacuum Breaks	17,844
Choke Components (Thermostats)	43,514
Throttle Dashpots	8,567
Idle Stop Solenoids	16,600
Decel Valves	3,024
Air Filters	189,956
IGNITION SYSTEM COMPONENTS	
Spark Plugs	3,903,000
Wires	138,668
Caps	93,636
Rotors	109,916
Replacement Distributors	12,800
Mechanical Advance Units	2,400
Vacuum Advance Units	10,260
Condensers	179,332
Coils	28,980
CD Electronic Ignition Systems	1,440
Electronic Ignition Distributor Kits	408
Electronic Ignition Replacement Components	3,600
FUEL INJECTION COMPONENTS	
Fuel Pumps	112,100
Throttle Valves	2,400
ENGINE COMPONENTS	
Intake/Exhaust Valves	62,544
Valve Lifters	85,467
Springs	31,630
Piston Rings	61,312
Intake Manifolds	888
Exhaust Manifolds	600
Headers	396
Heat Riser Components	6,446
Pistons	17,468
Head Gaskets	61,920
Exhaust Pipes/Systems	812,136
Cams	3,404
Camshafts	61,312

Table 2-13. GROSS ANNUAL AFTER-MARKET SALES VOLUME FROM WAREHOUSE DISTRIBUTORS RESPONDING TO SURVEY (Cont'd)

EMISSION CONTROL COMPONENTS	
Evaporative Emission Filters	18,460
PCV Valves	109,660
PCV Breather Filters	43,344
Air Cleaner Thermostats	6,800
Ram Air Ducts	600
Air Cleaner Preheater Ducts	16,000
Air Cleaner Vacuum Motors	10,000
Vacuum Hoses	8,476
EGR Valves	5,800
EGR Vacuum Amplifiers	3,000
Thermal Vacuum Valves	20,000
Temperature Switches	5,300
Vacuum Solenoid Valves	5,620
Air Injection Pumps	716
Air Injection Hoses	8,750
Air Injection Diverter/Bypass Valves	2,636
In-line Delay Valves (Spark Delay)	20,200

Table 2-14 summarizes repairs performed in commercial garages, service stations, and dealerships (Ref. 106) on certain engine, ignition, and carburetion components during 1975. Except for filters and PCV valves, however, no emission control components were included.

The second approach consisted of using estimated component usage developed during the Phase I portion of the study on original equipment (Ref. 107). These estimates were based on determining how many of each component was used and how many replacements were recommended during the emission warranty period by engine family. The above information was obtained from the Emission Control Service Manuals (Ref. 27) published by Mitchell Manuals, Inc., San Diego, California, and from the recommended maintenance instructions provided by the vehicle manufacturers. The total component sales estimates were then generated by multiplying the component usage of each engine family by its estimated sales volume (Ref. 26 and 103). These sales volume factors are shown in Paragraph 4.2.4. Their development is discussed more fully in the Phase I final report (Ref. 107).

Table 2-14. GROSS ANNUAL REPAIR JOBS PERFORMED BY 355,000 REPAIR/SERVICE SHOPS[1] (JOBS IN THOUSANDS)

CARBURETION WORK	
Carburetors Installed (New)	1,515
Carburetors Installed (Rebuilt)	2,567
Carburetors Cleaned on Vehicles	7,336
Carburetors Overhauled (In Shop)	8,271
Fuel Pumps Installed (New)	5,224
Fuel Pumps Installed (Rebuilt)	1,914
Fuel Filters Replaced	36,313
Air Filters Replaced (Engine Overhaul)	6,183
Air Filters Repl. (Non-Eng. Overhaul)	46,926
IGNITION WORK	
Engine Tune-Ups (Car)	57,021
Engine Tune-Ups (Truck/Bus)	9,452
Retiming Jobs	17,252
PCV Valves Cleaned or Replaced	35,778
Ignition Breaker Points Installed	61,200
Ignition Wiring Installed (Sets)	10,216
Ignition Wiring Installed (Wires)	10,876
Spark Plugs (New)	390,835
Spark Plugs (Cleaned/Regapped/Reinstalled)	23,646
Electronic Ignition Installed (Retrofit)	1,069
Electronic Ignition Control Units Replaced	1,295
Reluctors or Trigger Wheels Replaced	1,779
Pick-up Unit or Pole Piece Replaced	725
Voltage Regulators Installed (New)	8,970
Voltage Regulators Installed (Reblt)	1,437
Voltage Regulators Adjusted	2,777

[1]Abstracted from Ref. 106, "1975 Service Job Analysis," Hunter Publishing Co., Chicago - 1976, pages 10-15.

Table 2-14. GROSS ANNUAL REPAIR JOBS PERFORMED BY 355,000 REPAIR/SERVICE SHOPS[1] (JOBS IN THOUSANDS - Continued)

ENGINE WORK	
Valve Grinding Jobs (Car)	5,653
Valve Grinding Jobs (Truck/Bus)	1.464
Cylinder Blocks Recond'ed (Blocks)	1,150
Cylinder Blocks Recond'ed (Cyl's)	7,864
Crankshafts Reconditioned	1,016
Piston Rings Inst. (8 Cyl. Cars-Sets)	1,909
Piston Rings Inst. (6 Cyl. Cars-Sets)	690
Piston Rings Inst. (4 Cyl. Cars-Sets)	821
Piston Rings Inst. (8 Cyl. Trk/Bus-Sets)	902
Piston Rings Inst. (6 Cyl. Trk/Bus-Sets)	549
Piston Rings Inst. (4 Cyl. Trk/Bus-Sets)	130
Rod Bearings Installed (Sets)	3,376
Main Bearings Installed (Sets)	2,838
Valves Replaced	13,248
Hydraulic Valve Lifters Installed	17,419
Timing Gears Installed	3,426
Camshafts Installed (New)	775
Camshafts Installed (Reground)	873
Timing Chains Installed (New)	3,217

Section 3

EMISSIONS-RELATED COMPONENTS

This section describes the emissions-related systems and their components. Functions, typical applications and characteristic modes of failure are described. The systems and components discussed in this Phase II report consist of those available through the after-market for 1972 and subsequent model-year engines and vehicles. A list of the components determined to be emissions-related is presented at the end of this section.

3.1 CRITERIA AND ASSUMPTIONS

Emissions-related systems, parts, and components were defined by the study contract to be emissions-related if they had to be built to certain specifications and/or perform within certain specifications, or one or more pollutant (HC, CO, NO_x, smoke) would exceed applicable standards for the vehicle or engine. This definition was sufficiently broad to include essentially all engine and emission control systems used on vehicles.

For the purpose of this study, "after-market" included all automotive systems, parts, and components which were not built by or for the vehicle or engine manufacturers. These components are not necessarily in compliance with regulations issued under Title II of the Clean Air Act. Under this contract, after-market equipment did not include those replacement parts which were identical to factory installed components if they were built by or for the vehicle or engine manufacturer. This definition was interpreted so that all replacement parts or components distributed by the original vehicle/engine manufacturers through their dealer or authorized service center networks were excluded from the analysis of after-market part criticality, even though these components are generally considered after-market parts by the industry.

Although the contract defined emissions-related parts to be those whose failure would cause violation of emissions standards, it was not possible to determine from the literature or engineering analysis if defects in all of the components would always cause an emissions failure. It was also impossible to determine whether a nominally functioning after-market component used in an improper application would necessarily cause an emission failure. This was because even though emissions might be doubled, low emitters might still pass the standard. Therefore, rather than arbitrarily exclude a component from further consideration because its failure was assumed not to cause emissions failure, all components with potential effects on emissions were considered.

To facilitate the analysis, individual parts with similar design and function were grouped together into part categories (i.e.; spark plugs, air filters, thermal vacuum valves, etc.). Individual components within each part category were then assigned average parameter values representative of typical components included in that category. Assignment of specific values for each input parameter is described in Section 4.

In order to assign specific values to the input parameters, it was necessary to define a typical failure mode for components in each category. For most components, individual design, fabrication, assembly, and application characteristics could differ depending on manufacturer and model resulting in a different failure mode or failure threshold for individual components within each category. However, since the scope of this study could not include all individual components, it was necessary to select representative components from each category and to define the characteristic failure modes for that component.

Several component categories within emission control systems use similar components (i.e.; thermal vacuum switches, vacuum hoses, speed/transmission sensors). These components were assigned identical failure modes and probabilities of failure even though they were used in different applications. Emissions increase and probability of repair factors may have been different, however, depending on the application.

Engine and emission control components are functionally or physically related to other specific components. This permitted the grouping of related categories of components into subsystems and major functional systems. Each system and its component parts were assigned a part code number based on the following system:

X. XX. XXX

Part Category Code

Subsystem Code

Major System Code

The part code system provided a systematic method of compiling and processing the data. The relationship of emissions to the following major systems and their respective components are discussed in this Section:

- Carburetion system
- Ignition system

- Air induction system
- Fuel injection system
- Miscellaneous engine systems
- Emission control systems

The literature surveyed in Section 2 and an engineering evaluation formed the basis for the discussion presented below.

3.2 CARBURETION SYSTEM

The carburetion system is responsible for correctly metering the required amount of fuel to the engine. Carburetion systems depend upon relatively complex mechanical and vacuum controls which, if defective, can severely impair the functioning of the overall system. For purposes of this study, the carburetion system was divided into the following three subsystems:

- Complete carburetor assemblies, either new replacement or rebuilt.
- Carburetor control devices external to the carburetor itself which modify the carburetor performance under special operating conditions.
- Individual carburetor components including carburetor rebuilding kits.

In general, carburetor components and control devices can be associated with either closed-throttle (idle) or open-throttle (acceleration or cruise) operation. The certification test for light-duty vehicles (1972 FTP and 1975 FTP) contains substantial idle operation. However, defects in cruise or power circuits can result in very high mass emissions due to the high exhaust flow rate under these operating conditions. The certification test results are also highly dependent on cold start emissions and rapid warm-up. Therefore, defects which result in delayed or improper choke opening can cause substantial emission increases.

Carburetion system defects generally result in excessively rich operation which leads to high CO emissions and occasionally high HC if the CO increase is severe enough. Typical defects resulting in rich operation include the following (Ref. 2 and 3):

- Improper choke setting or rate of opening.
- Ruptured power valve (economiser) vacuum diaphragm.
- Worn or improperly set metering rods.
- Improperly set or defective float and needle valve.
- Improper idle adjustment.
- Improper jet size.
- Defective idle stop solenoid, throttle positioner, or dashpot.

Some component defects can cause lean operation resulting in misfire (Ref. 2 and 3). The misfire may be detected by performance (stumble and hesitation) or by excessive HC emissions. These components include:

- Worn accelerator pump plunger.
- Ruptured accelerator pump vacuum diaphragm (if equipped).
- Worn or broken gaskets.
- Ruptured vacuum diaphragms.
- Improper idle adjustment.
- Improperly set float level.

- Improperly set metering rods.
- Restricted fuel filter.

In general, defects leading to rich operation are associated with open-throttle conditions and contribute high mass emissions. Exception to this include grossly rich idle mixture. Defects leading to lean operation tend to be associated with closed-throttle conditions (i.e., high manifold vacuum) which are intermittent and contribute low mass emissions. Therefore, defects in carburetor components causing rich operation generally result in substantial CO mass emission increases while components causing lean operation usually result in marginal HC mass emission increases.

The effect of carburetor defects on NO_x emissions are inversely related to the effect on CO emissions (Ref. 2). Rich operation resulting in high CO will generally result in reduced NO_x. Lean operation resulting in high HC may also result in increased NO_x due to higher combustion temperatures and mass flow rate because the throttle must be held open further to compensate for the power loss resulting from misfire. However, since conditions where lean misfire occur are usually intermittent or at closed throttle, the effect on NO_x may be negligible.

3.2.1 Assembled Carburetors

Complete carburetors, either new or rebuilt, are sold ready for installation on the vehicle. All necessary interface and accessory components, including gaskets, dashpots, choke, and throttle linkage are generally provided with the carburetor. Considerable data has been generated which indicates that the metering accuracy and reliability of new carburetors built and distributed as OEM or OEM-replacement carburetors are generally better than after-market replacement carburetors, factory rebuilt carburetors, or carburetors repaired by mechanics. Therefore, separate part categories have been defined for new after-market and rebuilt after-market carburetors. In many cases, after-market carburetors are dimensionally equivalent to OEM carburetors but have different flow calibrations. Replacement carburetors can also be used on different engines than for which they were originally sold. They can, therefore, have high emissions even though no overt defects are present.

Carburetor performance can affect all three pollutants, although CO is usually the most sensitive to defects or improper adjustment. Gross carburetor malfunction is usually associated with one or more of the following components (Ref. 2, 3, 16, 78, and 27):

- Choke
- Power valve
- Metering jets and rods
- Float adjustment
- Accelerator pump
- Idle adjustment
- Gaskets

Other components can also increase CO emissions under certain operating conditions or circumstances. The actual impact of each defect depends on the engine and carburetor under consideration. Since each of the above components is individually repairable or adjustable, they have been treated individually in this study.

In addition to fuel metering and mixing, carburetors can also affect the strength and characteristics of vacuum signals used to control ignition timing advance and EGR valve operation, and to operate other emissions, performance, or comfort-related accessories. Replacement carburetors which do not provide equivalent vacuum signals as a function of engine speed and load can affect both emissions and performance.

There are three sources of vacuum, each of which behave differently for any given engine operating condition. These three vacuum signals have been named venturi vacuum, ported vacuum, and intake manifold vacuum corresponding to the location of the source in the carburetor.

Figure 3-1 illustrates the general location of these sources in a typical carburetor.

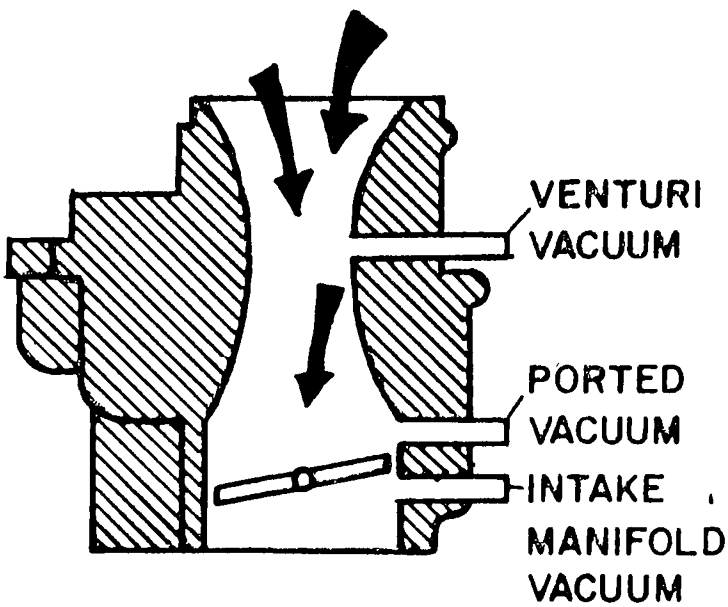


Figure 3-1. CARBURETOR VACUUM SIGNALS

The venturi vacuum tap is located in the carburetor venturi. The amount of vacuum present at this venturi tap depends on the velocity of air flowing through the carburetor which, in turn, depends on engine speed and throttle opening. Therefore, a stronger vacuum is available at high speed and load than at low speed and/or load. Venturi vacuum, which typically ranges between 0 to 5 inches of mercury, is frequently used to control EGR valve operation in those applications where EGR is proportional to high load and/or speed.

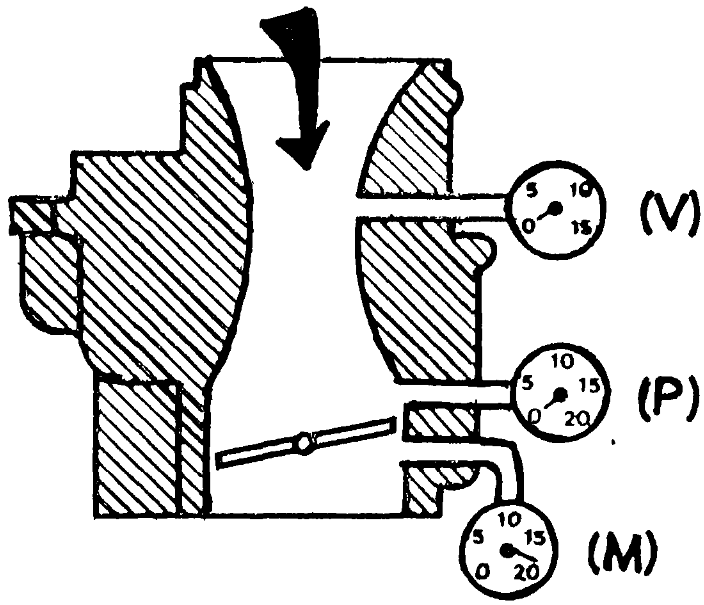
The intake manifold vacuum tap is located somewhere below the throttle plate. This tap can be in the carburetor itself or in the intake manifold. This source of vacuum is at a maximum when the throttle plate is closed and at a minimum when the throttle plate is wide open. This vacuum typically varies from 17 to 22 inches of mercury at idle to about 0 inches of mercury at wide open throttle. Manifold vacuum is usually used for vacuum-operated accessories and may include a vacuum reservoir to ensure that vacuum is present during all operating conditions. Manifold vacuum is frequently used to modulate ignition timing and to provide PCV and evaporative canister purging.

The ported vacuum tap is usually located just above the throttle plate. For this reason, when the engine is idling and the throttle plate is closed, there is no vacuum signal at the ported vacuum tap. When the throttle is opened, the ported vacuum tap will be exposed and will sense the vacuum below the throttle plate. This vacuum will be essentially the same as manifold vacuum and will behave much the same as manifold vacuum except during closed throttle operation. This ported vacuum typically varies from 0 to about 14 inches of mercury, depending on throttle opening and the port configuration. Ported vacuum is often used to control emission control systems and ignition timing.

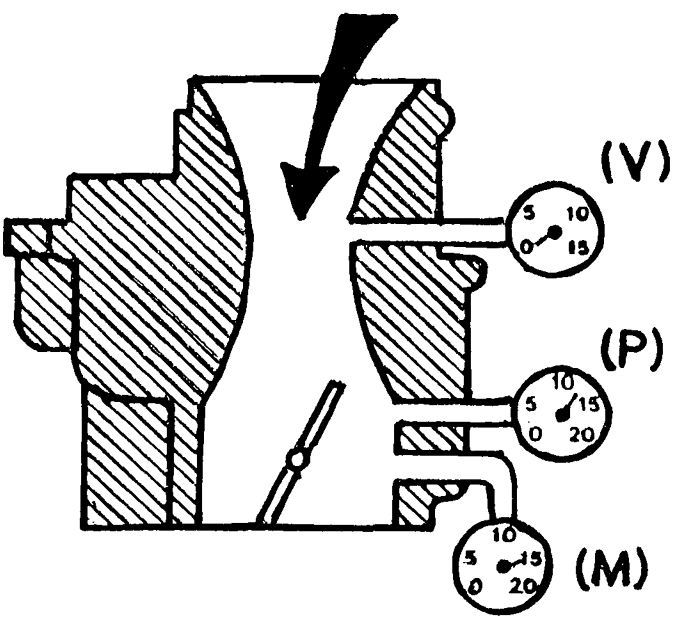
Figure 3-2 shows the relationship between vacuum signals at different ports for different throttle plate positions.

3.2.2 Carburetor Control Devices

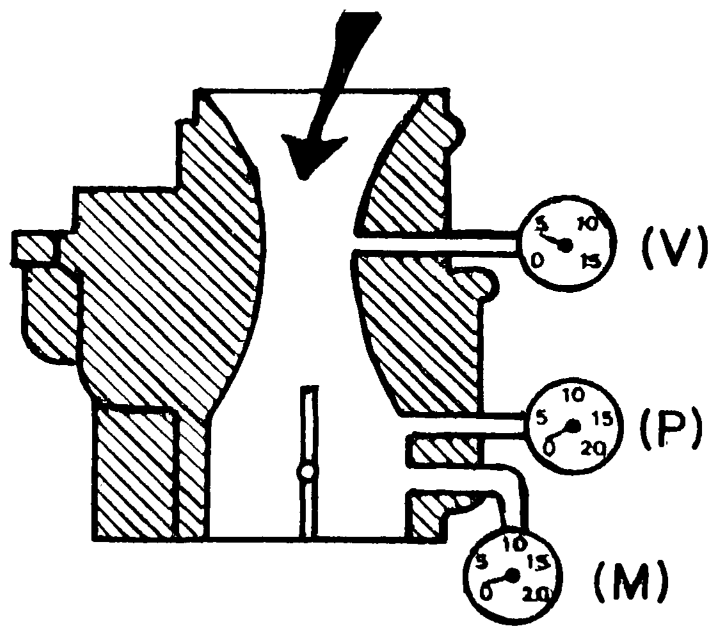
Several emission control devices have been developed to regulate or modify the carburetor's operation under certain operating conditions. These devices generally regulate throttle closure in such a way as to modify the normal fuel-metering characteristics of the vehicle. Defects in these devices can increase HC and CO emissions but the increases are generally not as severe as from fundamental



a) IDLE



b) OFF IDLE



c) WIDE OPEN THROTTLE

Figure 3-2. EFFECT OF THROTTLE POSITION ON VACUUM SIGNALS carburetor defects. These components are generally available from after-market distributors although they are manufactured by OEM vendors.

3.2.2.1 Idle-Stop Solenoid

The idle-stop solenoid is used on most 1972 and later model-year vehicles to provide a predetermined throttle setting. The solenoid becomes energized when the ignition key is turned on. When energized, the plunger extends and contacts the carburetor throttle lever preventing full closing of the throttle plates. When the solenoid is de-energized (plunger retracted), the throttle plates close beyond the normal idle position. This action shuts off carburetor air supply, starving the engine so that it will shut down without dieseling (Ref. 3 and 27).

For precatalyst-equipped vehicles, the idle-stop solenoid is primarily a performance-related device to ensure that the lean calibrated carburetors used in these model-years did not promote dieseling of the engine and subsequent customer complaints. However, for catalyst-equipped vehicles, the idle-stop solenoid becomes important as a catalyst protection device to prevent excess fuel flow and subsequent catalyst overheating during engine shut down (Ref. 27).

Failures of the idle-stop solenoid would involve misadjustment or shorted or open windings in the solenoid which prevent extension of the plunger. This would prevent opening of the throttle causing slow and rough idle. Excessive throttle opening and throttle operation by the driver would be required to maintain satisfactory idle performance. This defect would increase HC and CO emissions during closed throttle operation.

3.2.2.2 Throttle Dashpot

The dashpot is a mechanical device which acts as a damper to prevent too rapid throttle closure. This device can be used to prevent stalling and/or to reduce emissions by reducing the momentary rich condition caused when the throttle is closed rapidly (Ref. 3 and 27).

Failure of the dashpot is usually due to deterioration of seals. This results in too rapid throttle closure leading to higher HC/CO emissions during deceleration.

3.2.2.3 Throttle Positioners

Throttle positioners are used to hold the throttle slightly open during deceleration to provide a more combustible mixture to the engine and, thus, reduce emissions. An additional control device is generally provided to allow the throttle to close to normal idle position after a certain length of time, or when vehicle speed decreases to a certain point. These devices are usually operated electrically but may be vacuum operated (Ref. 3 and 27).

Throttle positioners are active devices which perform a function similar to the passive dashpot described in the preceding paragraph. Throttle positioners are used on some domestic and foreign vehicles for improved HC/CO emission control. They can be regulated more precisely than dashpots using electrical sensors for speed, temperature, vacuum, etc.

Failures of the electrically operated throttle positioner are similar to the idle-stop solenoid. If vacuum operated, failures are generally associated with ruptured diaphragms. Both failures result in normal closed throttle operation during all temperature and speed conditions. Temperature and speed sensors for the throttle positioner are usually associated with systems to modify timing and are discussed under TCS or EGR.

3.2.3 Carburetor Components

The following carburetor components are grouped together because they can be clearly distinguished as separate components, are readily replaceable, and are routinely adjusted or repaired by mechanics. A carburetor malfunction is generally attributable to a defect or maladjustment of one or more of these components. These components are generally sold in kit form (see paragraph 3.2.3.8), but may be purchased individually. Normal shop practice is to replace all major carburetor components when a carburetor is rebuilt.

3.2.3.1 Metering Jets

Metering jets are calibrated orifices through which fuel passes in response to the vacuum created by the carburetor venturi. The metering jet may be located in the venturi or near the float chamber. The jets generally control fuel metering from about 1/4-throttle opening to about 3/4-throttle opening. Over extended periods of operation, the throttle jet can erode due to the passage of fuel resulting in fuel enrichening (Ref. 2 and 3). More importantly for the after-market, however, larger carburetor jets can be installed in most carburetors to improve driveability and performance. This results in increased CO and possibly HC emissions.

3.2.3.2 Metering Rods

Some carburetors use metering rods instead of, or in addition to, metering jets. The metering rod is a variable diameter rod which moves in and out of the jet to cause different effective orifice sizes. The metering rod is, therefore, better able to control fuel metering to variations in throttle position or vacuum. Metering rods are moved by mechanical linkage to the throttle or by vacuum diaphragms.

Metering rod accuracy is strongly related to position of the rod in relation to the load condition. Rod position determines fuel metering at the particular throttle opening. Therefore, the characteristic defect defined for metering rods will be incorrect positioning, resulting in excessive metering of fuel at all off-idle load conditions. This results in higher CO and possibly HC emissions (Ref. 2, 3, and 27).

3.2.3.3 Vacuum Break Valves

Vacuum break valves, also called vacuum kick or choke pull down valves, are used on most carburetors to modulate the choke position. The basic choke position is determined by the choke thermostat as described in paragraph 3.2.3.4. The vacuum break valve is used to adjust the choke position to suit actual load condition as reflected by vacuum. The vacuum break valve opens the choke slightly to lean out mixture as soon as the engine starts.

Defective vacuum break valves will result in normal choke opening causing higher CO emissions. The typical failure mode is a ruptured vacuum diaphragm. This may result in lean misfire at idle due to a vacuum leak, as well as the overall rich condition (Ref. 2, 3 and 27).

3.2.3.4 Choke Thermostat and Linkage

All carburetors employ a choke which restricts airflow into the engine during cold starts. Since emission control is very dependent on correct choke operation, automatic chokes have replaced manually-operated chokes on most emission-certified vehicles. The automatic choke is activated by a thermostatic coil spring which unwinds as heat is applied. As the spring unwinds, it causes the choke valve or plate to open permitting proportionally more air to enter the carburetor. The fully-open choke does not restrict airflow and, therefore, normal fuel metering is accomplished by the idle and cruise circuit of the carburetor.

Choke failures are often due to sticking linkages which cause the choke to remain either open or closed. An open choke will cause poor starting, idle running, and driveability during cold starts and will usually be corrected. A closed choke may cause excessively rich mixtures (10 percent CO), particularly under part throttle loaded operation, and may not be detected by driveability problems. Very rich mixtures can also cause moderate increases in hydrocarbon emissions (Ref. 2, 3, 16, 78, and 103).

Other choke failures may be due to broken choke springs, incorrect choke adjustment, defective vacuum break unit, or defective or disconnected choke heater (Ref. 3).

3.2.3.5 Accelerator Pumps

The accelerator pump is used on nearly all carburetors and provides a quick burst of fuel during rapid acceleration. Without the accelerator pump, the mixture would lean out and possibly cause intermittent lean misfire as shown by hesitation or stumbling performance. The accelerator pump consists of a mechanically- or vacuum-operated plunger, check valves, and metering jet. The accelerator pump can cause excessively rich operation and high CO emissions if it is improperly adjusted or if there are defects or wear in the check valves, metering jet, or vacuum diaphragm. However, the probable defect of the accelerator pump in the aftermarket will be incorrect adjustment or loose pump piston seal. Both situations will enrichen the mixture and increase CO and HC mass emissions (Ref. 2, 3 and 27).

3.2.3.6 Power Valves

The power valve, or economiser valve, provides additional fuel through the high speed circuit for full power operation at wide-open throttle. The power valve is vacuum-, or in some cases, mechanically-operated. Not all carburetors, however, are equipped with true power valves. Some carburetors only use metering rods (Section 3.2.3.2) which provide more fuel to the high speed circuit at wide-open throttle (Ref. 2, 3 and 27).

Power valves open in response to low manifold vacuum during open throttle operation. During closed or part throttle operation, the manifold vacuum increases, pulling the power valve closed. Any obstruction in the vacuum passages or rupture of the vacuum diaphragm causes the power valve to remain open at all times and meter excessive fuel under off-idle operation. The characteristic defect of power valves are, therefore, ruptured vacuum diaphragms leading to high CO mass emissions (Ref. 2 and 3).

3.2.3.7 Gaskets

Gaskets are used to join the carburetor to the manifold and to join together the individual assemblies of the carburetor. The gaskets provide an air seal against the engine intake vacuum. Gaskets are subject to thermal and mechanical deterioration. Periodic tightening of the carburetor mounting bolts are recommended by most manufacturers to compensate for gradual compression of the gaskets (Ref. 3 and 27).

Air leaks past defective gaskets can result in lean misfire and high HC emissions. In some cases, internal gaskets can be eroded by gasoline and fuel enrichening can occur. Gaskets have complex shapes and can be installed improperly during assembly or repair of the carburetor.

However, vacuum leaks past defective gaskets are the most likely failure mode (Ref. 3).

3.2.3.8 Rebuilding Kits

Rebuilding kits for carburetors normally include gaskets and replacement parts subject to wear such as needle valve and seat, power valve and accelerator pump diaphragms, dashpot, and small springs and connectors. Rebuilding kits are considered an after-market component in this study even though some kits are distributed by the OEM vehicle manufacturers.

Rebuilding kits should normally return a carburetor to "like new" condition. However, considerable experience has shown that a large percentage of carburetors rebuilt by vehicle owners or mechanics using kits did not operate correctly. This is generally due to improper or incomplete cleaning of air bleed passages in the carburetor or incorrect installation of gaskets or other components. Improperly rebuilt carburetors can have high CO and HC emissions (Ref. 16, 33, and 78).

3.2.3.9 Float and Valve

The float and valve assembly serves as the fuel reservoir for the carburetor. All the jets (idle, main, and power circuits) are fed with fuel from the float chamber. The rate of fuel metering by all circuits depends on the height of the fuel column which, in turn, is controlled by the float in the carburetor bowl. The needle valve for the fuel inlet is connected to the float so that additional fuel is admitted to the reservoir as the float drops (Ref. 2, 3 and 27).

Over long periods, the float may develop leaks or the needle valve and seat may wear so that excessive fuel may be admitted to the reservoir. This will result in rich operation and excessive CO emissions under all operating conditions. The float is subject to adjustment and may be set incorrectly either during assembly or during repair or rebuilding (Ref. 2, 3, and 78).

3.2.3.10 Idle Adjustment

Setting idle mixture is a fundamental tune-up step which is usually specified, although not always performed. Idle adjustment affects idle HC and CO emissions. Low idle emissions tend to give lower FTP emissions although statistical correlation between the measurements is poor (Ref. 60 and 84). The idle adjustment usually regulates by pass (bleed) airflow which is introduced below the closed throttle plate to mix with idle fuel flow. The idle mixture screws provide a convenient method to adjust each vehicle for optimum idle operation under actual operating conditions. It also provides compensation for clogged or restricted idle air or fuel jets (Ref. 2 and 3). The idle adjustment has not been included in the after-market parts analyses since it was not a physical part and problems with carburetor idle adjustments are related to excessive emissions after-market carbeuretors.

The idle emissions are poorly correlated to FTP emissions because most of the mass flow of the FTP emissions are provided by the main or power valves. Therefore, the idle mixture may be lean while the FTP emissions are high due to choke or power valve defects. Similarly, the idle mixture may be excessively rich but the FTP emissions satisfactory because of lean cruise operation. Inspection and maintenance studies, however, show that most vehicles with incorrect idle adjustment are set rich resulting in high CO and, in some cases, high HC emissions (Ref. 12, 16, 33, 74, 90, 94, and 99).

3.2.3.11 Idle Enrichment System

The idle enrichment system, used on a few engines, provides additional vacuum-operated choking during cold starts. This system consists of an air bleed on the carburetor which is closed by a solenoid and a thermal vacuum valve. The thermal vacuum valve responds to coolant temperature to disable enrichment during hot starts. The solenoid valve is activated by the starting circuit and a timer which holds the solenoid open for 35 seconds. This system is utilized to prevent engine stalling immediately following the cold start. Failure of the system is most likely to defeat the enrichment process. Therefore, an increase in HC emissions might result from the system due to lean misfire when cold (Ref. 27).

3.2.4 Fuel Filter

The fuel filter is used to remove any entrained particles and dirt in the fuel. If the filter was missing, foreign particles could lodge in the fuel metering passages of the carburetor and affect operation. By itself, however, the fuel filter does not have a significant impact on emissions unless it becomes so clogged as to restrict fuel flow (Ref. 2 and 3). Under this condition, the fuel filter could result in excessive HC emissions due to misfire. Although unlikely, this has been observed in some surveillance and inspection/maintenance programs. Therefore, the failure mode for fuel filters is flow restriction leading to lean misfire.

3.3 IGNITION SYSTEM

Ignition component defects are generally related to increased HC emissions resulting from misfire (Ref. 12, 16, 33, 74, 78, and 100). In some cases (i.e., distributor advance mechanisms), the component performance may affect CO or NO_x because of changes in ignition timing (Ref. 17, 92, and 98). Specific individual components within each category do not have identical design or performance characteristics. However, the general component descriptions, functions and modes of failure are presented below for the following ignition system components:

- Points
- Condenser
- Distributor cap
- Distributor rotor
- Mechanical advance
- Vacuum advance
- Distributor drive
- Dual diaphragm distributors
- Spark delay valve
- Magnetic/Optical triggers
- Spark plugs
- Ignition wires
- Coils
- Capacitive discharge systems
- Ballast resistor
- Electronic ignition circuits
- Glow plug
- Ignition timing adjustment

These components are generally grouped into primary (low voltage) or secondary (high voltage) circuits. In general, secondary ignition components (spark plugs, wires, distributor cap and rotor) cause misfire in specific cylinders. Complete misfire on one plug may be due to a fouled plug or shorted ignition wire. Intermittent misfire, which is more likely, can occur under certain operating conditions depending on plug gap and condition, mixture richness, wire resistance, and engine speed. Intermittent misfire may not be noticeable by the driver but may cause increased HC emissions. The emissions increase depends on the number of cylinders, misfire frequency, engine speed, and whether air injection and catalytic emission control system are present.

Primary ignition components include points, condenser, advance mechanisms, coils, capacitive discharge systems, ballast resistors, and electronic ignition components. Primary ignition system defects may cause random intermittent misfire on all cylinders. However, in practice, misfire will characteristically appear on the cylinder with the weakest secondary ignition components. Misfire is caused by faulty coil, points, and electronic ignition components because insufficient voltage and current is supplied to the spark plug. High HC emissions can also be caused without actual misfire if the timing of spark plug firing is incorrect (Ref. 16, 17, 92, and 99). In these cases, the advance mechanisms, basic timing, or distributor cap/rotor may be faulty.

3.3.1 Points

The points constitute a switch which energizes the primary circuit of the coil. As the points make contact, current flows through the coil creating a magnetic field. As the points open, the current flow stops and the magnetic field collapses creating a high voltage surge in the secondary system. The points wear mechanically and may also erode electrically due to improper alignment, polarity, or condenser capacitance. As the gap between the points open, they may no longer make sufficient contact to adequately charge the coil. The low voltage may then cause intermittent misfiring of the spark plugs and increased HC emissions (Ref. 2 and 3).

3.3.2 Condenser/Capacitor

The condenser is a capacitor which prevents an electrical arc across the points as they open. The condenser absorbs the current flow until the points are fully open. Arcing of the points results in an electrical erosion or transfer of material from one point to the other. Condensers normally are very durable but are routinely replaced as a preventative step at each tune-up. They are emissions-related because of their effect on coil and point life Ref. 3).

3.3.3 Distributor

The ignition distributor controls the making and breaking of the primary ignition points and distributes the high voltage current to the proper spark plug at the correct time. Detailed construction of distributors varies considerably between manufacturers. Basically, however, each can be divided into the following categories:

- Cap
- Rotor
- Mechanical advance
- Vacuum advance
- Distributor drive
- Dual diaphragm distributor
- Spark delay valve.

3.3.3.1 Cap

The cap provides terminals for connecting the spark plug wires and the rotor contact. The terminals in the cap are subject to corrosion, wear, and electrical erosion due to arcing. This deterioration can reduce the peak voltage and duration of the secondary current. It is also possible for conductive trails to be formed between contact terminals of the cap resulting in crossfiring of the wrong spark plug. Either situation causes intermittent misfire, thereby, increasing HC emissions (Ref. 2 and 3).

3.3.3.2 Rotor

The rotor is a rotating conductor which distributes the high voltage current to the correct spark plug by contacting the corresponding terminal in the base of the cap. The contact terminal of the rotor is subject to wear and erosion as are the terminals of the cap. As the rotor wears, the resistance of the circuit increases which reduces peak voltage and firing time. These, in turn, may result in misfire and excessive HC emissions (Ref. 2 and 3).

3.3.3.3 Mechanical Advance Mechanism

The mechanical advance mechanism, also called centrifugal advance, regulates the time at which the points open and close relative to the position of the piston in the cylinder. The mechanical advance provides an earlier spark firing at high rpm because the time available to burn the charge is shorter at high speed than low speed. The advance mechanism consists of two weights held by springs which are thrown outward from the distributor shaft by the centrifugal force of the rotating distributor. The faster the distributor shaft rotates, the greater the movement of the advance weights. The movement of the weights rotates the breaker plate containing the points and changes the time at which the points make contact. The mechanical advance unit is very durable and generally does not need to be replaced or serviced over the life of the vehicle. However, modification of the advance mechanism is relatively easy and constitues the after-market failure mode. Changing springs can advance ignition timing and affect HC and NO_x emissions (Ref. 2 and 3).

3.3.3.4 Vacuum Advance Mechanism

The vacuum advance mechanism provides the same function for vacuum as mechanical advance does for engine speed. The intake manifold vacuum is transmitted to a diaphragm connected to the breaker plate. The diaphragm is spring-loaded and airtight on one side, and open to the vacuum line on the other. As vacuum increases, the diaphragm deflects and moves the breaker plate via connecting linkage (Ref. 3).

The ignition advance affects both HC and NO_x emissions (Ref. 16, 17, and 99). Because vacuum advance can be easily modulated by controlling the vacuum signal, vacuum control valves are an integral part of emission control systems. In general, vehicles manufactured after 1972 have used modulated vacuum advance as part of the NO_x control system. The systems and components which control vacuum are discussed in the section on emission control systems.

Vacuum advance systems fail more frequently than mechanical advance due to fatiguing of the diaphragm and subsquent failure to correctly adjust timing to vacuum changes (Ref. 78). Substitution of after-market vacuum advance mechanisms can alter ignition timing although the easiest method of advancing ignition timing is to advance basic timing or switch from a ported vacuum source to a manifold vacuum source.

3.3.3.5 Distributor Drive Mechanism

The distributor drive consists of the distributor shaft, cam, and breaker arm. The distributor shaft is connected directly to the engine and is driven at one-half of the engine rpm. The distributor shaft rotates the cam which has one lobe for each cylinder. The breaker arm is held against the cam by spring tension. As the cam rotates, the breaker arm rides in and out on the lobes. The point mounted on the breaker arm then makes and breaks contact with the stationary point (Ref. 3).

Mechanical wear of the distributor shaft, bearings, bushings, cam lobes, and breaker arm all cause deviation from specification of point opening and closing. The deviation may be consistently on one cylinder (defective cam lobe) or randomly on all cylinders (defective bearings). This deterioration can result in intermittent misfire and excessive HC emissions (Ref. 3).

3.3.3.6 Dual Diaphragm Distributor

Some vehicles are equipped with dual diaphragm distributors which are similar to standard distributors except that two vacuum advance diaphragms are provided. This distributor allows the spark timing to be retarded in a normal manner during starting. During acceleration and part throttle cruise, the spark timing is advanced in a normal manner. However, during idle and deceleration, the timing is retarded even more than would normally occur. This provides HC emission control during idle and deceleration by encouraging higher engine rpm and smaller quench volume in the cylinder at the time of spark firing. Failure of either diaphragm will effect emissions of HC and CO (Ref. 3 and 27).

3.3.3.7 Spark Delay Valve

The spark delay valve, used on some engines, aids in control of HC and NO_x emissions by delaying vacuum spark advance during light acceleration. Immediate spark retard is still permitted during deceleration. The valve controls vacuum by means of an integral sintered metal disk and check valve. The delay valve is connected in the vacuum line between the carburetor spark port and advance diaphragm of the distributor. Several different valves are used which provide slightly different delay times depending on engine application. Failure of the valve occurs when the check valve fails to seal. In these conditions, normal spark advance is provided which can increase HC and NO_x (Ref. 2, 3 and 27).

3.3.4 Magnetic or Optical Triggers

Electronic ignition systems use either magnetic proximity detectors or photodiodes to indicate the correct firing time of each spark plug. OEM systems generally use magnetic systems. Some after-market systems which directly replace the standard breaker points use optical detectors. The magnetic or optical triggers are rigidly mounted on a breaker plate connected to the vacuum advance unit. The distributor cam is replaced by either magnetic or opaque bars mounted on the distributor shaft. One bar is provided for each cylinder. As the distributor shaft rotates, the bars move past the magnetic pickup or block a light beam between a lamp and photodiode. The magnetic or optical pickup then generates a signal pulse which is sent to the electronic ignition control circuit (Ref. 3 and 46).

The alignment of the ignition triggers is critical in these systems, but there is little wear or deterioration. Problems can still develop in the distributor drive or vacuum advance mechanism, however, since they are identical to standard units.

Failures of the electronic triggers are unlikely and would probably disable the vehicle. It is possible, however, for deterioration in a detector to cause an intermittent misfire due to failure to detect one of the bars. This is analogous to a faulty distributor cam and results in increased HC emissions.

3.3.5 Spark Plugs

Spark plugs provide the gap in the cylinder across which the high tension voltage arcs. The resulting spark ionizes the charge between the electrodes of the spark plug igniting the combustion process. A variety of spark plugs are manufactured with varying electrical, thermal, and physical characteristics. Selection of the correct spark plug is important since accelerated fouling or deterioration of the plug can occur if it is not suited to the application.

Spark plugs significantly affect HC emissions due to intermittent or total misfire of the air-fuel mixture. Spark plug performance depends on gap width which is dependent on thermal and electrical erosion. Fouling which can be caused by carbon residue, lead residue, or oil also affects plug performance (Ref. 2, 3, 16, 42, 43 and 78).

Spark plugs are routinely replaced as a preventative measure every 12,000 miles or 12 months. Some manufacturers of 1975 and later model-year vehicles, however, now recommend longer replacement intervals because factors responsible for plug fouling, such as lead deposits, have been modified as part of catalyst and high voltage ignition system design.

3.3.6 Ignition Wires

Ignition wires conduct the current from the distributor cap to the spark plug. Ignition wires are subject to thermal and mechanical deterioration which either increase their internal resistance or decrease the effectiveness of their insulation. Both effects reduce the current and voltage available at the spark plug. The reduced voltage then causes reduced spark intensity and intermittent or total misfire. Misfire will usually occur under load when the high frequency of coil charging results in lower average available voltage to all spark plugs. Crossfire or firing of a cylinder at the wrong time, can also result if two wires cross and touch each other at a point where their insulation is defective (Ref. 3 and 78).

3.3.7 Coils

The coil is the OEM high voltage source on most vehicles. The coil is a pulse transformer designed to step up the primary (12V) voltage to the high (20,000V to 40,000V) voltage required to fire the spark plug. Failures of the coil result in low available voltage to the spark plug and may result in intermittent misfire particularly at high speed (Ref. 3, 35 and 78).

3.3.8 Capacitive Discharge Systems

A variety of capacitive discharge (CD) ignition systems are sold for after-market, high performance applications. The CD ignition provides high secondary voltage with very fast rise time. The spark gets to the plug faster, and although the voltage is higher, the spark duration is shorter which extends plug life. The higher voltage also is better able to fire fouled plugs than the standard ignition system (Ref. 3).

The CD system may utilize either electronic or breaker point timing. A transformer is used to step up the primary voltage to several hundred volts which is then discharged through a standard ignition coil using a capacitor switch. The higher primary voltage permits lower primary current flow which extends point life if points are used.

The coil is able to output a higher secondary voltage which is then distributed to the cylinders by a conventional distributor (Ref. 3).

3.3.9 Ballast Resistor

In most ignition systems, one and sometimes two resistors are used. In standard breaker point systems, the resistor is in series with the coil during normal operation. However, during cranking when the starter motor load reduces the available voltage, the resistor is bypassed. The resistor, therefore, simulates the starter motor load and ensures that the coil is exposed to consistent primary voltages. A defective resistor will disable the engine, either through an open circuit or by rapidly burning out the coil. A resistor with low resistance can also result in burned points (Ref. 2 and 3).

Electronic ignition systems usually use two resistors, one for the coil and a second one for the electronic switching circuits. The coil resistor maintains stable voltage at the coil and output of the power transistor. The starting resistor performs the same function described above for the ballast resistor in a standard ignition system (Ref. 3).

3.3.10 Electronic Ignition Circuits

The switching and amplifying circuits of electronic ignition systems take the low level signal from the magnetic or optical triggers and provide a 5 to 10V signal to the ignition coil. The electronic ignition circuits are generally reliable and not subject to deterioration unless other components in the electrical system become defective. The electronic circuits will disable the vehicle if they fail; therefore, these components are not emissions-related (Ref. 3).

3.3.11 Glow Plug

The glow plug, used in diesel engines, is a resistor coil which becomes hot enough to act as an ignition source for compression ignition engines. The glow plugs are turned on prior to starting a cold engine and allowed to heat the cylinders for several minutes. The engine can then be easily started. Without a glow plug, the engine might not start when cold. The glow plug, if defective, can result in excessive emissions of unburned fuel and smoke during cranking and warm up. However, the heavy-duty diesel test procedures are conducted with the engine fully warmed up so that the glow plug is not emissions-related in terms of exceeding emission standards (Ref. 2 and 3).

3.3.12 Ignition Timing Adjustment

Basic ignition timing controls the moment at which the spark plug fires. Timing is adjusted at a specified idle engine speed and is expressed in crankshaft degrees before or after top dead center in the number one cylinder. Timing affects performance, emissions, and fuel economy because different combustion conditions occur as timing changes. In general, advanced timing causes the spark to fire earlier in the compression stroke. This usually increases HC (larger quench surface), reduces CO (longer burning time), and increases NO_x (higher mixture temperature and pressure). Retarded timing generally causes the spark to fire during the power stroke at or after top dead center. This usually reduces HC (smaller quench surface), increases CO (shorter burning time), and decreases NO_x (lower mixture temperature and pressure). Exhaust treatment systems may modify the measured exhaust emissions by thermal or catalytic oxidation (Ref. 2, 3, 16, 17, 21, 60, 78, 92, 93, 95, 96, 97 and 98).

Timing adjustments must be made carefully to ensure that the intended setting is actually achieved. This includes disconnecting vacuum lines from the distributor, ensuring that idle speed and mixture adjustments are correct, measuring timing correctly, setting the timing to the correct specification, and locking the adjustment without altering it. The chance of incorrectly setting timing is, therefore, fairly high (Ref. 2, 3 and 27). Timing adjustment was not included in the after-market parts study since it is not a physical component.

3.4 AIR INDUCTION SYSTEM

The air induction system includes the air cleaner, air cleaner housing, manifolds, superchargers, turbochargers and associated hoses, ducts, pumps, and vacuum and electrical controls. The air induction system can have significant impact on the air-fuel ratio and, therefore, emissions of CO, smoke and, to a lesser degree, NO_x and HC.

3.4.1 Thermostatically Controlled Air Inlet

Thermostatically controlled air (TAC) inlets pre heat cold air to promote better fuel mixing and vaporization. The specific design varies according to manufacturer. However, each system uses some or all of the following components:

- Shroud and hose
- Thermostat

- Vacuum motor and hoses
- Fresh air inlet

Failure of the TAC shroud, hose, thermostat, vacuum motor or vacuum hoses will generally result in loss of heated air during warm-up. This will have the effect of reducing the vaporization of fuel and of increasing the mean air density during warm-up (Ref. 2). Both effects will tend to cause lean misfire and increased HC. The vacuum hose failure will also result in a vacuum leak which would be present at all operating conditions and would be expected to further increase HC emissions. The fresh air inlet on some vehicles extends the snorkel to the grill. This provides uniformly cool air in spite of overheating of the underhood air which could occur during prolonged idle. This maintains proper air-fuel ratios by controlling the air density (Ref. 3 and 27).

3.4.1.1 Shroud and Hose

Cold air is heated by passing it near the exhaust manifold. The shroud is a sheet metal enclosure which covers the exhaust manifold and directs air along it. The duct or hose connects the shroud to the air cleaner. The duct and shroud may become damaged due to maintenance on the vehicle which requires removal of the air cleaner. This will probably result in increased HC emissions during the cold start.

3.4.1.2 Thermostat

The thermostat is mounted in the air cleaner assembly and controls the opening and closing of a damper which is used to select either underhood air or preheated air from the shroud. The thermostat senses incoming air temperature and if it becomes too low, will direct preheated air into the carburetor. The thermostat may be directly linked to the hot air valve or it may be connected to a vacuum switch. Failure of the thermostat may occur in either position but is more likely to be stuck open since this is its usual position. This will prevent heated air from entering the carburetor and have the same effect as a damaged hose.

3.4.1.3 Vacuum Motor and Hoses

Some systems use vacuum motors to operate the hot air valve. The vacuum signal originates at the manifold and is transmitted to the vacuum motor by standard vacuum hoses. The hoses are subject to thermal and mechanical deterioration. The vacuum motor is a diaphragm which moves when vacuum is applied and is returned by a spring to its original position when vacuum is removed. The vacuum motor is subject to the same diaphragm failures as any other vacuum activated device. Failure of the vacuum motor or hoses would result in the engine always receiving cool air and would also introduce a manifold vacuum leak when the motor would normally be activated; i.e., during cold start.

3.4.1.4 Fresh Air Inlet

Beginning with some 1975 model-year vehicles, the fresh air inlet to the carburetor was moved from the carburetor air cleaner assembly to the radiator grill. A flexible, reinforced paper duct is used. This provides a ram jet effect to counteract the characteristic of carburetors to enrichen the mixture at high airflows. The air available at the radiator is also somewhat colder and, therefore, more dense than underhood air, particularly during low speed operation when air movement in the engine compartment is restricted. The fresh air inlet is subject to mechanical and thermal deterioration, especially when inspecting or servicing the carburetor. Failure of the inlet duct would result in hotter underhood air being drawn into the engine resulting in slight enrichment and increased CO emissions.

3.4.2 Air Cleaner Element

The air cleaner removes particulates in the incoming air and, in some applications, must also remove entrained oil droplets or exhaust particulates from the PCV system. The filter element eventually becomes clogged with material and does not allow sufficient air into the carburetor. This results in fuel enrichening and excessive CO and possibly HC emissions (Ref. 2, 3, 12, 16, 78 and 100).

3.4.3 Intake Manifolds

The OEM intake manifold generally is not replaced except for unusual cases of manufacturing defects or to install an after-market, specialty manifold. Intake manifolds connect the carburetor to the cylinders and provide the passages to introduce the air-fuel mixture into each cylinder. Some mixing of air and fuel occurs in the manifold although this is not subject to maintenance. Emission controlled vehicles have connections between the exhaust and intake manifolds. Specific emissions control components (i.e.; heat risers, cross-overs, EGR valves, and back-pressure sensors), are discussed below under emission control systems.

There is no specific emissions failure mode for a manifold (Ref. 2 and 3). However, replacement of an OEM manifold with after-market manifolds can result in emissions increases although data on non-catalyst-equipped vehicles suggest that some specific after-market manifolds do not increase emissions (Ref. 104). The differences in emissions effect depends on the engine, manifold, and carburetor combinations and the optimizing adjustments made.

3.4.4 Turbochargers

Turbochargers are turbine-driven blowers which pressurize the intake manifold in proportion to exhaust gas flow rate. This permits higher volumetric efficiency of the engine, particularly during acceleration. The turbocharger results in improved horsepower and may help to reduce emissions due to leaning out of the air-fuel ratio (Ref. 2 and 3).

Turbochargers are not generally used on OEM spark ignition engines but are available as retrofit kits for some after-market applications. Turbochargers are used on many OEM diesel engines for improved economy and power.

After-market turbochargers may improve or degrade emissions depending on the specific engine, carburetor, and turbocharger combination.

Failure of an installed turbocharger results in fuel enrichening due to reduced air intake which will cause increased smoke emissions from diesels or HC and CO emissions from gasoline engines (Ref. 2, 3, 37, 63 and 89).

3.4.5 Superchargers

Superchargers are belt-driven compressors which continuously pressurize the intake manifold. Superchargers are unusual for after-market installations because they represent a continuous load on the engine and do not provide significantly better performance than turbochargers (Ref. 2 and 3). Superchargers are available on some diesel engines. Supercharger kits are available for retrofit to spark ignition engines.

3.5 FUEL INJECTION SYSTEM

Some spark ignition and all compression ignition engines employ fuel injection systems which inject fuel into either the intake manifold or directly into the cylinder or its prechamber. Fuel injection systems provide more precise fuel metering than carburetors and, on diesels, are also needed to overcome the cylinder pressure occurring during the compression stroke when the fuel is injected (Ref. 2). After-market fuel injection components are distributed by the OEM suppliers.

Fuel injection systems must fulfill the following basic functions:

- Meter the correct quantity of fuel for the speed and load condition.
- Inject the fuel at the correct time.
- Inject the fuel at the correct rate.
- Atomize the fuel into fine droplets.
- Distribute the fuel in the cylinder.

The specific design employed to accomplish these functions depends on the particular engine. The injection system may be mechanically or electrically controlled. In general, mechanically controlled systems are used in diesel engines and electrically controlled systems are used in gasoline engines (Ref. 2 and 3).

3.5.1 Accumulator

The accumulator is used on the common rail type of fuel injection system. It provides a damping reservoir in a high pressure system and does not have a specific failure mode (Ref. 3). The accumulator is not used on systems with return lines to the fuel tank.

3.5.2 Fuel Pump (High Pressure)

Except for manifold injection of gasoline and the unit injector system for diesel engines, all fuel injection systems utilize high pressure fuel pumps in the supply line. Fuel pumps are driven directly by the engine using accessory shafts. The pumps are positive displacement using either a gear pump or plunger and barrel design. Some pumps incorporate speed governors and idle adjustments. Fuel pumps are generally very durable and do not require adjustment or maintenance within the 50,000-mile service life (Ref. 2 and 3).

3.5.3 Fuel Pressure Sensors/Regulators

Regulators are used to ensure that the pressure of the fuel is constant at the injection valves or injectors. The regulators bypass excess fuel back to the fuel tank or to the low pressure side of the fuel pump. Fuel regulators are usually mechanical, spring-loaded devices. Pressure sensors connected to electronically controlled injection systems are used on some gasoline injection systems. Failure of the pressure regulators will usually result in higher than normal fuel pressure which is analogous to high float level in a carburetor (Ref. 2 and 3).

3.5.4 Throttle Linkage and Valve

Throttling of diesel engines is performed by regulating the quantity of fuel injected. The gasoline engine, however, is throttled by regulating the quantity of fuel and air. The throttle linkage and valve is not emissions-related for gasoline engines. Throttling of the fuel injection system is controlled either at the high pressure pump or in the injector. The throttle linkage activates rotary valves which control the quantity of fuel admitted into the injectors. The valves are subject to wear which tends to increase the amount of fuel injected (Ref. 2 and 3).

3.5.5 Injection Valves

The injection valves consist of spring-loaded plungers which open when the fuel pressure exceeds the spring tension. The high pressure fuel then flows through the injector tips into the cylinder (Ref. 2 and 3).

The unit injector system uses a cam-actuated plunger and barrel assembly directly coupled to the injector tip. In this manner, all fuel supply lines are low pressure. Each cylinder has its own crank adjustment which throttles the fuel. This system is only used on direct cylinder diesel injection systems (Ref. 3).

Injection valves must be cleaned and adjusted periodically to ensure that they are metering the correct quantity of fuel. The injectors will tend to dribble fuel if foreign particles become lodged between the needle and seat. This results in excess HC, CO, and smoke emissions (Ref. 3 and 63).

3.5.6 Air Sensors/Switches

Air pressure (vacuum) or air flow rate sensors are used on some gasoline electronic injection systems to help control the correct air-fuel ratio. The sensors provide a signal which an electronic module uses to calculate the required quantity of fuel. The pressure sensors are reliable but are subject to diaphragm deterioration as in any vacuum sensing device. The air flow sensors may stick open indicating a high air flow rate incorrectly. Both defects will cause the EFI system to meter excessive fuel (Ref. 3, 27 and 58).

In addition to air flow sensors, exhaust oxygen sensors are also in use, or planned for use in conjunction with three-way catalyst systems. The O_2 sensors generally have life expectancy similar to spark plugs. Their failure should result in excess fuel metering, although most systems have limited the range of enrichment controlled by the O_2 sensor (Ref. 15 and 62).

3.5.7 Temperature Sensors/Switches

Sensors of air, water, or oil temperature are employed in gasoline injection systems to modulate the quantity of fuel injected. Some systems also employ temperature sensors to regulate air flow during cold starts or under idling conditions. Temperature sensors are generally reliable and free from wear or deterioration. Their failure, however, is analogous to a stuck choke and will cause high CO and possibly HC emissions (Ref. 3 and 58).

3.5.8 Fuel Distribution Manifold

Fuel distribution manifolds consist of the fuel distribution pipes connecting the fuel pump to the injectors. Fuel distribution manifolds may be either high or low pressure systems. Fuel distribution manifolds are not subject to wear or deterioration and are normally only replaced if physically damaged. Therefore, they are not considered in the OEM criticality analysis.

3.5.9 Injectors (Solenoid)

Electronic manifold fuel injection systems use solenoid-activated injectors. The solenoid is energized by an electronic distributor which provides the correct timing of the fuel flow. The injector is closed by a return spring when the solenoid is deactivated. The injector contains a calibrated orifice and needle valve which must be adjusted for precise fuel metering. The injectors are subject to the same problems as described in paragraph 3.5.5 for mechanically operated, direct cylinder injectors. The characteristic mode of failure is sticking which will inject excess fuel to one or more cylinders (Ref. 2, 3, 27 and 58).

3.5.10 Triggering Switches

Electronic fuel injection systems are operated by distributor contacts which control the timing and sometimes the duration of the opening of the injector valves. These contacts are similar to point contacts and are timed to coincide with intake valve opening. Trigger contacts are normally not adjustable; therefore, little maintenance is required. If the distributor shaft wears, however, the timing of the injection can become erratic which would increase emissions of HC and CO (Ref 3, 27 and 58).

3.5.11 Electronic Fuel Injection Control Circuits

Electronic fuel injection systems use electronic control circuits to modulate the frequency and duration of injector valve opening. The circuits utilize engine rpm, manifold vacuum, and air temperature to calculate the actual airflow, and corresponding fuel flow required to maintain the desired air-fuel ratio. These circuits are highly reliable and if they fail, will disable the vehicle. They are, therefore, excluded from the criticality analysis (Ref. 2, 3 and 58).

3.5.12 Starting Valve

Both mechanical and electronic fuel injection systems employ starting valves. These valves provide additional fuel during cold starts and warm up. Mechanically-operated valves provide additional flow through the cylinder injection valves. Electrically-operated injectors in gasoline fuel injection systems provide additional fuel in the intake manifold. Failure of these valves will result in excessive CO and HC emissions if they continue to provide starting mixture enrichment after the engine is warmed up (Ref. 3).

3.6 ENGINE SYSTEMS

The mechanical components of the engine can also affect emissions, particularly as a result of wear and deterioration leading to misalignment. The engine system components which are emissions-related include the following:

- Exhaust valves and valve components such as lifters, cams, guides, and seals.
- Piston rings.
- Piston including piston, rod, head, and cylinder wall.
- Head gaskets.
- Camshafts.

After-market components, with the exception of cams, lifters and springs, are designed and sold as OEM equivalent parts. They are, therefore, expected to suffer similar rates of deterioration and wear as the OEM components. The other components, however, can involve performance-oriented nonstandard OEM replacement parts which can affect emissions from the time of installation.

3.6.1 Exhaust Valve Components

The exhaust valves seal the combustion chamber to prevent escape of hot combustion products until after the expansion stroke of the piston. The exhaust valves can become burned, misaligned, worn, or stuck, in which case unburned combustion products would be released. The components which affect the closing and sealing of the exhaust valves are discussed below.

3.6.1.1 Lifters and Springs

The valves are opened by push rods and lifters, and closed by springs. Changes in the physical dimensions or mechanical properties of either lifters or springs will result in changes in valve timing. Valve timing has a strong relationship to performance and emissions because the valves may open or close at the wrong time (Ref. 3).

The valve lifter transmits the action of the cam to the valve. Lifters may be directly connected to the valve stem or may act on push rods which, in turn, act to open the valve. The lifters may be either simple mechanical rods or the more complex hydraulic lifters. Mechanical lifters must be adjusted so that the correct gap (lash) in a cold engine exists between the valve stem and valve lifter. The gap allows for thermal expansion of the valve. Hydraulic lifters are used on most engines to avoid valve lash adjustments and to provide quieter lifter operation (Ref. 3).

3.6.1.2 Cams and Camshafts

The cam lifts the valve at the correct time to obtain the most efficient filling and emptying of the cylinder. The operation of the valves is controlled by precision-machined cams. The cams are hardened to minimize wear.

However, over a long period of operation, or in the case of improper operation or fabrication, the shape of the cam will change. Wear usually occurs on the highest point of the cam decreasing the lift of the valve. This results in a smaller opening and reduced breathing of the engine. This does not significantly effect emissions, but does reduce engine power. Wear can also occur on the sides of the cam, particularly with strong springs or hydraulic lifters. In this case, the valve timing will change which can affect emissions (Ref. 3).

Installation of after-market camshafts or grinding of OEM cams which modifies the timing or degree of valve opening can affect emissions.

3.6.1.3 Guides

Valve guides are pressed into the head of the block and serve to correctly align the valve with its seat in the cylinder. Similar guides are provided for push rods if they are used. The guides are lubricated by oil running down the valve stem. As the guides and valve stem wear, more oil can flow down the stem and into the manifold or into the cylinder. This can increase smoke and HC/CO emissions (Ref. 3).

3.6.1.4 Seals

Seals are installed to prevent leakage of lubricating oil past the valve guides and into the manifold or cylinder. The seals are subject to wear and deterioration and will cause increased CO and smoke emissions if defective due to incomplete combustion of the heavy lubricating oil (Ref. 3).

3.6.1.5 Valves

The valves and seats in the cylinder must make a tight seal at the correct time to ensure that the combustion processes in the cylinder can be utilized efficiently without excessive emissions. Intake valves are not subject to the wear and deterioration typical of exhaust valves because they operate at low temperatures. Exhaust valves, however, are subject to high temperature, vibration, and impact stress. Valve leaks can be caused by improper alignment of the valve train, by erosion or wear of the valve and seat, or by deposits which prevent a positive seal. Under these conditions, exhaust gases will escape from the cylinder before combustion is complete causing generally higher HC, CO, and smoke, but lower NO_x emissions (Ref. 3).

3.6.2 Piston Rings

Piston rings consist of oil control rings and compression rings. The oil control ring is the lowest on the piston and is designed to minimize movement of oil from the crankcase into the cylinder where it would burn, resulting in excessive CO, HC, and smoke emissions. The compression rings (two or more) are located near the top of the piston and are designed to seal the combustion gases in the cylinder. Leakage past the compression rings is called blowby which occurs during the compression stroke and initial phase of the expansion stroke. Blowby is captured by the PCV system and returned to the intake manifold for subsequent combustion. Excessive blowby has the effect of enrichening the mixture particularly at idle and, therefore, increasing CO emissions (Ref. 2 and 3).

3.6.3 Pistons

The piston is related to emissions because the design of the piston surface is peculiar to the specific engine design. Some pistons are manufactured with special depressions to permit localization of the flame front. The surface is subject to pitting or deposits which affect the ignition and quenching properties of the combustion chamber. As OEM parts, the pistons are not significantly related to emissions because the rate of wear and deposition is so small during the design life (Ref. 3). As after-market components, however, there is a possibility of changing cylinder geometry by using nonstandard replacement pistons. This may affect HC and NO_x emissions due to changes in compression ratio and surface to volume ratios (Ref. 2).

3.6.4 Gaskets

Gaskets are used to provide positive seals between the sections of the engine. Defective engine gaskets create water or oil leaks inside the engine block which affect the combustion process (Ref. 3). Gaskets should not fail during the certification period unless the engine has been improperly fabricated or operated.

3.6.5 Exhaust Manifolds and Headers

OEM equivalent replacement exhaust manifolds and specialty headers are available from after-market sources. Replacement manifolds should have small affect on emissions. Specialty manifolds or headers, however, may affect emissions because of changes they create in mixture distribution pumping efficiency and interconnection with various OEM emissions control components and systems. Since emission changes may be different, separate component categories have been established for replacement exhaust manifold and headers.

3.7 EMISSION CONTROL SYSTEMS

A large number of systems and components have been developed by or for engine and vehicle manufacturers specifically to control emissions. Defects in these systems will usually result in increased emissions of at least one pollutant. Some systems are used on most engines and may be available in the after-market. Others maybe used on only a few engines or by a single manufacturer and are probably not available in the after-market. In general, emission control components available in the after-market are produced by the same companies which manufacturered the equivalent OEM component.

The following emission control systems and their components are discussed in this section:

- Crankcase ventilation (PCV)
- Evaporative emissions (EVAP)
- Air injection (AIR)
- Exhaust gas recirculation (EGR)
- Transmission-controlled spark (TCS)
- Speed-controlled spark (SCS)
- Orifice spark advance control (OSAC)
- Electronic spark control (ESC)
- Catalytic reactor (CAT)

Most of the above systems use the same or similar components. They are discussed individually, however, since their effect on emissions may depend on their application. Several individual components have been developed and are discussed separately under Miscellaneous Emissions-Related Parts:

- Heat riser
- Electric assist choke
- Staged choke pulldown
- Decel valve
- Distributor vacuum deceleration valve
- Thermal vacuum valves
- Distributor starting solenoid

3.7.1 Positive Crankcase Ventilation (PCV) Systems

The first emission control system used on vehicles was the positive crankcase ventilation system. The PCV system provides a controlled flow of fresh air through the engine crankcase. The closed type of PCV system, used on 1968 and later vehicles, prevents escape of blowby gases into the atmosphere. Individual system designs vary by manufacturer but generally include the following components:

- PCV valve
- PCV hoses
- PCV fresh air filter
- PCV oil separator

After-market PCV valves are available from a number of mass merchandisers under private or brand labels. These valves are sold as OEM replacement parts for specific engines. Other PCV system components are also available.

3.7.1.1 PCV Valve

The purpose of the PCV valve is to reduce the flow through the system during idle and deceleration when manifold vacuum is high. Without the PCV valve, the flow through the PCV system would be very high due to the vacuum. At the same time, the carburetor airflow is low. The extra airflow through the PCV system would cause lean misfire and possibly stalling of the engine (Ref. 3).

The PCV valve is a spring-loaded plunger which is open at low vacuum; i.e., open throttle. This enables relatively high flow rate through the valve during times of high speed operation. Under high vacuum, the valve is closed against the spring leaving small orifices for the gases to flow through. This maintains PCV flow in proportion to the low carburetor airflow in spite of the high manifold vacuum.

Flow through the PCV valve can be restricted by clogging from particles and oil droplets drawn out of the engine crankcase. This results in some fuel enrichment and increased HC and CO emissions because less air is drawn into the engine and can result in backflowing of crankcase gases, under pressure, to the air cleaner (Ref. 3 and 27). This can also result in flow restriction of the air cleaner.

3.7.1.2 PCV Hoses

The PCV valve is connected to the manifold vacuum port by reinforced rubber vacuum hoses. Similar hoses connect the air cleaner to the crankcase air inlet which may be in the oil filler cap or the valve covers. The PCV system may also be interconnected with the EGR or EVAP systems (Ref. 3).

Breaks or loose connections in the PCV hoses can result in loss of blowby fumes, primarily unburned fuel, into the atmosphere. They may also create a manifold vacuum leak if the break occurs in the hose connecting the manifold to the PCV valve.

3.7.1.3 PCV Fresh Air Filter

An auxiliary filter is usually supplied to filter airborne particulates from the crankcase ventilation air.

Clogging of the filter will reduce ventilation flow. If oil is clogging the filter, it may indicate that the PCV valve is also clogged. Reduced flow through the filter will result in enrichening of the air-fuel ratio and higher CO emissions (Ref. 3).

3.7.1.4 PCV Oil Separator

An oil separator is supplied with some engines to help remove entrained oil droplets from the crankcase vapors. However, most of these are integral parts of the engine block or valve covers and cannot be serviced. Failure of an oil separator results in more oil passing through the PCV system which encourages early failures due to clogging (Ref. 3).

3.7.2 Evaporative Emission Control (EVAP) System

Evaporative emission control systems prevent escape of gasoline vapors from the fuel tank and carburetor. All manufacturers use similar systems, although the specific components and flowpaths may differ. The EVAP system generally consists of the following components:

- Activated carbon canister
- Vacuum, vapor, and gasoline hoses and lines
- Fresh air filter
- Vapor-liquid separator
- Vapor control valves

EVAP system components are available to a limited degree through the after-market.

3.7.2.1 Activated Carbon Canister

Most systems employ an activated carbon canister to store the fuel vapors. During engine shutdown, the fuel vapors are routed to the activated carbon canister by the slight pressure of the expanding vapors. The activated carbon in the canister absorbs and holds the vapors allowing vapor-free air to escape to the atmosphere. When the engine is started, manifold vacuum draws the absorbed vapors into the engine. The carbon canister is very durable even if occasionally saturated. Failure of the canister causes excessive evaporative HC emissions (Ref. 3 and 27).

3.7.2.2 EVAP Hoses and Lines

The EVAP system involves several vapor, vacuum, and liquid lines and their associated connectors and fittings. A break in any line will release fuel vapor to the atmosphere. In addition, a break in the vacuum line between the carburetor and canister may cause lean misfire due to the vacuum leak.

3.7.2.3 EVAP Fresh Air Filter

The canister incorporates a filter for removal of large particulates and droplets from the purge air. This prevents clogging of the carbon which could reduce its efficiency for storage and purging. A restricted EVAP system filter may increase evaporative HC emissions because the canister is not effectively purged between soaks (Ref. 3 and 27).

3.7.2.4 EVAP Vapor Liquid Separator

The liquid fuel is separated from the fuel vapor in or immediately adjacent to the fuel tank by a separator which directs the fuel vapors to the canister. The separator is usually of a simple standpipe design and, therefore, is durable and reliable. To prevent overfilling of the fuel tank and, consequently, flooding of the separator, an expansion void is frequently incorporated in the fuel tank (Ref. 27).

3.7.2.5 EVAP Vapor Control Valves

Several vapor control valves may be used in the EVAP system. These include check valves and vacuum valves which regulate the direction and flow rate of fuel vapors into and out of the canister. These valves are frequently an integral part of the activated carbon canister or fuel tank. However, where the valve is a separate replaceable component, it is included in this category. The vacuum valves control the purge air flow rate in the same manner as the PCV valve regulates crankcase ventilation air. At idle, low flow is allowed through small orifices. However, at higher speeds when higher flows from the EVAP system can be tolerated, the purge valve opens under spring action allowing flow through larger orifices (Ref. 27).

3.7.2.6 Fuel Tank

The fuel tanks are integral parts of the EVAP system and may include vapor separators, fuel return lines, and expansion chambers. The fuel tanks also incorporate a sealed gas cap which permits make-up air to enter the tank but prevents fuel vapors from escaping except to release dangerously high pressure. Failure of the gas cap will release fuel vapors to the atmosphere (Ref. 3 and 27).

Add-on after-market fuel tanks which are not adequately vented through the EVAP system may result in increased evaporative emissions.

3.7.3 Air Injection (AI) System

Air injection systems have been used for emissions control since 1966 with only slight modification. Air injection systems use auxiliary air injection adjacent to the exhaust valves to oxidize HC and CO emissions leaving the cylinder. Air injection systems are effective in reducing emissions because of incomplete combustion in the quench zones, scavenging of unburned carbureted mixture during intake and exhaust valve overlap, and excess emissions due to carburetor or ignition system defects. Some catalyst-equipped vehicles utilize air injection at the catalyst rather than in the exhaust manifold. The details of the systems vary somewhat, although similar components are generally used. Most air injection system components are available from after-market distributors.

Air injection systems consist of the following components:

- Distribution manifold and nozzles
- Hoses
- Inlet air filter
- Check valves
- Bypass or diverter valves
- Gulp valves
- Pump, belt, and seals

3.7.3.1 Manifold and Nozzles

The manifold and nozzles are fabricated in or on the engine. They should be good for the life of the engine since there is no significant emissions failure mode (Ref. 3). They are not generally available in the after-market.

3.7.3.2 Hoses

Reinforced vacuum hoses are used to connect the air injection pump to the air distribution manifold. The hoses are subject to thermal and mechanical deterioration. However, unless completely broken, there should not be a significant reduction in air delivery (Ref. 3 and 27).

3.7.3.3 Inlet Filter

A particulate filter is installed in the intake to the pump. This filter prevents the introduction of coarse particulates into the pump which could damage the pump and clog air control valves or injector tips. The air filter is usually integral to the pump and is designed to last the life of the pump under normal use (Ref. 3). They are not generally available in the after-market.

3.7.3.4 Check Valves

All AI systems employ check valves to prevent backflow of hot exhaust gases in the event of high pressure in the exhaust manifold or failure of the air pump or hoses. The check valves are generally good for the life of the engine and help prevent damage to the pump or hoses if backfiring or detonation occurs in the manifold (Ref. 3).

3.7.3.5 Bypass or Diverter Valves

Several different types of bypass or diverter valves are used to prevent backfiring, and in catalyst-equipped vehicles, excessive temperature due to certain engine operating conditions. The bypass or diverter valves dump air into the atmosphere during deceleration (high vacuum) and high speed (high air supply pressure). The valves are generally operated by manifold vacuum. Catalyst-equipped vehicles may also have thermally controlled switches which activate the diverter valve to prevent high temperatures in the catalyst during deceleration, cold start, or engine malfunction. The diverter valve is subject to diaphragm deterioration which can prevent the valves from operating during deceleration (Ref. 3 and 27).

3.7.3.6 Gulp Valves

Gulp valves were incorporated on early air injection systems but generally have been eliminated in favor of the diverter or bypass values presently used. Some foreign manufacturers use a form of gulp valve for control of deceleration hydrocarbon emissions. These valves admit additional air to the carburetor or intake manifold to prevent excessive fuel enrichment during deceleration. Gulp and mixture control valves are used to regulate airflow into the intake manifold. Throttle-poppet valves regulate airflow past the throttle. All three valve types are spring-controlled vacuum valves which open under conditions of high manifold vacuum. Failure of the valve will result in mixture enrichment during decelerations and higher HC and CO emissions (Ref. 3 and 27).

3.7.3.7 Pump and Belts

The air injection pump and associated belts, pulleys, and seals provide the air supply for the AI system. The pump is highly reliable and should operate well beyond the certification period. However, improper belt tension adjustment can cause slippage or excessive wear of the belt. Excessive tension can also cause accelerated wear of the pump pulley bearings. Pumps are generally not serviceable and are replaced when defective. If defective, the AI system will be disabled causing higher HC and CO emissions (Ref. 3 and 27). Air injection pumps are available through the after-market from companies which manufacture the OEM pumps and from rebuilders who refurbish used pumps.

3.7.4 Exhaust Gas Recirculation (EGR) Systems

Control of NO_x emissions is partly accomplished by EGR, in which a portion of the inert exhaust gases are metered back into the intake manifold. The exhaust gases reduce combustion temperatures and prevent formation of NO_x. Two EGR concepts have been employed: passive bleed jets between the exhaust and intake manifolds; and actively modulated EGR valves modulated by temperature, vacuum and/or exhaust pressure. As emission standards have become more stringent, the complexity of EGR systems have increased. EGR systems can be composed of the following components:

- EGR valves or orifices
- Hoses
- Temperature-controlled vacuum valves
- Solenoid-controlled vacuum valves
- Temperature switches
- Speed/transmission switches
- Time delays
- Vacuum amplifiers
- Vacuum-reducing valves
- Carburetor spacers
- Back pressure sensors
- Check valves

3.7.4.1 EGR Valves or Orifice

The fixed orifice or floor jet type EGR valve was used only in a few engine families. Therefore, these systems will not be discussed other than to say that plugging of the orifices was common. The vacuum-modulated EGR valve, now used exclusively, consists of a vacuum, diaphragm-operated valve. Vacuum signals, modulated by load and sometimes thermal conditions, are used to open the valve in proportion to throttle opening. The valve is closed by return springs. The EGR valve is subject to thermal and mechanical deterioration and clogging by particulates, condensed water, and oil in the exhaust gases. Failure of the EGR valve increases NO_x significantly (Ref. 2, 3, 27 and 86). Some EGR valves are available in the after-market; however, others are available only through OEM parts distribution channels.

3.7.4.2 EGR Hoses

Hoses or tubes carrying the exhaust gases are generally metalic to resist the high exhaust gas temperature. EGR vacuum control lines, however, are standard vacuum hoses. Failure of vacuum hoses or fittings can result in a vacuum leak as well as disabling the EGR system. This will increase both HC and NO_x emissions (Ref. 3 and 27).

3.7.4.3 EGR Temperature-Controlled Vacuum Valves

Thermal vacuum valves (discussed in paragraph 3.7.9.7) are used in some applications to modulate EGR during cold temperature operation. This promotes more rapid warm up for control of cold start HC and CO emissions. Failure of the valve to open would increase NO_x substantially. Failure of the valve to close would slightly increase HC and CO during warm up (Ref. 3 and 27). The characteristic failure mode will be failure to open since it has the most significant emissions failure.

3.7.4.4 EGR Solenoid-Controlled Vacuum Valves

Some systems are modulated by electrically-operated solenoid valves which may be interconnected with TCS, SCS, or thermal vacuum switch systems. The solenoid vacuum valves are generally more reliable than vacuum-operated valves. The characteristic failure will prevent opening of the valve which prevents any EGR (Ref. 3 and 27).

3.7.4.5 EGR Temperature Switches

Temperature switches are used in conjunction with solenoid-controlled vacuum valves to regulate EGR during cold temperature operation. They are analogous to thermal vacuum valves. Their failure will prevent any EGR (Ref. 3 and 27).

3.7.4.6 EGR Speed/Transmission Switches

Some systems modulate EGR in conjunction with transmission gear position or speed. These systems are often interconnected with timing retard systems. Their failure will prevent EGR at any speed (Ref. 3 and 27).

3.7.4.7 EGR Time Delays

Some applications use electrical delays to prevent EGR immediately following start-up to ensure stable idling These systems employ electrical timers which activate a vacuum solenoid valve to prevent EGR even though the coolant temperature is high enough to permit EGR. Failure of the time delay mechanism may prevent any EGR (Ref. 3 and 27). Since this is a more severe failure condition than providing EGR at all times, it has been selected as the mode of failure for this study.

3.7.4.8 EGR Vacuum Amplifiers

Some systems employ a ported vacuum signal to control EGR in proportion to the throttle opening. The ported vacuum signal, however, may not be strong enough to actuate the EGR valve. Therefore, manifold vacuum is used to operate the valve and is modulated by the ported vacuum in a manner similar to electric relays. A defective EGR vacuum amplifier will create a large intake manifold vacuum leak. This can affect performance and increase both HC (misfire) and NO_x (no EGR) (Ref. 2, 3 and 27).

3.7.4.9 EGR Vacuum-Reducing Valves

Some applications use a vacuum-reducing valve to reduce the manifold vacuum under certain conditions. This valve consists of, or is used in conjunction with, a solenoid or thermal vacuum valve which opens an air bleed to release or reduce the vacuum signal. Vacuum-reducing valves are used to modulate EGR under certain throttle or temperature conditions (Ref. 3 and 27).

3.7.4.10 EGR Carburetor Spacers

The carburetor spacer contains passages for introducing the recirculated exhaust gases into the carbureted mixture. The spacer does not usually deteriorate significantly, however, the passages can become clogged with exhaust gas particles or corrosion. The failure of the spacer would increase NO_x because EGR flow would be reduced (Ref. 3 and 27). These components are not generally available in the after-market since they are specific to particular engines.

3.7.4.11 EGR Back Pressure Sensors

Some California-configuration vehicles employ a back pressure sensor to more accurately proportion the EGR to load and throttle opening. The back pressure sensor responds to pressure in the exhaust manifold which increases with throttle opening. The pressure moves a diaphragm against a spring to close an air bleed in the vacuum line of the EGR valve. This increases the vacuum signal and results in higher EGR. This valve can become clogged resulting in reduced EGR at all times and, consequently, higher NO_x (Ref. 3 and 27). These components are specific to particular engines and are not available in the after-market.

3.7.4.12 EGR Check Valves

Some applications use a check valve to hold the highest ported vacuum obtained during acceleration to ensure high EGR and reduced NO_x. Their failure will result in normal vacuum variations and a slight reduction in EGR (Ref 3 and 27). These valves are similar to other vacuum check valves and are available in the after-market.

3.7.5 <u>Transmission-Controlled Spark (TCS)</u>

Most manufacturers use transmission-controlled spark systems to reduce timing advance during certain operating conditions. Acceleration and heavy load operation are typically performed in low gears. Therefore, TCS systems are designed to provide retarded timing except in the highest gear. Both manual and automatic transmissions may use speed sensors instead of transmission gear sensors, in which case the systems are referred to as SCS Systems. TCS systems incorporate numerous protective and override systems and are frequently interconnected with EGR systems.

TCS systems consist of the various combinations of the following components:

- Solenoid vacuum valve
- Vacuum lines and hoses
- Time delay control
- CEC solenoids
- Thermal vacuum valves
- Speed or transmission switches
- Reversing relays
- Temperature-controlled switches

3.7.5.1 TCS Solenoid Vacuum Valve

An electrically-operated solenoid valve controls the amount of vacuum provided to the distributor vacuum advance diaphragm. In some configurations, the valve selects either ported or manifold vacuum sources. In others, it provides full manifold vacuum or vents vacuum to the atmosphere which provides no vacuum advance at all. Depending on the configuration, the valve could fail providing either no or full advance at all times. For NO_x, full advance at all times is the most critical failure mode (Ref. 3 and 27). These solenoid valves are available in the after-market.

3.7.5.2 TCS Vacuum Lines and Hoses

The distributor advance unit is connected to the manifold vacuum by a complex routing of vacuum lines. Any leak in the lines will result in reduced vacuum advance which will reduce NO_x and may create vacuum leaks resulting in higher HC emissions due to lean misfire (Ref. 3 and 27).

3.7.5.3 TCS Time Delay Controls

Some systems incorporate time delays to permit stable idling before the TCS system is activated. They operate in the same manner described above for EGR time delay controls and will prevent TCS operation if defective (Ref. 3 and 27).

3.7.5.4 TCS CEC Solenoids

Some vehicles use a CEC solenoid in the TCS system. The CEC solenoid incorporates the functions of a throttle positioner and a vacuum solenoid. The CEC solenoid simultaneously regulates distributor vacuum advance and throttle closure. The CEC plunger must be properly adjusted to correctly regulate deceleration from high speed to prevent excess HC emissions. Once adjusted, however, the valve and plunger should not require service during the certification period. Failure of the CEC solenoid will result in no deceleration throttle control and no vacuum advance. This will cause reduced NO_x but higher HC and CO (Ref. 3 and 27).

3.7.5.5 TCS Thermal Vacuum Valves

The TCS system may be modulated by several thermal vacuum valves (discussed in paragraph 3.7.9.7) which sense coolant temperature. The vacuum valves are usually used to disable TCS vacuum retard when the coolant temperature is less than or greater than specified limits (Ref. 3 and 27). If they fail, they will most likely fail in the normal operating position providing normal vacuum advance at all times.

3.7.5.6 TCS Speed or Transmission Switches

The TCS solenoid vacuum valve is actuated by a transmission switch which senses road speed or gear selection. It is identical in nature and operation to the EGR speed/ transmission switch described above (Ref. 3 and 27).

3.7.5.7 TCS Reversing Relays

A relay is provided in a few applications which defeats the vacuum retard function of the TCS system. One configuration employs a latching relay which prevents TCS as long as carburetor inlet air temperature is low. Once the air temperature becomes higher, the TCS function is restored. This system could prevent any vacuum retard, if defective, resulting in increased NO_x emissions (Ref. 3 and 27).

3.7.5.8 TCS Temperature-Controlled Switches

In some applications, the temperature override function of the thermal vacuum valve is performed by an electrical switch wired in series between the speed switch and solenoid vacuum valve. This switch functions in the same manner as described for EGR temperature-controlled switches (Ref. 3 and 27).

3.7.6 Orifice Spark Advance Control (OSAC)

The orifice spark control system is a method of modulating vacuum advance used by one manufacturer. Replacement parts are not generally available outside of authorized OEM distributors. The system is used in conjunction with EGR or TCS for control of NO_x. The system incorporates override systems during certain engine operating conditions.

The OSAC system incorporates the following components:

- OSAC orifice valves
- OSAC vacuum hoses
- OSAC vacuum control valves
- OSAC temperature sensors

3.7.6.1 OSAC Orifice Valves

The OSAC orifice valve is similar in function to the spark delay valve. The valve delays increase of ported vacuum to the distributor vacuum advance unit as the throttle is opened. During throttle closure, the reduction of ported vacuum is instantaneous. This effectively retards timing during loaded accelerations. The OSAC valve consists of an integral orifice and check valve which restricts flow in one direction but not the other. The OSAC valve is typically located on the air cleaner housing where it senses air temperature in the air cleaner. Failure of the valve enables normal vacuum signals to reach the distributor and increase NO_x (Ref. 3 and 27).

3.7.6.2 OSAC Vacuum Hoses

Vacuum hoses are routed between the OSAC valve, the distributor vacuum advance unit and the thermal control valves. The hoses must be leak tight to ensure correct operation of the OSAC system. Vacuum hose failure between the OSAC valve and thermal vacuum valve will result in no vacuum advance unless overheating occurs; then full vacuum advance. Vacuum hose failure between the manifold vacuum source and distributor vacuum advance unit may result in no vacuum advance and/or intake manifold vacuum leak depending on temperature. Emissions of NO_x and possibly HC will increase (Ref. 3).

3.7.6.3 OSAC Vacuum Control Valves

The OSAC vacuum control valve is a thermal vacuum valve (discussed in paragraph 3.7.9.7), which is used to apply full manifold vacuum to the distributor advance unit if the engine overheats. The higher manifold vacuum causes higher engine rpm and improved cooling. The valve is located in the cooling jacket or the radiator, depending on application. Failure of the valve provides either delayed ported or full vacuum advance at all times (Ref. 3 and 27).

3.7.6.4 OSAC Temperature Sensors

Some OSAC systems were modulated by air temperature using a temperature sensor integral to the OSAC orifice valve body. This sensor defeats the OSAC valve during cold ambient temperatures to improve driveability. The temperature sensor bypasses the ported vacuum around the orifice in the OSAC valve (Ref. 3 and 27).

3.7.7 Electronic Spark Control (ESC) System

The electronic spark control system was used in some applications to modulate vacuum advance during various operating conditions. The system regulated vacuum advance using electrical sensors and solenoids rather than thermal vacuum valves. The ESC system is not related to electronic ignition systems. The ESC system is composed of the following components:

- Electronic modules
- Vacuum hoses/wires
- Solenoid vacuum valves
- Temperature-sensing switches
- Speed-sensing switches

3.7.7.1 ESC Electronic Modules

The distributor vacuum is modulated by a solenoid which is controlled by the electronic module. The electronic module compares ambient temperature and vehicle speed to specified values. Above 65°F, the module will disable the vacuum advance at low speed and enable it at high speed (23 to 35 mph depending on application). Below 49°F, the module will enable vacuum advance at all speeds. The module consists of solid-state circuits and is highly reliable. Failure of the module will result in normal vacuum advance at all times (Ref. 3 and 27).

3.7.7.2 ESC Hoses/Wires

The solenoid vacuum valve is placed between the manifold vacuum source and distributor advance unit. Failure of the hoses will result in loss of advance to the distributor and may create a vacuum leak causing high HC (Ref. 27).

3.7.7.3 ESC Solenoid Vacuum Valves

The ESC solenoid vacuum valve, also called a distributor modulator valve (DMV), controls the vacuum to the distributor. Failure of the solenoid will result in normal vacuum advance at all times and higher NO_x emissions (Ref. 27).

3.7.7.4 ESC Temperature Sensing Switches

The ambient air switch overrides the speed modulation of the distributor. Failure of the switch disables the ESC system resulting in normal vacuum advance (Ref. 27).

3.7.7.5 ESC Speed-Sensing Switches

The speed sensor is driven by the speedometer cable. It is a DC tachometer generator and is highly reliable. Failure of the sensor would result in no vacuum advance at anytime. This reduces NO_x but also can increase emissions HC and CO slightly (Ref. 27).

3.7.8 Catalytic Reactor

Most 1975 and 1976 model-year vehicles are equipped with oxidation catalysts for control of HC and CO emissions. Catalysts also permit some reduction of NO_x emissions as a consequence of richer carburetor adjustments. Catalysts are not now available as after-market parts, although it is conceivable that in the future they may become available.

Several dual catalyst and three-way catalyst systems are under active development and pre-certification testing. These catalyst systems have not been included in this study. They are expected to have similar relationships to emissions as conventional oxidation catalysts.

3.7.9 Miscellaneous Emissions-Related Parts

Several components are not specifically included in any emissions control system. These parts include:

- Heat riser
- Electric assist choke
- Staged choke pulldown
- Decel valve
- Distributor vacuum deceleration valve
- Distributor starting solenoid
- Thermal vacuum valve
- Distributor vacuum valve

3.7.9.1 Heat Riser

The heat riser, also called manifold heat control has been employed on most engines for many years to improve cold start performance and emissions and to reduce warm-up time. The heat riser is a thermostatically-controlled valve which directs exhaust gases against the intake manifold when the engine is cold. When the engine is hot, the valve closes to direct the exhaust gases into the exhaust pipe. The heat riser can stick, typically closed, so that warm-up is delayed causing increased HC and CO emissions. Some engines use vacuum-operated valves (Early Fuel Evaporation, Exhaust Heat Control) modulated by thermal vacuum switches to activate the heat riser (Ref. 2, 3, 48 and 78). Heat risers are available through after-market sources.

3.7.9.2 Electric Assist Choke

Some engines use electric resistance heaters to cause more rapid choke opening. The choke thermostat operates normally. At low ambient temperatures, the heater is deactivated by a bimetal thermostat. At higher ambient temperatures ($60^{o}F$), the heater is activated providing additional heat to the choke thermostat. The more rapid choke opening reduces HC and CO emissions. Failure of the system would cause higher HC and CO cold start emissions (Ref. 3 and 27). After-market choke heater components are available.

3.7.9.3 Staged Choke Pulldown

The staged choke pulldown used on some models provides more accurate choke modulation as a function of temperature. The pulldown consists of a temperature-controlled vacuum valve which pulls the choke open more rapidly than normal. The rate of opening is controlled by fluid flowing through an orifice. This permits a vacuum diaphragm connected to the choke plate to move. At temperatures above 60°F, the temperature valve opens allowing vacuum to pull the choke nearly open soon after engine start. At colder temperatures, normal choke opening is provided. Failure of the valve will usually result in normal choke action and slightly higher CO and HC emissions (Ref. 3 and 27). After-market choke pulldowns are available.

3.7.9.4 Decel Valve

The decel valve is used to provides additional carbureted mixture during periods of high intake manifold vacuum, (i.e., decelerations). The valve is a diaphragm which opens under vacuum to admit a mixture of fuel and air to the intake manifold. The added fuel maintains stable combustion and engine operation, thereby, reducing HC and CO emissions. Defects in the valve will usually cause increased emissions either due to insufficient or excessive additional mixture (Ref. 2, 3 and 27). After-market valves and parts are available.

3.7.9.5 Distributor Vacuum Deceleration Valve

The distributor vacuum deceleration valve (DVDV) also called deceleration or vacuum advance control valve is used to provide maximum vacuum advance of ignition timing during deceleration (high manifold vacuum). At idle and normal part throttle operation (low vacuum), the distributor advance is connected to the carburetor spark port for normal advance modulation. The DVDV consists of a spring-loaded vacuum diaphragm which responds to manifold vacuum to control the vacuum source provided to the distributor. Failure of the valve diaphragm will result in manifold vacuum applied to the distributor due to leakage past the diaphragm. This will cause increased NO_x emissions (Ref. 2, 3 and 27). These valves are available through the after-market.

3.7.9.6 Distributor Starting Solenoid

The distributor starting solenoid is a mechanical advance mechanism to provide additional spark advance during engine cranking. This improves engine starting while maintaining low HC and CO emissions during idle. The advance is provided by a solenoid directly connected to the vacuum advance linkage. Failure of the solenoid will result in normal advance (none) during starting, but will not increase emissions significantly unless the engine stalls after starting (Ref. 3 and 27). This component has limited usage and is not generally available except from the OEM distributors.

3.7.9.7 Thermal Vacuum Valve

All manufacturers use thermal vacuum valves in a variety of applications. These valves usually sense coolant temperatures either in the radiator or cooling jacket to modulate vacuum signals controlling EGR, carburetor pulldown, or spark advance. These valves are also called ported vacuum switches (PVS), coolant temperature override (CTO) valves, thermal ignition control (TIC) valves, and temperature operated bypass (TOB) valves, depending on OEM vehicle manufacturer and application. Thermal vacuum valves come in numerous configurations such as two, three, four, and five port valves and various temperature ranges (Ref. 3 and 27). These valves are available through after-market distributors.

3.7.9.8 Distributor Vacuum Valve

The distributor vacuum valve is similar to the distributor vacuum deceleration valve described above, but is used to modulate part throttle advance rather than deceleration advance. The valve selects ported vacuum at open throttle acceleration but switches to the EGR port at higher vacuum. This change in vacuum source at part throttle cruise improves driveability of vehicles. Failure of the distributor vacuum valve would result in slightly increased emissions of NO_x and ported vacuum at all times (Ref. 3 and 27).

3.8 EMISSIONS-RELATED PARTS LIST

The system descriptions, probable defect conditions, and the effect of defects on emissions discussed above were used to identify emissions-related components. Although nearly all components can have some effect on emissions, not all can cause an emissions failure. An emission failure depends on both the increase from baseline and the relationship of the baseline to the applicable standard. Therefore, all components which appeared to have more than a negligible effect on one or more pollutant were included in the emissions-related parts list presented in Table 3-1. The components are associated with their respective engine or emission control system even though this results in repetitive entries of the same component categories in some cases.

Table 3-1. EMISSIONS-RELATED PARTS LIST
AFTER-MARKET PARTS

PART OR COMPONENT	RELATED EMISSION			
	HC	CO	NO_x	Smoke
Carburetor System				
New Carburetors	x	x		
Rebuilt Carburetors	x	x		
Idle Stop Solenoid	x	x		
Throttle Dashpot	x	x		
Throttle Positioner	x	x		
Metering Jets	x	x		
Metering Rods	x	x		
Vacuum Break Valves	x	x		
Choke Mechanism	x	x		
Accelerator Pumps	x	x		
Power Valves	x	x		
Gaskets	x	x		
Float and Valve	x	x		
Heat Riser	x	x		
Idle Enrichment System	x	x		
Electric Assisted Choke	x	x		
Staged Choke Pulldown	x	x		
Fuel Filter	x	x		
Ignition System				
Points	x	x		
Condenser/Capacitor	x	x		
Distributor Cap	x	x		
Distributor Rotor	x	x		
Mechanical Advance Mechanism		x		
Vacuum Advance Mechanism		x		
Distributor Drive Mechanism	x	x		
Magnetic or Optical Triggers	x	x		
Spark Plugs	x	x		
Ignition Wires	x	x		
Coil - Inductive	x	x		
Electronic (CD) Ignition	x	x		
Ballast Resistor	x	x		
Spark Delay Valve	x		x	
Air Induction System				
Thermostatically-Controlled Air Inlet	x	x		
Vacuum Motor and Hoses	x	x		
Air Cleaner Element	x	x		
Intake Manifold	x	x		
Turbochargers				x
Superchargers				x

Table 3-1. EMISSIONS-RELATED PARTS LIST
AFTER-MARKET PARTS (Continued)

PART OR COMPONENT	RELATED EMISSION			
	HC	CO	NO_x	Smoke
Fuel Injection System				
Accumlator				x
Fuel Pressure Sensors/Regulators	x	x		x
Throttle Linkage and Valve	x	x		x
Injection Valves				x
Air Sensors/Switches	x	x		
Temperature Sensors/Switches	x	x		
Injectors	x	x		
Triggering Switches	x	x	x	
Starting Valve	x	x		
Engine System				
Valve Lifters and Springs	x	x		x
Cams and Camshafts	x	x		x
Valves, Guides and Seats	x	x		x
Seals	x	x		x
Rings	x	x		x
Gaskets	x	x		x
Exhaust Manifolds and Headers	x	x	x	
Emission Control System				
PCV Valve	x	x		
PCV Hoses	x	x		
PCV Fresh Air Filter	x	x		
AI Distribution Manifold	x	x		
AI Hoses	x	x		
AI Inlet Filter	x	x		
AI Check Valves	x	x		
AI Bypass/Diverter Valves	x	x		
AI Gulp Valves	x	x		
AI Pump	x	x		
EVAP Canister Body and Carbon Media	x			
EVAP Hoses	x	x		
EVAP Fresh Air Filter	x			
EVAP Vapor Liquid Separator	x			
EVAP System Vapor Control Valves	x			
EVAP Fuel Tank Cap	x			
EGR Valves or Orifices			x	
EGR Hoses, Gaskets, Seals	x		x	
EGR Temperature-Controlled Valve			x	
EGR Solenoid-Controlled Valve			x	

Table 3-1. EMISSIONS-RELATED PARTS LIST
AFTER-MARKET PARTS (Continued)

PART OR COMPONENT	RELATED EMISSION			
	HC	CO	NO_x	Smoke
Emission Control System (Cont'd)				
EGR Temperature Switch			x	
EGR Speed/Transmission Switch			x	
EGR Time Delay Control			x	
EGR Vacuum Amplifier	x		x	
EGR Vacuum Reducing Valve			x	
EGR Carburetor Spacer			x	
EGR Back Pressure Sensor			x	
EGR Check Valve			x	
TCS Vacuum Solenoid	x		x	
TCS Vacuum Lines and Hoses	x	x	x	
TCS Time Delay Control	x		x	
TCS CEC Valve	x	x		
TCS Temperature Control Valve	x		x	
TCS Transmission Switch	x		x	
TCS Reversing Relay	x		x	
SCS Vacuum Solenoid	x		x	
SCS Vacuum Lines	x	x		
SCS Time Delay Control	x		x	
SCS Speed Sensing Switch	x		x	
SCS Temperature-Controlled Valve	x		x	
OSAC Vacuum Orifice Valve	x		x	
OSAC Vacuum Hoses	x	x		
OSAC Thermal Valve	x		x	
OSAC Vacuum Bypass Valve	x		x	
OSAC Temperature Sensor	x		x	
ESC Electronic Module	x		x	
ESC Hoses	x	x		
ESC Vacuum Valves	x		x	
ESC Temperature Sensing	x		x	
ESC Speed Sensing Switch	x		x	
CAT Body	x	x		
CAT Active Media	x	x		
Heat Riser	x	x		
Decel Valve	x	x		
Distributor Vacuum Deceleration Valve	x		x	
Distributor Starting Solenoid	x	x		
Thermal Vacuum Valve	x		x	

Section 4

EMISSION-CRITICAL COMPONENTS

The emissions-related components described in Section 3 were ranked in the order of their criticality in causing excessive emissions. The ranking was based on the following four factors: increase in emissions, component usage, probability of failure and probability of repair. This section describes the model used to rank the components, the values assigned to the input parameters of the model, and the resulting rank-ordered lists of emission-critical components.

4.1 CRITICALITY INDEX MODEL

A computer model was developed during Phase I on OEM parts which selected the most emission-critical components. This model calculated a criticality index for each component and then ranked the indices in descending order. Separate rank-ordered lists were prepared for each pollutant (HC, CO, NO_x, smoke). This model was modified during Phase II to directly use values for each input factor. The general flowchart of the model is shown in Figure 4-1. Specifically, the model performed the following functions:

- Read-in data by part code.
- Calculate a criticality index (CI) by pollutant for each part.

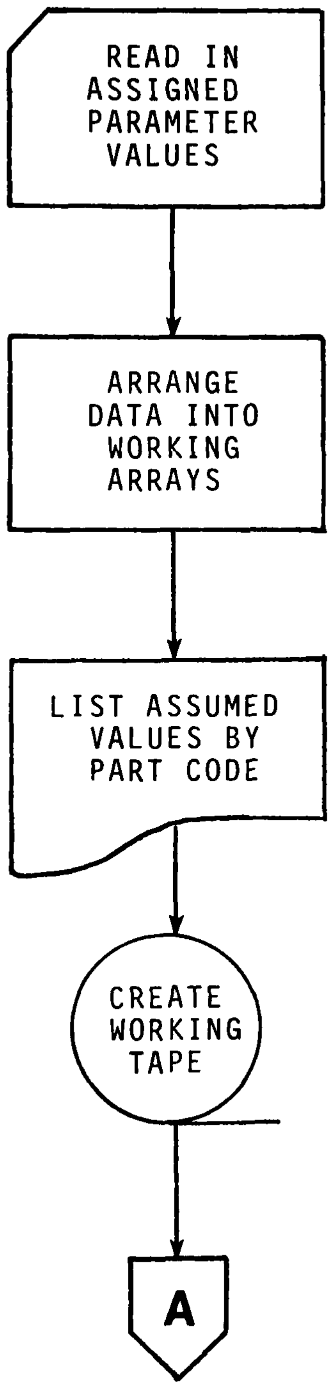


Figure 4-1. CRITICALITY MODEL FLOWCHART

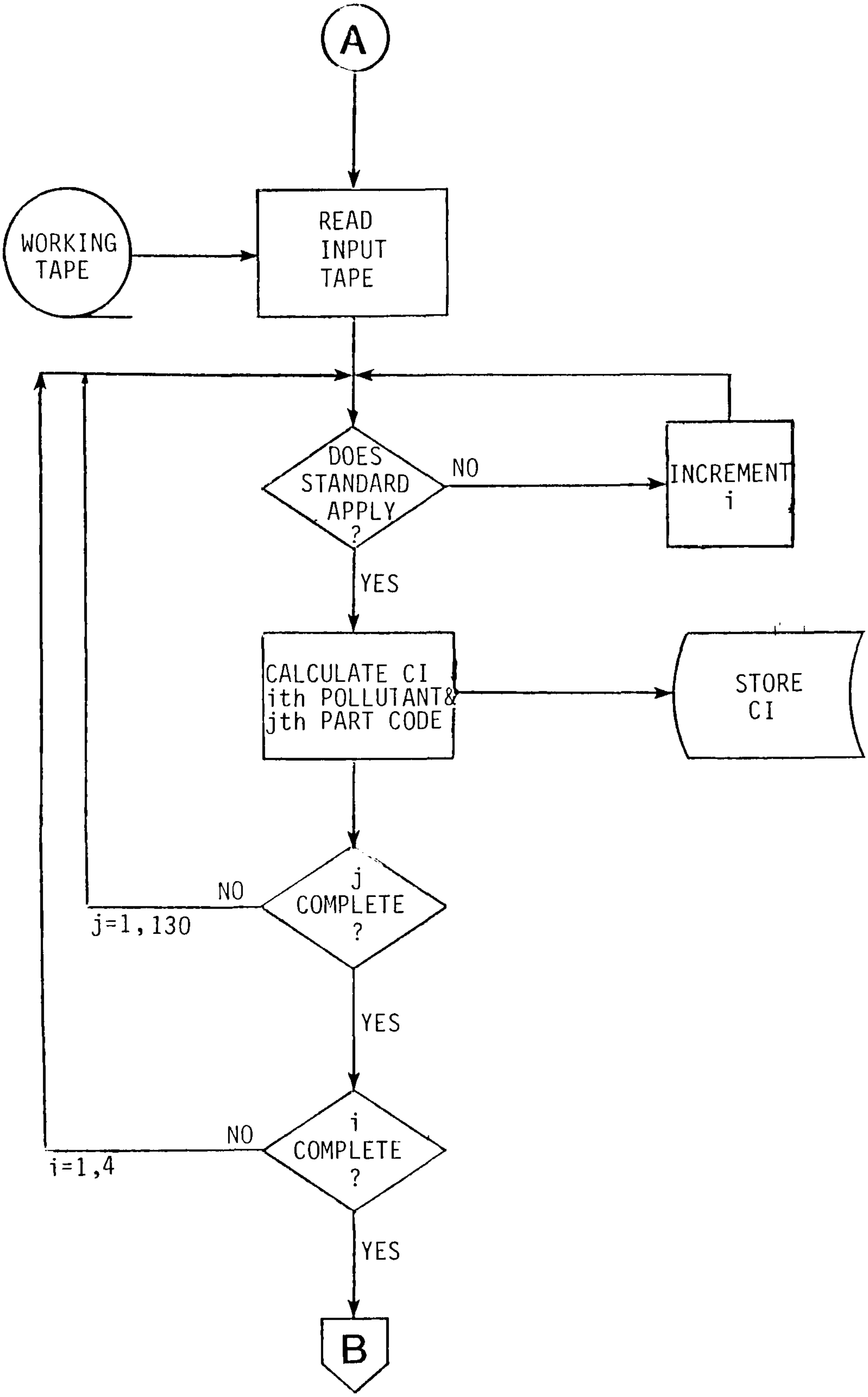


Figure 4-1. CRITICALITY MODEL FLOWCHART (Continued)

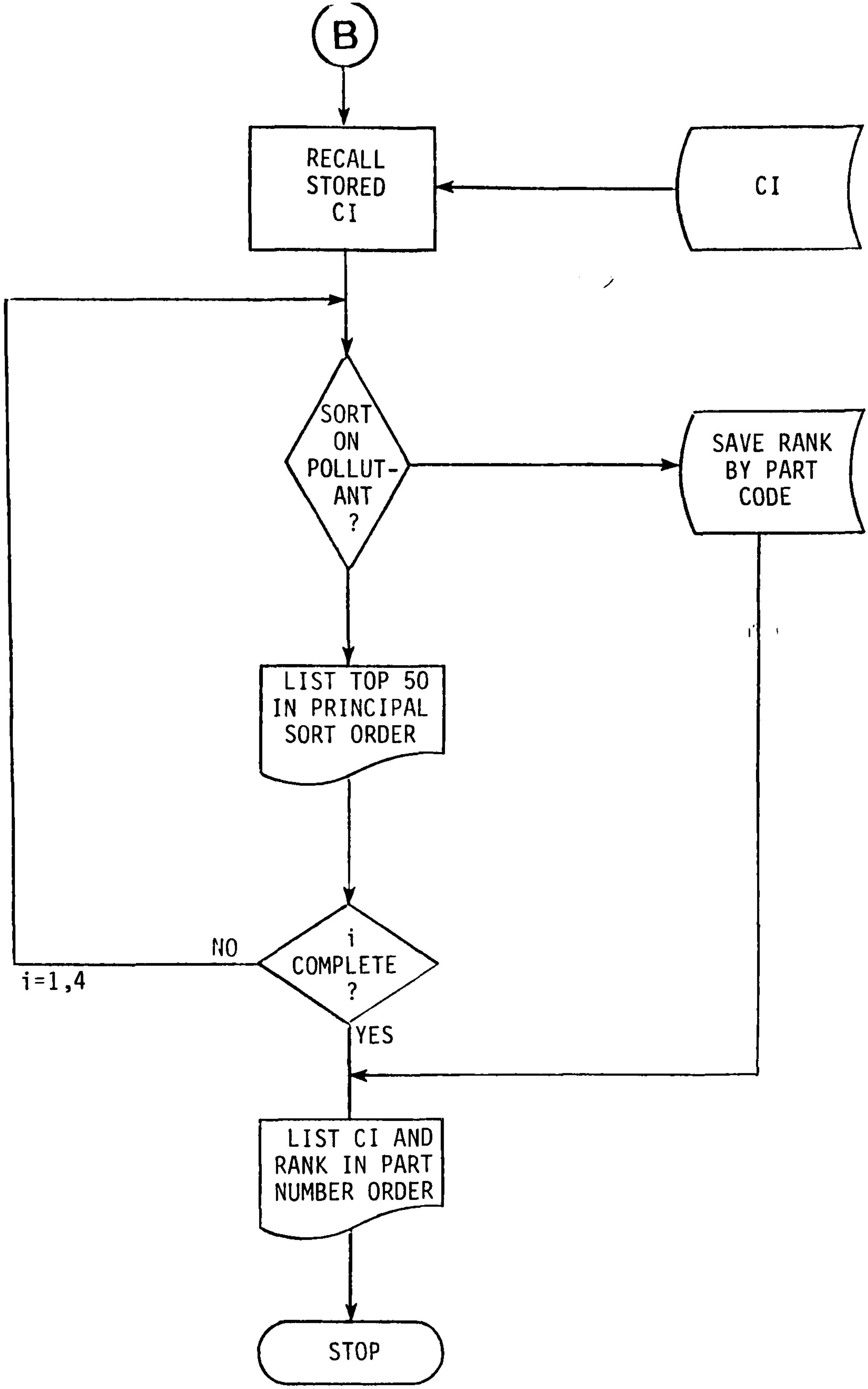


Figure 4-1. CRITICALITY MODEL FLOWCHART (Continued)

- Rank the CI values in descending order
- Print lists of rank-ordered parts by pollutant.

The model can readily be expanded to include additional component categories and pollutants or revisions of the input parameter values.

4.1.1 Criticality Index

The criticality index (CI) was a dimensionless number representing the relative criticality of each part. The CI was calculated as follows:

$$CI_{ij} = (E_{ij}) \bullet (PF_j) \bullet (PR_j) \bullet (V_j)$$

where:

CI_{ij} Represented the relative criticality of the j^{th} part or component in affecting the emissions of the i^{th} pollutant.

E_{ij} Represented the estimated impact on emissions of the i^{th} pollutant by a defect in the j^{th} part or component.

PF_j Represented the estimated probability that the j^{th} part or component would become defective prior to the end of its design life.

PR_j Represented the probability that the j^{th} defective component would not be repaired prior to the end of its design life.

V_j Represented the sales volume factor for the j^{th} component.

4.1.2 Emission Increase Factors

The emission increase factors (E_{ij}) were based on the expected change in emissions with respect to the emission standards applicable to the engines or vehicles using the specific component. Emission increase factors were defined for Federally certified engine families and Federal emission standards. The values of E_{ij} and corresponding emission increase criteria are shown in Table 4-1.

Table 4-1. CRITERIA FOR EMISSION INCREASE FACTORS

E VALUE	EMISSION INCREASE
0.0	No change or decrease in emissions from defect (vehicle may be disabled by defect in this component).
0.1	Emissions may increase but probably not enough to fail standard.
1.0	Slight emission increase (enough to fail standards).
2.0	Moderate emission increase (about twice the standard).
5.0	Substantial emission increase (several times the standard).
10.0	Severe emission increase (order of magnitude higher than standard).

The emission increase factors used in Phase I were generally used in Phase II. Different emission increase factors were assigned to after-market components not included in the Phase I analysis or which had different failure modes than as OEM components. The emission increase factors were determined independently for pre-1975 (noncatalyst) and post-1975 (catalyst-equipped) vehicles since these model-year groups reflected significant differences in emission standards and control system configurations. The emission increase factors for each component were assigned on the assumption that other components were not defective.

For the HC criticality rankings, the evaporative emission increase factor for each component was combined with the corresponding exhaust emission increase factor as follows:

$$E_{HC} = E_{Exhaust} + 1/3\ E_{EVAP}$$

The smoke emission increase factors for each test mode were averaged to provide a composite smoke emission increase factor as follows:

$$E_{smoke} = \frac{E_{accel} + E_{lugging} + E_{peak}}{3}$$

4.1.3 Probability of Failure Factors

The probability of a component's failure (PF_j) prior to the expiration of its design life was estimated on the basis of durability data, available published data, and Olson's experience during inspection and maintenance studies. The same factors assigned during Phase I were generally used during Phase II. Some components, however, may have a higher probability of failure as after-market parts than as OEM parts because of incorrect calibration, application or installation.

The probability of failure was based on defects and excluded failures due to tampering. The design life of each part or component was assumed to be 50,000 miles or the OEM manufacturer's recommended replacement interval of the part, whichever was lower. Based on the available data and engineering judgement, a relative factor representing the probability of component failure was assigned using the criteria shown in Table 4-2. The same PF_j factors were assigned to components for all model years.

Table 4-2. CRITERIA FOR PROBABILITY OF FAILURE FACTORS

PF VALUE	PROBABILITY OF FAILURE
0.01	Failure extremely unlikely during component design life - failure typically does not occur during vehicle's useful life (over 100,000 miles).
0.10	Failure very unlikely during component design life - failure typically occurs late in vehicle useful life (75,000 to 100,000 miles).
0.30	Failure unlikely during component design life - failure typically occurs between 50,000 to 75,000 miles.
0.50	Failure may occur during component design life.
0.70	Failure likely to occur during component design life.
0.90	Failure very likely to occur during component design life.

4.1.4 Probability of Repair Factors

The probability that a defective component would not be repaired (PR_j) prior to the end of its design life was based on the detectability of the failure and the nature of the component in relation to normal tune-up practice. The same probability of repair factors used in Phase I were used in Phase II. Components which had noticeable performance effects (plugs) or were routinely replaced (condenser) had a low probability of remaining defective. However, defective components which were not normally serviced (thermal vacuum valves) or had no noticeable effect on performance (EVAP canister) would probably not be repaired. The same PR_j factor was assigned to all model-year vehicles. Based on available data and engineering judgement, PR_j factors were assigned using the criteria shown in Table 4-3.

Table 4-3. CRITERIA FOR PROBABILITY OF REPAIR FACTORS

PR VALUE	PROBABILITY OF REPAIR
0.10	Repair extremely likely due to severe performance impact.
0.30	Repair likely due to performance impact and routine diagnostic/service procedures.
0.50	Repair may occur depending on diagnostic/service procedure and skill.
0.70	Repair unlikely due to small performance impact or unusual failure mode.
0.90	Repair very unlikely due to small performance impact and unusual failure mode.

4.1.5 Sales Volume Factors

Sales volume data by component category was generally unavailable except for a few common after-market parts. Published marketing data tended to reflect only generally product areas and dollar volume. The large number of manufacturers and models of each component type precluded compilation of comprehensive unpublished data by the contractor. Furthermore, most manufacturers were unwilling to provide data on unit sales volume because of competitive concerns or internal manpower required to compile the data.

Many components were used on several model years, only some of which were subject to regulations. Many OEM part vendors and vehicle manufacturers also distribute parts in the after-market. Some components, such as vacuum switching valves, temperature sensors, and vacuum or air hoses may be used in different applications which are not recorded at point of manufacture and distribution.

Therefore, the criticality index model developed in Phase I was modified to calculate a relative sales volume factor as follows for each component:

$$V_j = \frac{n_j}{\sum_{j=1} n_j}$$

where:

n_j was a value representing the sales volume of the j^{th} component.

Three independent sets of n_j were developed and are described in paragraph 4.2.4. These n_j were based generally on the following criteria:

- Actual annual component sales by dealerships, service stations, and independent garages.
- Actual annual component sales by warehouse distributors to retail parts stores and repair facilities.
- Estimated annual component sales based on OEM sales volume factors developed in Phase I.

The first two sets of sales volume factors were based on published or surveyed sales data. The last set of sales volume factors were based on sales volume factors estimated from OEM component usage and recommended replacement intervals.

4.2 ASSIGNMENT OF CRITICALITY INDEX MODEL PARAMETERS

This paragraph describes the values of the CI model input parameters assigned to each after-market component. These values are based on the characteristic defect or failure mode described in Section 3. Pertinent literature is cited where available. However, many of the assigned values are based on engineering judgement. The resulting rank-ordered lists of emission-critical OEM components are presented and discussed in paragraph 4.3. Appendix B summarizes the input parameter values by part name.

4.2.1 Effect of Defect on Emissions

Each after-market component category was assigned an emission increase factor for each of the following pollutants:

- <u>Gasoline Engines</u>
  Evaporative hydrocarbons
  Hydrocarbons
  Carbon monoxide
  Nitrogen oxides

- <u>Diesel Engines</u>
  Acceleration smoke
  Lugging smoke
  Peak smoke (post-1974 model-year engines)

The smoke emission increase factors were assigned only to components on heavy-duty diesel engines. Components used only on gasoline engines were assigned 0.0 values for the smoke emission increase factors. Separate emission increase factors were assigned to early model-years (1972 through 1974 for light-duty, 1972 through 1973 for heavy-duty) and late model-years (1975 for light-duty, 1974 through 1975 for heavy-duty) to reflect different engine/emission control system configurations corresponding to the different emission standards.

4.2.1.1 Carburetion System

Carburetion systems include completely assembled carburetors, carburetor components, and carburetor (throttle) control devices. Complete carburetors are discussed in addition to major components of the carburetor which are subject to after-market adjustment or replacement. Specific emission increase factors for HC, CO and NO_x are discussed below for the following components categories based on the functional description and characteristic defects described in Section 3.2. The same emission increase factors were assigned to components which can have similar effects on carburetion.

- <u>Assembled carburetors</u>
  - New replacement
  - Rebuilt replacement
  - Performance modified
- <u>Carburetor control devices</u>
  - Idle stop solenoid
  - Throttle dashpot
  - Throttle positioner
- <u>Carburetor components</u>
  - Metering jets
  - Metering rods
  - Vacuum break valves
  - Choke mechanism (except electric assists)
  - Accelerator pump

Power valve

Rebuilding kits

Float and needle valve

Idle adjustment

Idle enrichment systems

- Fuel filter

Assembled Carburetors: New or rebuilt replacement carburetors are nominally identical to the OEM carburetor that they replace. In some cases, the same carburetor model as the OEM carburetor may be specified. In other cases, an equivalent carburetor from a manufacturer other than the OEM supplier may be specified. Unfortunately, emission certified OEM carburetors have subtle differences in metering, power enrichening, and vacuum ports which are not necessarily present in after-market replacement carburetors, even though they may appear physically identical. Therefore, emissions may increase with respect to emission certification levels on a particular vehicle even though they are lower than from a defective OEM carburetor. The following emissions increase factors for replacement carburetors were, therefore, assigned on the basis of engineering judgment to reflect differences in calibration if compared to OEM certified carburetors.

	HC	CO	NO_x
1972-1974	1.0	2.0	0.1
1975	1.0	2.0	0.1

After-market carburetors are available which promise improved performance, driveability or fuel economy relative to the OEM carburetor. These after-market carburetors are usually recalibrated or employ different components than the stock OEM carburetor. These differences result in mixture enrichment during accelerations and open throttle operation. Components which may differ from the OEM configuration include accelerator pump stroke, float adjustment, power enrichment, metering jet size, metering rod size or adjustment, venturi vacuum depression, and the location of and vacuum signals from spark timing and EGR ports. A recent study by the California Air Resources Board (Ref. 108), indicated that substantial emission increases on pre-1975 model year vehicles could occur from a performance carburetor. Higher emission increase factors were assigned to late model vehicles because the large emission increase expected and lower emission standards relative to pre-1975 model year vehicles.

	HC	CO	NO_x
1972-1974	1.0	2.0	1.0
1975	2.0	5.0	1.0

Carburetor Control Devices: These control include the idle stop (anti-dieseling) solenoid and dashpots or positioners for deceleration control. The idle stop solenoid defect would result in excessive throttle closure (anti-dieseling) during idling. This results in low engine speed and rich operation at idle. An improperly adjusted idle stop solenoid was identified as the cause of an HC emissions failure of a catalyst equipped vehicle (Ref. 93). A recent study (Ref. 17) indicates that a 1 percent CO increase in idle CO concentration approximately doubles the hot 1972 FTP emissions of CO from all vehicles and HC emissions from catalyst vehicles. Emissions of NO_x from all vehicles and HC emissions from noncatalyst vehicles were not affected. These results generally confirm the CRC APRAC CAPE-13 study (Ref. 16) performed on pre-1972 model-year vehicles.

Defective dashpots result in more rapid throttle closure during deceleration. Defective throttle positioners result in full throttle closure during decelerations. These defects result in momentary mixture enrichment (Ref. 3) during deceleration. No data was obtained which related defective dashpots or throttle positioners to increased emissions. However, it was assumed that the defect would be similar to overall idle enrichment.

Throttle control devices generally affect idle mixture and are analogous to improper idle adjustment. The emissions increase resulting from defects or improper adjustment depends on the degree of misadjustment, engine size, and emission control system. Rich operation, however, is common as shown by surveillance and inspection programs (Ref. 12, 16, 78, and 94).

Therefore, the following emission increase factors were assigned to throttle control devices (idle stop solenoids, throttle dashpots and throttle positioners) on the basis of a moderate enrichment (1 to 2 percent CO at idle):

	HC	CO	NO_x
1972-1974	0.1	1.0	0.0
1975	1.0	1.0	0.0

Carburetor Components: Failures in carburetors are generally related to defects or misadjustments of one or more of the following specific components. In addition, most of these components are individually available from after-market distributors and retailers. Components which tend to have the same magnitude of emissions increase have grouped together.

Components with relatively moderate influence on overall emissions include incorrect metering jet size, metering rod adjustment, and accelerator pump stroke. No specific data on the relationship of these components to FTP emission levels was obtained. However, the general result of after-market modification or replacement of these components is probably mixture enrichment relative to the OEM configuration. Although post-1975 model year vehicles are probably more sensitive to these changes than pre-1975 model year vehicles as a result of the more stringent emission standards, these components were assigned the following emissions increase factors on the basis of engineering judgment:

	HC	CO	NO_x
1972-1974	0.1	2.0	0.0
1975	0.1	2.0	0.0

Defective or improperly adjusted vacuum break valves result in normal thermostatic choke opening rather than load or temperature modulated opening. This results in longer and richer warm-up and higher cold-start emissions of HC and CO. The CO emission increase relative to the standards should be greater on catalyst-equipped vehicles than on noncatalyst vehicles because of the large weighting of cold-start emissions. The HC emission may also increase since the vacuum is below the throttle plate (Ref. 27) and lean misfire can occur during closed throttle. The following emission increase factors were, therefore, assigned:

	HC	CO	NO_x
1972-1974	0.1	1.0	0.0
1975	1.0	1.0	0.0

The choke, power valve, float, and needle valve can all significantly affect carburetion if defective or improperly installed or adjusted. These components can cause higher HC and CO emissions particularly during open-throttle operation. The degree of emission increase depends on engine size, and emission control system and nature of defect or misadjustment. This defect may also result in accelerated catalyst aging for catalyst-equipped vehicles as well as higher emissions (Ref. 12, 16, 17, 70, 78, 92, 93 and 100). The HC/CO emission increase factors were, therefore, assigned as follows:

	HC	CO	NO_x
1972-1974	2.0	10.0	0.0
1975	2.0	10.0	0.0

Defective gaskets result in vacuum leaks and lean misfire at closed throttle (high vacuum). The resulting increase in mass emissions though is small due to the small effective size of the leak and because it occurs primarily during closed throttle (Ref. 27). No specific data on gasket failures were obtained, however, the failure is expected to cause slight emission increases of HC from none catalyst-equipped vehicle and slight HC and CO emission increases from catalyst-equipped vehicles. Therefore, the following emission increase factors were assigned on the basis of engineering judgment:

	HC	CO	NO_x
1972-1974	0.1	0.0	0.0
1975	0.1	0.1	0.0

Gaskets, vacuum diaphragms, needle valves and other carburetor components are generally sold in rebuilding kits rather than individually. Carburetor kits are installed in carburetors by the vehicle owner or a mechanic. The rebuilding process requires disassembly of the carburetor, complete cleaning in solvents, and reassembly, reinstallation and final adjustment of the carburetor. The carburetor kit components generally are not defective, however, the chance of reassembling and readjusting the carburetor to give the same emissions performance is relatively low. Therefore, the same emissions increase factors assigned to factory rebuilt carburetors were assigned to carburetor kits:

	HC	CO	NO_x
1972-1974	1.0	2.0	0.1
1975	1.0	2.0	0.1

Defective idle enrichment systems can result in excessive enrichment at all temperatures rather than at low temperature only (Ref. 27). This is equivalent to excessively rich idle adjustment. The same emission increase factors as assigned for throttle control devices were, therefore, assigned:

	HC	CO	NO_x
1972-1974	0.1	1.0	0.0
1975	1.0	1.0	0.0

Fuel Filter: The defect mode results in reduced fuel flow to the carburetor causing lean operation and power loss under heavy load conditions. On gasoline engines flow restriction may lead to slight increases in HC emissions but no change or decreases in CO and NO_x emissions. On diesel engines, flow restriction can lead to power loss but not increased smoke since excess air is already present (Ref. 2 and 3). The following emission increase factors were, therefore, assigned.

	HC	CO	NO_x	Smoke
1972-1974	0.1	0.0	0.0	0.0
1975	0.1	0.1	0.0	0.0

4.2.1.2 Ignition System

Defects in the ignition system can lead to misfire and increased HC emissions. Some defects can affect the timing of the ignition spark and, consequently, NO_x emissions. Some defects leading to misfire or changes in spark timing may also increase CO emissions due to the increased throttle opening which is required to maintain desired speed and load conditions. Catalysts are generally able to oxidize HC emissions more easily than CO. Therefore, some of the unburned fuel may be oxidized resulting in smaller increases in HC and larger increases in CO emissions than expected compared to noncatalyst-equipped vehicles.

The following after-market ignition system components are discussed below:

- Points
- Condenser
- Distributor cap
- Distributor rotor
- Distributor mechanical advance
- Distributor vacuum advance
- Spark delay valves
- Electronic ignition triggers
- Spark plugs
- Ignition wires
- Coils
- Ballast resistor
- Electronic ignition circuits

The above components can generally be divided into primary ignition components, secondary ignition components, and distributor timing components. In general, primary ignition component defects do not cause as severe misfire as a secondary ignition defect which may essentially disable one cylinder. Specific data relating defects to emission increases were not available for individual primary ignition system components. However, since misfire is distributed intermittently over all cylinders, the emissions increases should not be as severe as for plugs or wires.

After-market ignition components are sold under many brand names and private labels. After-market replacements are generally available for OEM ignition components. In addition, after-market components are also available which offer improved performance, durability or fuel economy than the OEM configuration components. After-market electronic ignition retrofit kits are the best example of this component category. In general, the same basic design and operating characteristics are found in OEM and after-market ignition components. Therefore, the modes of failure and the resulting emission increases for after-market components were based on the analysis of OEM components.

Primary Ignition Components: The primary ignition system includes points, condensor, coil, CD ignition system, ballast resistor and distributor drive mechanisms which affect point operation. These components were all assigned the same emission increase factors because specific data on each component was not available, and all components generally cause a random intermittent misfire in the secondary ignition system. The actual emission increase on any specific vehicle or engine depends on the deviation of the component from specification, the number of cylinders, and the emission control system configuration.

Misfire on pre-catalyst-equipped vehicles generally causes HC emissions to increase with little or no change in CO and NO_x (Ref. 12, 78, and 94). On catalyst-equipped vehicles, however, the catalyst should be able to partially oxidize the HC emission increase (Ref. 15) resulting in a small increase in both HC and CO. Emissions of NO_x should not be significantly affected by intermittent misfire (Ref. 7, 15, 35, and 70). Therefore, the following emission increase factors were assigned to the primary ignition components described above:

	HC	CO	NO_x
1972-1974	1.0	0.0	0.0
1975	0.1	0.1	0.0

Distributor Rotor and Cap: A defective distributor cap and/or rotor increases the resistance of the secondary ignition circuit and reduces the available firing voltage at the spark plug. No data was obtained relating rotor or cap failure to FTP emissions. However, frequent misfire on one or more spark plugs (usually the plug/wire with highest internal resistance) may result if severe cap or rotor deterioration occurs. Frequent misfire causes moderate increases in emissions of HC (Ref. 3, 7, 16, 70, 78, and 92). Changes in CO or NO_x emissions are small. Therefore, the following emission increase factors were assigned to both the rotor and cap:

	HC	CO	NO_x
1972-1974	2.0	0.0	0.0
1975	2.0	0.1	0.0

Distributor Mechanical/Vacuum Advance: Defective mechanical or vacuum advance including dual diaphragm advance results in incorrect or no spark advance as engine speed and/or load increase from idle (Ref. 3). This is equivalent to improper basic timing which can effect HC, CO and NO_x emissions depending on engine speed and/or load condition. The change in timing due to a defective advance mechanism may lead to misfire but is more likely to affect the time of combustion with respect to valve opening.

After-market distributor springs and weights are likely to have a different advance curve than OEM springs. In particular, after-market advance springs are sold which intentionally increase the spark advance at a given speed in order to improve acceleration and performance. This would be expected to increase HC and NO_x emissions and possibly reduce CO emissions (Ref. 16, 17, and 100). An EPA study, however, indicated that a commercial after-market distributor spring did increase NO_x (30 percent) and HC (13 percent) but also increased CO (12 percent). These tests were based on hot start tests on noncatalyst-equipped vehicles. Although the HC, CO emissions increases are low, the NO_x emission increase could result in an emission failure.

	HC	CO	NO_x
1972-1974	0.1	0.1	1.0
1975	0.1	0.1	1.0

After-market vacuum advance mechanisms are more likely to result in retarded advance than after-market mechanical advance mechanisms. This is because advance mechanisms are interchangeable over several model years and more recent components tend to be more available. Recent vacuum advance characteristics tend to be more retarded than early curves so that it is more likely to obtain retarded timing. Actual failure of the vacuum diaphragm will also cause retarded timing. Emissions of HC decrease due to late firing and smaller surface to volume ratios. Emissions of NO_x decrease due to the combustion occurring at lower compression ratios than normal. Emissions of CO increase because additional throttle angle is required and mass flow rates are higher. The following emission increase factors were, therefore, assigned to distributor advance mechanisms.

	HC	CO	NO_x
1972-1974	0.0	0.1	0.0
1975	0.0	1.0	0.0

Spark Delay Valves: After-market spark delay valves may be bypassed, missing, or incorrect for the application. This will generally result in normal vacuum advance during initial throttle opening which increases NO_x emissions and may also increase HC emissions slightly (Ref. 3 and 27). Similar emission increase factors were assigned for spark delay valves as were assigned for advanced timing and defective OSAC valves since they result in advanced timing.

	HC	CO	NO_x
1972-1974	0.1	0.0	1.0
1975	0.1	0.0	1.0

Electronic Ignition Trigger and Control Circuits: Several after-market retrofit kits for electronic optical or magnetic sensing of spark timing are available. No data was obtained relating failures of the electronic ignition to emissions. Defective electronic ignition triggers, however, can cause intermittent misfire since a plug will not fire if the trigger signal is missing (Ref. 46). The same emission increase factors assigned to spark plug and wires were, therefore, assigned to electronic ignition triggers:

	HC	CO	NO_x
1972-1974	10.0	0.0	0.0
1975	10.0	0.1	0.0

Spark Plugs/Wires: Defective plugs or wires cause ignition misfire. Typically, one cylinder is affected because of an open or shorted wire or a fouled plug. This can result in continuous HC emissions, in excess of 2,000 ppm C_6, which is equivalent to 20 or more grams per mile by the FTP. In addition, for some catalyst-equipped vehicles, total misfire on one cylinder may damage the catalyst if continued for an extended period and if the over temperature protection system (air dump) fails. Emissions of NO_x may increase but not enough to fail (Ref. 16, 78, 92, 93, and 100). On catalyst vehicles, the excess HC emissions may be partially oxidized to CO. Therefore, the following emission increase factors were assigned to defective plugs and wires:

	HC	CO	NO_x
1972-1974	10.0	0.0	0.0
1975	10.0	0.1	0.0

4.2.1.3 Air Induction System

Defects in the air induction system can result in either excessively lean or rich carburetion depending on the component. The emissions-related components of the induction system are:

- Thermostatic Air Cleaner (TAC) including shroud and hose, thermostat, vacuum motor, vacuum hoses, fresh air inlet
- Air cleaner element
- Manifolds
- Turbocharger and supercharger

Except for turbochargers, superchargers and manifolds, after-market components are essentially OEM equivalent. Therefore, failure modes and emission increases resulting from failures were the same as for OEM components.

<u>TAC Shroud, Hose, and Thermostat</u>: Failure of these components affects only the cold start FTP results. No data was available relating defects in these components to emissions. However, the expected affect is lean misfire due to mixture enleanment from unheated dense air (Ref. 3 and 27). The effect on CO and NO_x emissions is expected to be negligible. Vehicles equipped with catalysts are more sensitive to cold start emissions. Therefore, the following emission increase factors were assigned to these components:

	HC	CO	NO_x
1972-1974	0.1	0.0	0.0
1975	1.0	0.0	0.0

TAC Vacuum Hoses and Vacuum Motor; Defective vacuum hoses or vacuum motor produce a vacuum leak in the intake manifold in addition to preventing rapid warm-up. The leak is present at all operating temperatures and, therefore, has more effect on HC emissions than the other TAC components which only influence cold start performance (Ref. 3). The HC and CO emissions will probably decrease on noncatalyst vehicles but CO emissions may increase slightly on catalyst vehicles due to partial oxidation of the HC emissions. NO_x emissions will probably not be affected (Ref. 92 and 93). The following emission increase factors were, therefore, assigned:

	HC	CO	NO_x
1972-1974	0.1	0.0	0.0
1975	1.0	0.1	0.0

TAC Fresh Air Inlet: A defective TAC air inlet for underhood, or cool air, results in hotter than normal air being drawn into the engine. This will cause a decrease in air density and, consequently, mixture enrichment (Ref. 2). This will increase CO and HC emissions slightly, but decrease NO_x. No data was obtained on the relation of this defect to emissions. However, the HC and CO emissions increase for catalyst vehicles were assigned the same value as for non-catalyst vehicles since reserve activity of the catalyst should compensate for the slightly higher emissions. Therefore, the following emission increase factors were assigned:

	HC	CO	NO_x
1972-1974	0.1	0.1	0.0
1975	0.1	0.1	0.0

Air Cleaner Element: The air cleaner element is subject to clogging which reduces the air flow under any given vacuum. This has the effect of decreasing the air-fuel ratio which increases CO and HC emissions but decreases NO_x emissions. However, a previous study (Ref. 16), has shown that substantial restriction of the air cleaner is required before significant changes are observed in CO emissions. Catalytic reactors are expected to partially control CO emission increases. Some carryover of high CO into HC may also occur. The actual emission increase is highly dependent on the engine size control system configuration, and degree of restriction (Ref. 92, 92 and 100). Therefore, the following emission increase factors are assigned which are the same as those assigned for metering rods, float and valve in the carburetor:

	HC	CO	NO_x
1972-1974	0.1	2.0	0.0
1975	0.1	2.0	0.0

The air cleaner also can affect smoke emissions from diesel engines due to the fuel enrichment which occurs when the air cleaner is clogged (Ref. 2 and 3). This effect is independent of the model-year and is significant only for the acceleration and peak smoke measurements (Ref. 3). The following smoke emission increase factors were assigned:

	ACCEL	LUGGING	PEAK
1972-1973	1.0	0.0	-
1974-1975	1.0	0.0	1.0

Manifolds: After-market manifolds are sold as OEM replacement or specialty. The replacement manifolds are dimensionally and materially equivalent to the original OEM manifold. The specialty manifolds have differing configurations and are typically sold for use in conjunction with air after-market specialty carburetor. Two reports documented the effect of changes in manifold. One study (Ref. 105), indicated that emissions from pre-1975 model year vehicles could either increase or decrease slightly depending on the specific manifold and engine. The second study (Ref. 108) indicated that an after-market manifold installed on a 1974 model year vehicle did not significantly affect emissions. No data, however, was available for catalyst-equipped vehicles. Therefore, the following emissions increase factors were assigned for after-market intake manifolds:

	HC	CO	NO_x
1972-1974	0.1	0.1	0.0
1975	0.1	0.1	0.0

Turbocharger and Supercharger: The turbocharger and supercharger increases the volumetric efficiency of the engine due to pressurizing the intake manifold (Ref. 2). The turbocharger only functions during acceleration or high load conditions, however, the supercharger operates at all times. Defective or improperly sized units would be expected to reduce the air pumped through the engine and, thereby, result in mixture enrichment (Ref. 2). The emission increase factors are shown below:

	HC	CO	NO_x
1972-1974	1.0	2.0	0.0
1975	1.0	2.0	0.0

	ACCEL	LUGGING	PEAK
1972-1973	1.0	0.1	-
1974-1975	1.0	0.1	1.0

4.2.1.4 Fuel Injection Systems

Fuel injection systems are used in both gasoline and diesel engines. Fuel injection systems may be mechanically operated (MFI) or electrically operated (EFI). Gasoline engines use either MFI or EFI. Diesel engines, however, use MFI. Defects in these systems generally result in excess fuel supply leading to excessive CO, HC and smoke emissions. Conditions of insufficient fuel supply produce unacceptable driveability problems and are rapidly corrected by owners. Emission increase factors were, therefore, assigned for the more typical failure; i.e., excess fuel metering.

After-market fuel injection systems are distributed by the same companies which sell to the OEM vehicle and engine manufacturers utilizing fuel injection systems. Replacement parts for these systems are distributed by the vehicle manufacturers as well as through the after-market by the fuel injection manufacturers. The after-market components are, therefore, OEM equivalent replacement parts with the same failure modes and emission increases as for the OEM component.

The following fuel injection components are discussed below:

- Accumulator
- Fuel pressure sensors/regulators
- Throttle linkage and valve
- Injection valves
- Air sensors/switches
- Temperature sensors/switches
- Injectors

- Triggering switches
- Starting valve

Accumulator: The accumulator is not likely to fail. However, if it did fail, overfueling is the probable result due to pressure shock waves developing in the fuel lines (Ref. 3). This probably causes slightly higher smoke emissions as follows:

	ACCEL	LUGGING	PEAK
1972-1973	0.1	0.1	-
1974-1975	0.1	0.1	0.1

Fuel Pressure Sensor/Regulators: Incorrect fuel pressure is most likely to cause overfueling, particularly during acceleration. Incorrect fuel pressure is analogous to incorrect float setting. The peak smoke reading may also be high. High fuel injection pressure in gasoline engines would cause higher CO and slightly higher HC but lower NO_x on the FTP. Therefore, the following emission increase factors were assigned:

	HC	CO	NO_x
1972-1974	0.1	1.0	0.0
1975	0.1	1.0	0.0

	ACCEL	LUGGING	PEAK
1972-1973	1.0	0.1	-
1974-1975	1.0	0.1	1.0

Throttle Linkage and Valve: Incorrect throttle valve adjustment in mechanical injection systems will tend to overfuel all cylinders. This is particularly true for heavy-duty engines in which overfueling can increase the useful power of the engine. Higher smoke emission increase factors were assigned for late-model engines due to tighter standards. Overfueling occurs at all load conditions (Ref. 3 and 63). The following smoke emission increase factors were, therefore, assigned:

	ACCEL	LUGGING	PEAK
1972-1973	1.0	0.1	-
1974-1975	2.0	0.1	2.0

Injection Valves (MFI): Defective injection valves result in excessive fueling of individual cylinders under all operating conditions (Ref. 3). The most severe effect probably occurs during low load when the fuel flow is not completely shut off (Ref. 3). Therefore, the following emission increase factors were assigned:

	ACCEL	LUGGING	PEAK
1972-1973	1.0	1.0	-
1974-1975	1.0	1.0	2.0

Air Flow or Temperature Sensors/Switches (EFI): Characteristic defects in air or oxygen sensors/switches result in mixture enrichment either due to restricted air flow (auxiliary air regulator) or increased fuel flow (defective manifold vacuum switch, intake air flowmeter, or O_2 sensor). Failure of any temperature sensor results in overfueling because cold start enrichment continues at all times (Ref. 3 and 27). These failures are analogous to defective power valves and chokes in carburetors. The following emission increase factors were, therefore, assigned:

	HC	CO	NO_x
1972-1974	1.0	5.0	0.0
1975	1.0	5.0	0.0

Injectors-Solenoid (EFI): Defective injectors fail to shut off, thereby, dribbling fuel at all times into the intake manifold or port. This results in mixture enrichment of at least one cylinder (Ref. 3). The following emission increase factors were, therefore, assigned:

	HC	CO	NO_x
1972-1974	0.1	2.0	0.0
1975	0.1	2.0	0.0

Triggering Switches (EFI): The triggering switches are contacts in the distributor which signal the time with respect to TDC at which the fuel is to be injected (Ref. 3). Failure of the triggering switches tends to produce lean misfire particularly at high speed and load. Catalyst activity, however, partially oxidizes the increased HC to CO. Therefore, the following emission increase factors were assigned:

	HC	CO	NO_x
1972-1974	2.0	0.1	0.1
1975	2.0	1.0	0.1

Starting Valve: The starting valve is used for enrichening the mixture of gasoline engines during cold start. A defective starting valve enriches the mixture at all times. This is analogous to a partially closed choke (Ref. 3). Therefore, emission increase factors were assigned which are half of those assigned to chokes:

	HC	CO	NO_x
1972-1974	1.0	5.0	0.0
1975	1.0	5.0	0.0

4.2.1.5 Engine Systems

The following after-market engine components are emissions-related:

- Exhaust valves and associated components such as seals, lifters, springs, guides, cams, camshafts and timing chains.
- Piston rings.
- Head gaskets.
- Exhaust manifolds/headers.

No data was obtained relating defects in these components to FTP emission levels. However, design and development information on the effect of valve operation on emissions was available in several references. Emissions from both gasoline and diesel engines are affected by defects in these components. Therefore, values were assigned to emission increase factors for HC, CO, NO_x, and smoke.

The components which control valve alignment and operation include lifters and springs, valve cams and camshafts, and valve guides. These components, if defective, cause the valves to open and close incorrectly resulting in loss of unburned mixture from one or more cylinders. This causes increased HC and smoke emissions. Defective valve seals and piston rings allow lubricating oil to enter the cylinders. This increases smoke and CO emissions because the heavy oils do not burn completely. Defective head gaskets may allow coolant to enter the engine. This results in quenching of the combustion process and increased emissions of HC, CO, and smoke. Performance engine components can also affect emissions, however, the increases are no worse than from defects in the OEM components (Ref. 105). The following emission increase factors were, therefore, assigned to all internal engine components using engineering judgment:

	HC	CO	NO_x
1972-1974	1.0	1.0	0.0
1975	0.1	0.1	0.0

	ACCEL	LUGGING	PEAK
1972-1973	1.0	1.0	-
1974-1975	1.0	1.0	1.0

4.2.1.6 Emission Control Systems

In general, there are no after-market sources of emission control system components since the same vendors sell the same components both to OEM vehicle manufacturers and to after-market parts distributors under private labels. Therefore, the same emission increase factors established for OEM components were used for after-market components.

The same emission increase factors were assigned to similar emission control components even though they were used in different systems. For example, all vacuum hoses were assigned the same factors for HC since a vacuum leak may be created whether a hose is employed in EGR, TCS, or ignition advance applications. Similarly, transmission or speed sensors were assigned the same emission increase for NO_x whether they were used in SCS, TCS or EGR applications. Some devices may fail in more than one state. Emission increase factors were assigned for the failure mode with either the greatest probability of occurring or with the greatest effect on emissions. None of these emission control systems are used on diesel engines and, therefore, no smoke emission increase factors were assigned. The emission control systems considered were the following:

- Crankcase ventilation (PCV)
- Evaporative emission (EVAP)

- Air injection (AIR)
- Exhaust gas recirculation (EGR)
- Transmission/speed controlled spark (TCS)
- Orifice spark advance control (OSAC)
- Electronic spark control (ESC)
- Catalytic reactor (CAT)
- Manifold heat control (Heat riser)
- Electric assist choke
- Staged choke pulldown
- Decel valve
- Distributor vacuum deceleration valve
- Thermal vacuum valve
- Distributor starting solenoid
- Distributor vacuum valve

PCV Valve and Breather (Air Inlet): Restrictions of the PCV valve or air inlet filter to the PCV system cause mixture enrichment since the PCV valve contribues ventilation air flow to the intake. The CAPE-13-68 study (Ref. 16) found that NO_x-controlled vehicles were quite sensitive to PCV restriction for CO, slightly sensitive for HC and insensitive for NO_x. No specific data for catalyst-equipped vehicles were available. However, PCV restriction is similar to rich idle adjustment. The same emission increase factors assigned idle adjustment were, therefore, assigned to PCV valves and breathers:

	HC	CO	NO_x
1972-1974	0.1	1.0	0.0
1975	1.0	1.0	0.0

PCV and EVAP Vacuum Hoses: PCV or EVAP hose failure (rupture or looseness) results in evaporative emissions and possibly lean misfire. Under high load, crankcase vapors may be forced into the atmosphere. If an intake manifold vacuum hose fails, a lean misfire will result due to the high air flow at idle (Ref. 3). Catalyst vehicles have the same evaporative emission increase but slightly higher CO emissions due to partial oxidation of the hydrocarbons from misfire (Ref. 70 and 93). The following emission increase factors were assigned:

	EVAP	HC	CO	NO_x
1972-1974	10.0	0.1	0.0	0.0
1975	10.0	0.1	0.1	0.0

<u>EVAP Canister</u>: Failure of the carbon canister involves deactivation or saturation of the activated carbon so that fuel vapors pass through and out of the canister. No data was available on the relationship of the EVAP canister to emissions. However, no effect on exhaust emissions is expected. The following emission increase factors were assigned on the basis of engineering judgment.

	EVAP	HC	CO	NO_x
1972-1974	10.0	0.0	0.0	0.0
1975	10.0	0.0	0.0	0.0

<u>EVAP System Components</u>: In addition to the carbon canister and vacuum hoses, the EVAP system includes a fresh air filter, check valves, and sealed gas cap. No data was obtained relating defects in these components to emissions. Clogging or restriction of the EVAP fresh air filter, however, reduces the rate of purging and may reduce the activity and storage capacity of the carbon. Since clogging will probably not be complete, lower EVAP emissions increase factors are assigned than for a defective canister. Similar affects are produced by defects in the purge valves vapor/liquid separator, or fuel tank cap. The following emission increase factors were assigned to the above EVAP system components on the basis of engineering judgment:

	EVAP	HC	CO	NO_x
1974-1974	2.0	0.0	0.0	0.0
1975	2.0	0.0	0.0	0.0

Air Injection (AI) System: The AI system is disabled by breakage of the manifold, hoses, fan belts, or pump. Failure of the air injection system results in increased HC and CO emissions but no significant change in NO_x emissions. Failure of the AI system on catalyst vehicles causes a large increase in CO and HC emissions particularly in large engines due to loss of excess secondary air (Ref. 70, 93, and 100). The following emission increase factors were assigned to the air pump, manifold and hoses:

	HC	CO	NO_x
1972-1974	1.0	1.0	0.0
1975	2.0	5.0	0.0

Air Injection (AI) Filter and Check Valves: These AI system components can affect the performance of the system because they protect the pump either from entrained material or from backfiring which may occur in the exhaust manifold. Their failure, however, does not necessarily defeat the AI system. Therefore, the following emission increase factors were assigned on the basis of engineering judgment:

	HC	CO	NO_x
1972-1974	0.1	0.1	0.0
1975	1.0	1.0	0.0

Air Injection (AI) Bypass, Diverter or Gulp Valves: These valves are used to prevent backfiring in the exhaust system and catalyst overheating during engine malfunctions. Failure of the valves do not affect NO_x emissions, but slightly increase HC and CO emissions from noncatalyst vehicles. They have potentially great effect on HC and CO emissions from catalyst vehicles since the catalyst may be destroyed if these systems fail during an engine malfunction (Ref. 70, and 100). Therefore, the following emission increase factors were assigned:

	HC	CO	NO_x
1972-1974	0.1	0.1	0.0
1975	2.0	5.0	0.0

EGR Valve and Control Components: Defective EGR valves have negligible effect on HC and CO but may double or triple NO_x (Ref. 70, 92, 93 and 100). Valves may either become clogged (orifice) or stuck (vacuum activated) due to corrosion, diaphragm rupture or vacuum system failure (Ref. 70). The vacuum signal may be modulated for specific load, speed, and/or temperature conditions. The control components include thermal vacuum valves, solenoid valves, speed/transmission switches, temperature switches, and time delays. Failure of any one of these components will defeat the EGR system by denying vacuum to the EGR valve (Ref. 3 and 27). Therefore, the same emission increase factors assigned to EGR valves were also assigned to the above EGR control components:

	HC	CO	NO_x
1972-1974	0.0	0.0	2.0
1975	0.0	0.0	2.0

EGR Vacuum Amplifier and Vacuum Hoses: A defective vacuum amplifier or vacuum hose creates a manifold vacuum leak and also defeats the EGR system. Therefore, the same emission increase factors used for EGR valves were assigned to these vacuum components. The vacuum leak may increase HC emissions slightly. However, CO emissions will not increase due to the excess air and higher combustion temperatures present without EGR (Ref. 2, 3, and 27). Therefore, the following emission increase factors were assigned.

	HC	CO	NO_x
1972-1974	0.1	0.0	2.0
1975	0.1	0.0	2.0

EGR Vacuum Reducing Valve, Carburetor Spacer, and Back Pressure Sensor: Defective vacuum reducing valves and back pressure sensors reduce the vacuum signal reaching the EGR valve. This reduces EGR but not as much as complete failure of the vacuum signals. The carburetor spacer can become clogged so that EGR does not occur, particularly at a low pressure differential between intake and exhaust manifolds. Total blockage of the system is unlikely, however, unless severe oil burning occurs. There is no significant increase of HC or CO from these failures (Ref 3 and 27). Therefore, the following emission increase factors were defined for these components:

	HC	CO	NO_x
1972-1974	0.0	0.0	1.0
1975	0.0	0.0	1.0

EGR Check Valves: The EGR check valves hold the highest manifold vacuum achieved during certain operating conditions. This reduces the effectiveness of EGR but not as much as defective back pressure sensors or vacuum reducing valves (Ref. 3 and 27). Therefore, the following emission increase factors were assigned:

	HC	CO	NO_x
1972-1974	0.0	0.0	0.1
1975	0.0	0.0	0.1

TCS, SCS, ESC Solenoid Valves and Control Components: Vacuum solenoids are normally deactivated allowing vacuum advance signals to reach the distributor. During low speeds, the solenoids are activated to prevent vacuum advance for NO_x control. Failure of the solenoids produce normal vacuum advance at all times. This results in a slight HC emission increase and substantial NO_x increases. Emissions of CO are reduced since average timing is advanced from normal. Failure of components which activate the TCS, SCS, or ESC solenoids (speed switches, thermal vacuum valves, and time delays) also results in total defeat of the system. Therefore, the following emission increase factors were assigned:

	HC	CO	NO_x
1972-1974	0.1	0.0	2.0
1975	0.1	0.0	2.0

TCS, SCS, ESC Vacuum Hoses: Failure of these vacuum lines results in manifold vacuum leaks and loss of vacuum advance. This results in reduced NO_x, slightly increased HC due to lean misfire, and higher CO due to retarded timing. The increased CO is proportionately higher on catalyst-equipped vehicles due to the lower standards and partial oxidation of the HC emissions. The following emission increase factors were, therefore, assigned (Ref. 3 and 70):

	HC	CO	NO_x
1972-1974	0.1	0.1	0.0
1975	0.1	1.0	0.0

CEC Solenoid: The CEC solenoid, used only on pre-1975 model-year vehicles, combined the vacuum solenoid and throttle positioner into one device. Failure of the solenoid prevents deceleration throttle modulation and vacuum advance at all times (Ref. 3 and 27). This increases HC and CO but reduces NO_x as shown below:

	HC	CO	NO_x
1972-1974	2.0	2.0	0.0

Orifice Spark Advance Control (OSAC) Valve: The OSAC valve delays the rate at which vacuum advance is applied to the distributor. Failure of this device results in normal spark advance at all times. This causes some increase in NO_x but small effect on HC and CO emissions. Vehicles equipped with OSAC also have other controls; i.e., EGR or TCS (Ref. 3 and 27). The following emission factors were, therefore, defined:

	HC	CO	NO_x
1972-1974	0.1	0.0	2.0
1975	0.1	0.0	1.0

Catalytic Reactors (CAT): Catalytic reactors are not presently available in the after-market nor is after-market distribution planned in the foreseeable future by any manufacturer. Therefore, catalysts are not included in this analysis.

Manifold Heat Control (Heat Riser): The heat riser aids in cold start warm-up by improving vaporization of the fuel. The heat riser is likely to stick in the closed position (hot manifold) which would delay the warm-up of the intake manifold and cause lean misfire due to vaporization of only the lighter fractions of the fuel (Ref. 2 and 78). This will increase HC emissions during the cold start (Ref. 16). Therefore, the following emission increase factors were assigned:

	HC	CO	NO_x
1972-1974	0.1	0.0	0.0
1975	1.0	0.1	0.0

Electric Assisted and Staged Pulldown Chokes: Failure of these components results in normal thermostatic choke opening. This increases emissions of HC and CO slightly but decreases NO_x (Ref. 27). The relative increase in CO emissions on catalyst-equipped vehicles is greater than on noncatalyst vehicles due to the relatively larger cold start effect and the lower emission standard.

	HC	CO	NO_x
1972-1974	0.1	0.1	0.0
1975	0.1	1.0	0.0

Decel Valve: Defective decel valves cause an increase in emissions of HC and CO during deceleration (high vacuum) conditions. Since this defect affects only deceleration conditions, the effect on composite FTP emission is relatively small. The same emission increase factors assigned to idle stop solenoids and rich idle mixture adjustment were assigned for the decel valve:

	HC	CO	NO_x
1972-1974	0.1	1.0	0.0
1975	1.0	1.0	0.0

Distributor Vacuum Deceleration Valve: The distributor vacuum deceleration valve applies full manifold vacuum to the distributor during deceleration (high vacuum). This increases engine speed to improve combustion during the deceleration period. Failure of the valve causes full vacuum advance at all times which will increase HC and NO_x but reduce CO emissions (Ref. 3 and 27). The following emission increase factors were assigned.

	HC	CO	NO_x
1972-1974	0.1	0.0	2.0
1975	0.1	0.0	2.0

Distributor Starting Solenoid: Failure of the distributor starting solenoid causes hard cold starting and prolonged cranking. This may increase cold start emissions due to flooding from excess gasoline. The following emission increase factors, therefore, were assigned on the basis of engineering judgment:

	HC	CO	NO_x
1972-1974	1.0	1.0	0.0
1975	1.0	1.0	0.0

Thermal Vacuum Valve: The thermal vacuum valve or switch is employed to switch spark advance from ported to manifold vacuum. When associated with EGR, TCS, SCS, CEC, or OSAC systems, the TVV has been included in those categories. Failure of a TVV results in normal spark advance at all temperatures. Therefore, the following emission increase factors were assigned:

	HC	CO	NO_x
1972-1974	0.1	0.0	2.0
1975	0.1	0.0	2.0

Distributor Vacuum Valve: Defective distributor vacuum valves result in small changes in spark advance because the vacuum source is shifted between the EGR and spark advance ports for improved driveability. Therefore, the following emission increase factors were assigned on the basis of engineering judgment:

	HC	CO	NO_x
1972-1974	0.1	0.0	0.1
1975	0.1	0.0	0.1

4.2.2 Probability of Component Failure Factor

Each component category was assigned a factor representing the probability of failure between installation and expiration of the vehicle OEM emission warranty or the component design life. Supporting data were either unavailable or contradictory. Therefore, the factors were assigned based on the general criteria discussed in paragraph 4.1.3. The same probability factors were assigned to similar components (i.e.; TVV, speed sensors) even if they were used in different applications. In determining the values for failure probability, consideration was given to the following factors:

- Operating environment (temperature, gas characteristics)
- Normal operating state (activated, deactivated)
- Operating principle (vacuum, mechanical, electrical)
- Similarity to OEM component
- Need for adjustment, calibration, or alignment at time of installation

4.2.2.1 Carburetion Systems

In addition to normal component deterioration, after-market carburetor components are subject to defects in installation which can result in a failure condition existing from the time of installation. The probability of failure at installation or shortly thereafter is relative with nominally OEM replacement carburetors having the lowest probability of failure (PF=0.30), factory rebuilt carburetors having a higher probability of failure (PF=0.50), and mechanic or owner rebuilt carburetors having a relatively high probability of failure (PF=0.70).

Carburetor components and control devices are generally quite reliable and are not usually reported as becoming defective during durability testing (Ref. 35, 47, 72 and 73). In general, components operated mechanically or electrically are more reliable than vacuum-operated devices (Ref. 3).

The following electrical or mechanical components were assigned a low probability of failure (PF=0.10) on the basis of their passive function and freedom from adjustment. The fuel filter is a standard replacement part with recommended replacements every 2 years. These components are rarely, if ever, associated with emissions failures (Ref. 12, 16, 78, 94, 101 and 102):

- Electric assist choke heaters
- Idle enrichment systems
- Metering jets
- Gaskets
- Fuel filters

The following mechanical- or vacuum-activated components were assigned a slightly higher probability of failure (PF=0.30) because of repetitive cyclical operation and sensitivity to adjustment:

- Idle stop solenoids
- Throttle dashpots and positioners
- Metering rods
- Choke mechanisms
- Float and needle valves
- Accelerator pumps
- Power valves
- Vacuum break valves
- Staged choke pulldowns

4.2.2.2 Ignition System

Ignition system components, particularly spark plugs and ignition wires, are closely related to emissions and performance degradation. Components known to be emissions- and performance-sensitive are routinely serviced or replaced at intervals intended to occur before the expected failure. In many cases, PVIM studies have shown that components which appear marginal or defective actually have satisfactory emissions (Ref. 12 and 94).

The following primary ignition system components were assigned a low probability of failure (PF=0.10) on the basis of long design and service lives, (Ref. 70), freedom from initial adjustment, and broad performance tolerances before misfire actually occurs:

- Condensers
- Distributor drive mechanisms
- Electronic ignition triggers
- Coils
- Ballast resistors
- Electronic ignition (CD) circuits

The following primary ignition system components were assigned a slightly higher probability of failure

(PF= 0.30) based on more rapid deterioration due to severe operating conditions or lose of modification. These components, however, are designed to last the certification period (Ref. 70):

- Ignition wires
- Distributor caps and rotors
- Distributor mechanical advance mechanisms
- Distributor vacuum advance diaphragms
- Dual diaphram vacuum advance mechanisms

The following components were assigned a relatively high probability of failure (PF=0.50) based on recommended replacement intervals which are shorter than the certification period and the need to carefully install and adjust them:

- Points
- Spark delay valves

The following component was assigned a relatively higher probability of failure (PF=0.70) based on durability data, garage experience and PVIM data.

- Spark plugs

4.2.2.3 Air Induction System

The air induction system components are reliable and durable. With the exception of the air cleaner, all components have design lives in excess of 50,000 miles. The air cleaner is routinely replaced or serviced several times during the certification period. Therefore, low probability of failure (PF=0.10) was assigned for the air cleaner.

The following air induction components were assigned a low probability of failure (PF=0.10) based on their durability:

- TAC shrouds and hoses
- TAC thermostats
- Turbochargers

The following air induction components were assigned a slightly higher probability of failure (PF=0.30) based on more rapid deterioration or less durable construction.

- TAC vacuum motors
- TAC vacuum hoses
- TAC fresh air inlets
- Superchargers

After-market specialty intake manifolds were assigned a relatively high probability of an emissions increase (PF=0.5) on the basis of published data.

4.2.2.4 Fuel Injection System

The probability of failure of fuel injection components was based on a design life of 50,000 miles and engineering analysis of recommended maintenance practice and system design.

The following mechanical components were assigned a very low probability of failure (PF=0.01) based on durability and broad tolerance of emissions to performance variations:

- Accumulator
- Fuel pump
- Fuel distribution manifold

The following mechanical and/or electrical fuel injection components were assigned a low probability of failure (PF=0.30) based on adjustments or deterioration:

- Pressure sensors/regulators
- Air sensors/switches
- Temperature sensors/switches
- Triggering switches
- Electronic fuel injection circuits

The following mechanical components were assigned a moderate probability of failure (PF=0.50) on the basis of the need for periodic adjustment or replacement due to mechanical deterioration:

- Throttle valve(s)
- Injection valves
- Solenoid injectors
- Starting valves

4.2.2.5 Engine System

The following engine components were assigned a very low probability of failure (PF=0.01) since they should last considerably beyond the end of the certification period:

- Valve cam lobes
- Valve guides
- Piston rings
- Gaskets
- Camshafts
- Exhaust manifolds and headers

A low probability of failure (PF=0.10) was assigned to failure of the valve, valve seat, and valve seals since burned or leaking valves can be caused by numerous operating conditions before 100,000 miles.

A slightly higher probability of failure (PF=0.30) was assigned to failure of the valve lifters and springs because of the need to periodically adjust some of these valve mechanisms on some engines.

4.2.2.6 Emission Control Systems

The probability of failure of emission control components depends on design life, typical maintenance practice, and operating environment. The following paragraphs are devoted to discussions of the probability of failure of specific component categories.

PCV Valve, and Fresh Air Filter - The PCV valve and filter is replaced on most engines every 2 years or 24,000 miles. The replacement is designed to occur prior to significant deterioration of the PCV system. Therefore, a low probability of failure was assigned (PF=0.30).

PCV and Other Vacuum Hoses - The PCV hoses and other vacuum hoses are normally not serviced during the certification period. The probable failure of these components is relatively low, even over the life of the vehicle. Therefore, the probability of failure was defined (PF= 0.10).

EVAP Canister - The carbon canister is replaced during the certification period on some engines. However, on most vehicles, the canister is not included in mandatory replacement. Activated carbon is durable, providing that it is purged adequately and pore spaces are not clogged with oil or particulates. Therefore, a relatively low probability of failure was assigned (PF=0.30).

EVAP Fresh Air Filter, Control Valves, and Fuel Tank Cap - These components of the EVAP system are reliable and have low probability of failure. The filter is replaced, usually every 2 years or 24,000 miles, even on systems where the carbon canister is not replaced. Therefore, a low probability of failure was assigned for these components (PF=0.10).

AI System - Components of the AI system are rugged and designed to be service free. AI failure is rarely identified in surveillance or PVIM programs. Therefore, a low probability of failure is assigned to all of the AI system components (PF=0.10) except for the distribution manifold and internal engine passages which were assigned the lowest probability of failure (PF=0.01).

EGR Valves, and Back Pressure Sensor - These two components are exposed to particulates, water vapor, acids, and hot gases in the exhaust system. They are subject to clogging, sticking, and corrosion. These systems may be visually inspected but are generally not subject to performance testing or mandatory replacement. Therefore, a high probability of failure was assigned to these components (PF=0.70).

Thermal Vacuum Valves, Vacuum Amplifier, Reducing and Check Valves - These components are not serviceable and not included in scheduled maintenance. They are generally reliable but are subject to sticking, diaphragm deterioration, and valve leakage. These components were assigned a relatively low probability of failure (PF=0.30).

Electrically-Operated Vacuum Solenoid Valves, Sensors, and Electronic Components - Vacuum solenoid valves are used in various systems to regulate vacuum signals. Various temperature, transmission, and speed sensors provide signals to operate solenoid valves, status lights, and electronic control circuits. Electrical components including ESC electronic modules, time delay and latching relays are highly reliable and not subject to scheduled maintenance. These electrical and electronic components were assigned a low probability of failure (PF=0.10).

Heat Riser - The heat riser is exposed to hot, corrosive, and particulate laden exhaust gases. A relatively high probability of failure was, therefore, assigned (PF=0.70).

Decel Valve - The decel valve is a relatively reliable component once it has been correctly adjusted. No maintenance is specified and, therefore, a relatively low probability of failure was assigned (PF=0.30).

4.2.3 Probability of Repair Factor

The factor representing the probability of repairing a defective component was assigned using the criteria defined in paragraph 4.1.4. These factors were the same as defined for OEM components since the symptoms of failure for after-market components are similar. The probability of repair was based on the typical diagnostic and maintenance steps performed at scheduled maintenance, and on the detectability of the defect to the vehicle driver or mechanic.

4.2.3.1 Carburetion System

Most carburetion-related components, with the exception of the fuel filter and idle adjustment, are not included in scheduled maintenance. Carburetor replacement or rebuilding is usually performed when noticeable performance degradation occurs which can be attributed to leaking or sticking components. Emission increases can occur, however, before any obvious performance deterioration becomes apparent.

The following carburetion system components do not have a significant performance impact, are not included in normal scheduled or corrective maintenance, and are expensive to repair (Ref. 3). They were, therefore, assigned a high probability of no repair (PF=0.90).

- New or rebuilt replacement carburetors
- Metering jets
- Metering rods
- Chokes

- Gaskets
- Float and valve
- Idle enrichment systems
- Vacuum break valves
- Power valves
- Accelerator pumps

The following carburetion system components may have a performance impact depending on the degree of failure and compensating adjustments made to idle speed and mixture. These components are also readily adjustable or replaceable (Ref. 3 and 27). They were assigned a moderate probability of no repair (PR=0.50).

- Idle stop solenoid
- Dashpot
- Throttle positioner

The fuel filter is usually replaced during scheduled tune-ups (Ref. 3, 27, and 101). A low probability of no repair (PR=0.30) was therefore assigned.

4.2.3.2 Ignition System

Ignition system defects leading to misfire are typically very noticeable and have a low probability of no repair. Basic ignition system maintenance is routinely performed including substantial preventive maintenance. Some components, however, are expensive (distributors) and may not be repaired due to consumer resistance until significant performance deterioration has occurred (Ref. 3 and 27).

The following ignition system components do not have a significant performance effect and are not part of normal ignition tune-up service; or, in the case of distributor drives, are quite expensive (Ref. 3). The probability of not replacing these components was, therefore, quite high (PF=0.90).

- Distributor drives
- Spark delay valves
- Coils
- Ballast resistors

The following components are not part of routine tune-up practice, but have a significant performance impact. They will probably be repaired if defective. Therefore, a moderate probability of no repair was assigned (PR=0.50).

- Mechanical advances
- Vacuum advance including dual diaphragm distributors
- Ignition wires
- Distributor rotors
- Distributor caps

The following components are included in routine tune-up practice and/or they have a significant performance impact. They are expected to be replaced if defective (Ref. 3 and 27). Therefore, a low probability of no repair was assigned (PR=0.10).

- Points
- Condensers
- Electronic ignition trigger switches
- Spark plugs
- Electronic ignition circuits

4.2.3.3 Air Induction Systems

The air induction system regulates air flow into the engine. Physical defects may be noticeable in external components. They may not be repaired, however, due to relatively small performance degradation (Ref. 3). Therefore, the following components were assigned a high probability of no repair (PR=0.90).

- TAC shrouds and hoses
- TAC thermostats
- TAC vacuum motors
- TAC vacuum hoses
- TAC fresh air inlets
- Intake manifolds (OEM replacement or specialty)

Turbochargers and superchargers provide additional power and their failure is readily detectable (Ref. 3). They will probably be repaired in order to regain lost performance. Therefore, a low probability of no repair is assigned (PR=0.30).

The air filter is the only air induction component on which maintenance (replacement) is recommended and generally performed. However, there is no noticeable performance degradation and the rate of deterioration is low. Therefore, a moderate probability of no replacement was assigned for air filters (PR=0.50).

4.2.3.4 Fuel Injection System

Performance of the vehicle is relatively insensitive to defects in the fuel injection system since most defects result in overfueling. This is particularly true of mechanical fuel injection systems. Therefore, a high probability of no repair (PR=0.90) was assigned to the following components:

- Accumulators
- Fuel pressure sensors/regulators
- Throttle linkage and valves
- Injection valves
- Injectors
- Temperature sensors/switches
- Fuel distribution manifolds
- Starting valves.

Several components can have significant effect on the performance of electronic fuel injection systems. These components regulate the timing and quantity of fuel delivered to each cylinder. Failure of the components may disable the vehicle or significantly alter the air fuel ratio over the range of speed and load conditions. These components were, therefore, assigned a low probability of no repair (PR=0.10).

- Air sensors/switches
- Triggering switches
- Electronic fuel injection control circuits

4.2.3.5 Engine Systems

The probability of repairing any engine system during the certification period is very low because of the high expense and relatively small effect on performance from typical defects. Therefore, the probability of no repair assigned to all engine system components was PR=0.90.

The probability of adjusting valve lash or lifter operation, however, is greater since this is recommended for some 4-cylinder engines. Therefore, the probability of repair assigned to lifter/springs was PR=0.50.

4.2.3.6 Emission Control Systems

The probability of repairing defective emission control systems depends strongly on the performance effect of the failure. Unfortunately, most emission control components do not have severe performance effects (i.e.; performance and fuel economy may improve, or the performance decrement is not detectable). In addition, failure of these components is relatively unusual and diagnostic procedures are complicated. Therefore, mechanics rarely attempt to diagnose emission control system failures unless ignition and carburetion components have been determined to be satisfactory and performance is still poor. Several exceptions to the above comments do exist, however. These are components external to the engine which have specified maintenance schedules and include the PCV valve, EVAP canister, AI pump and hoses and all vacuum lines. These and other components are discussed below.

PCV Valve - The PCV valve can cause rough idle if severely restricted (Ref. 3). However, the PCV valve is a scheduled maintenance component and subject to periodic replacement during the certification period. Therefore, a relatively low probability of no repair was assigned (PR=0.30).

PCV Fresh Air Filter - The PCV air filter is not normally serviced during the certification period, even though it may be recommended. Failure of this component is not likely to be diagnosed due to the small performance effect. Therefore, a high probability of no repair was assigned (PR=0.70).

EVAP Canister and Fresh Air Filter - The EVAP canister and its air filter do not have a noticeable performance affect if defective. However, the canister, or at least the filter, is scheduled for periodic replacement. Therefore, a moderate probability of no repair was assigned (PR=0.50).

PCV, EVAP, EGR, and Other Vacuum and Amplifier Hoses - All hoses providing vacuum signals can cause manifold leaks if defective. The vacuum leaks are likely to cause intermittent misfire expecially at idle and during deceleration. The misfire is likely to be corrected because of rough idle and vacuum hoses are an easy and inexpensive component to replace. Therefore, a relatively low probability of no repair was assigned to all vacuum hose defects. (PR=0.50).

EVAP Control Valves and Fuel Tank Cap - Failure of these components will have essentially no performance affect and cannot be readily diagnosed. Therefore, a high probability of no repair was assigned (PR=0.90).

AI Pump, Belts and Hoses - Failure of these components may create objectional noise leading to corrective maintenance. No vehicle performance degradation should be noticed, however, unless a belt fails and disables some other accessory. Driveability of the vehicle should not be affected, however. Therefore, a high probability of no repair was assigned (PR=0.70) to the belts, hoses and pump. The AI manifold and injector nozzle, however, were very unlikely to be repaired (PR=0.90) due to the fact that they were integral to the engine.

AI Check, Bypass and Diverter Valves - These components will result in backfiring in the exhaust system, if defective. No other performance effect such as degraded driveability should be noticed, however. A moderate probability of no repair was, therefore, assigned (PR=0.50) since the cost of replacing these components is relatively low.

EGR Valves - EGR valve inspection is included in most recommended maintenance schedules. However, clogging of the valve is likely to improve driveability so that there is little incentive to diagnose and correct defective EGR valves. A high probability of no repair was, therefore, assigned (PR=0.70).

EGR Back Pressure Valves - Back pressure valves have been used for only two model-years. No data is available on their performance. However, it is likely that they will become clogged and inoperative. Since they are not generally included in the recommended maintenance schedules, it is even less likely that defects will be detected than in the EGR valve itself. The probability of no repair was therefore, very high (PR=0.90).

Thermal Vacuum Valves, Vacuum Reducing and Check Valves - These valves regulate spark advance control and EGR systems. They are not included in recommended scheduled maintenance. Their failure is generally not detectable and may improve driveability under some conditions. A high probability of no repair was therefore, assigned (PR=0.90).

Vacuum Solenoid Valves, Temperature, Transmission, and Speed Switches and Relays - These components are not included in recommended scheduled maintenance. Failure is also unlikely and may lead to improved driveability. Therefore, the probability of no repair was quite high (PR=0.90).

Heat Riser - A stuck heat riser valve may create cold start problems. However, service on it is difficult due to its location and may involve removal of the manifold. Since normal hot running of the engine is not degraded, it is very unlikely that corrective repair would be performed. Therefore, a high probability of no repair was assigned (PR=0.90).

Decel Valve and Distributor Vacuum Deceleration Valve - The decel valves regulate air fuel mixture during deceleration. Defects in these valves generally are not detectable since they occur during deceleration. Idle performance can also be compensated for by idle mixture or speed adjustments. Therefore, a high probability of no repair was assigned (PR=0.90) to both components.

Electric Assisted Choke - A defective electric assisted choke will result in normal choke action and possibly improved driveability. Therefore, the probability of no repair was very high (PR=0.90).

4.2.4 Component Sales Volume

Actual component sales data were not available for most of the component categories for the reasons stated in Section 2. This data was, however, estimated from three independent sources which provided three alternative criticality rankings. The three sources were the following:

- Component usage based on OEM engine configurations, recommended replacement intervals and sales volumes
- Service and repair actions reported by commercial garages
- Component sales by warehouse distributors

The input values assigned to each set of these sales volume factors are discussed below and are tabulated in Table 4-4. Appendix B presents the relative sales volume factors derived from the sales volume input factors.

4.2.4.1 OEM Sales Volume Factors

These sales volume factors were developed during Phase I (Ref. 107). The input factors used in Phase II represent the sum of the 1972-1974 model year and 1975 model year sales volume factors tabulated in the Phase I final report. The after-market OEM sales factors were multiplied by 100 to give them the same scale as for after-market warehouse and garage sales factors. The development of the OEM sales factors is described in the Phase I final report. Briefly, however, they were based on the following criteria:

Table 4-4. SALES VOLUME FACTORS

PART CODE	PART NAME	SALES DATA OEM SALES	SALES DATA GARAGE SALES	SALES DATA WAREHOUSE SALES	SALES VOLUME FACTORS OEM SALES	SALES VOLUME FACTORS GARAGE SALES	SALES VOLUME FACTORS WAREHOUSE SALES
1. 1. 1	NEW CARB	99	1515	83164	0.0062	0.0014	0.0136
1. 1. 2	REBUILT CARB	99	2567	80112	0.0062	0.0024	0.0131
1. 1. 3	SPECIALTY CARB	5	75	4158	0.0003	0.0001	0.0007
1. 2. 1	IDLE STPSOLENOID	75	0	16600	0.0047	0.0	0.0027
1. 2. 2	THROTTLE DASHPOT	14	0	8567	0.0009	0.0	0.0014
1. 2. 3	THRTTL POSITIONR	7	0	0	0.0004	0.0	0.0
1. 3. 1	METERING JETS	181	0	0	0.0114	0.0	0.0
1. 3. 2	METERING RODS	69	0	0	0.0043	0.0	0.0
1. 3. 3	VAC BRK VALVE	100	0	17844	0.0063	0.0	0.0029
1. 3. 4	CHOKE MECHANISM	98	0	43514	0.0062	0.0	0.0071
1. 3. 5	ACCELERATOR PUMP	99	0	0	0.0062	0.0	0.0
1. 3. 6	POWER VALVES	98	0	0	0.0062	0.0	0.0
1. 3. 7	GASKETS	98	0	0	0.0062	0.0	0.0
1. 3. 8	REBUILDING KITS	99	8217	82236	0.0062	0.0075	0.0134
1. 3. 9	FLOAT AND VALVE	99	8271	0	0.0062	0.0076	0.0
1. 3.10	IDLE ADJUSTMENT	0	0	0	0.0	0.0	0.0
1. 3.11	IDLE ENRICHMENT	3	0	0	0.0002	0.0	0.0
1. 4. 0	FUEL FILTER	381	36313	129057	0.0240	0.0333	0.0211
2. 1. 0	POINTS	231	61200	179332	0.0146	0.0561	0.0293
2. 2. 0	CONDENSER	68	61200	179332	0.0043	0.0561	0.0293
2. 3. 1	CAP	98	61200	93636	0.0062	0.0561	0.0153
2. 3. 2	ROTOR	99	61200	109916	0.0062	0.0561	0.0180
2. 3. 3	MECH ADVANCE	5	0	2400	0.0003	0.0	0.0004
2. 3. 4	VACUUM ADVANCE	99	0	10260	0.0062	0.0	0.0017
2. 3. 5	DISTRIBUTOR DRIV	99	0	12800	0.0062	0.0	0.0021
2. 3. 6	DUAL DIAPHM DIST	5	0	0	0.0003	0.0	0.0
2. 3. 7	SPARK DELAY VLV	43	0	20200	0.0027	0.0	0.0033
2. 4. 0	MAG/OPT TRIGGERS	31	4868	408	0.0020	0.0045	0.0001
2. 5. 0	SPARK PLUGS	4283	414481	3903000	0.2700	0.3802	0.6374
2. 6. 0	IGNITION WIRES	716	92604	138668	0.0451	0.0849	0.0226
2. 7. 0	COIL	99	0	28980	0.0062	0.0	0.0047
2. 8. 0	CAPACITIVE DISCH	5	0	1440	0.0003	0.0	0.0002
2. 9. 0	BALLAST RESISTOR	99	0	0	0.0062	0.0	0.0
2.10. 0	EI CONTROL CIRCT	31	4868	3600	0.0020	0.0045	0.0006
2.11. 0	IGN TIMING ADJ	99	17252	0	0.0062	0.0158	0.0
3. 1. 1	TAC SHROUD	97	0	16000	0.0061	0.0	0.0026

Table 4-4. SALES VOLUME FACTORS (Continued)

PART CODE	PART NAME	SALES DATA OEM SALES	GARAGE SALES	WAREHOUSE SALES	SALES VOLUME FACTORS OEM SALES	GARAGE SALES	WAREHOUSE SALES
3. 1. 2	TAC THERMOSTAT	97	0	6800	0.0061	0.0	0.0011
3. 1. 3	TAC VAC MOTOR	83	0	10000	0.0052	0.0	0.0016
3. 1. 4	TAC VAC HOSES	83	0	8476	0.0052	0.0	0.0014
3. 1. 5	TAC FRESH AIR IN	1	0	600	0.0001	0.0	0.0001
3. 2. 0	AIR CLEANER ELEM	335	53109	189956	0.0211	0.0487	0.0310
3. 3. 0	INTAKE MANIFOLD	5	0	888	0.0003	0.0	0.0001
3. 4. 0	TURBOCHARGER	1	0	0	0.0001	0.0	0.0
3. 5. 0	SUPERCHARGER	1	0	0	0.0001	0.0	0.0
4. 1. 0	MFI ACCUMULATOR	0	0	0	0.0	0.0	0.0
4. 2. 0	FI HI PRES PUMP	1	11	1121	0.0001	0.0000	0.0002
4. 3. 0	FI PRES SENS/REG	1	0	0	0.0001	0.0	0.0
4. 4. 0	FI THROTTLE VALV	1	0	2400	0.0001	0.0	0.0004
4. 5. 0	MFI VALVES	4	0	0	0.0003	0.0	0.0
4. 6. 0	EFI AIR SENS/SWH	0	0	0	0.0	0.0	0.0
4. 7. 0	EFI TEMPSENS/SWH	0	0	0	0.0	0.0	0.0
4. 8. 0	FI DIST MANIFOLD	1	0	0	0.0001	0.0	0.0
4. 9. 0	EFI INJECTORS	1	0	0	0.0001	0.0	0.0
4.10. 0	EFI TRIGGER SWCH	0	0	0	0.0	0.0	0.0
4.11. 0	EFI CONTROL CIRC	0	0	0	0.0	0.0	0.0
4.12. 0	FI STARTING VALV	1	0	0	0.0001	0.0	0.0
4.13. 0	FI IDLE ADJUST	0	0	0	0.0	0.0	0.0
5. 1. 1	VALVE LIFTER/SPR	750	17419	111097	0.0473	0.0160	0.0181
5. 1. 2	VALVE CAM LOBES	37	873	3404	0.0023	0.0008	0.0006
5. 1. 3	VALVE GUIDES	725	13248	62544	0.0457	0.0122	0.0102
5. 1. 4	VALVE SEALS	725	13248	62544	0.0457	0.0122	0.0102
5. 1. 5	EXHAUST VALVES	725	19248	62544	0.0457	0.0177	0.0102
5. 2. 0	PISTON RINGS	725	33726	61312	0.0457	0.0309	0.0100
5. 3. 0	PISTON/RODS	725	0	17468	0.0457	0.0	0.0029
5. 4. 1	HEAD GASKETS	173	2716	61920	0.0109	0.0025	0.0101
5. 5. 0	CAMSHAFTS	5	873	61312	0.0003	0.0008	0.0100
6. 1. 1	PCV VALVE	343	35778	109660	0.0216	0.0328	0.0179
6. 1. 2	PCV HOSES	99	0	0	0.0062	0.0	0.0
6. 1. 3	PCV FRSHAIR FLTR	244	0	43344	0.0154	0.0	0.0071
6. 1. 4	PCV OIL SEPARATR	2	0	0	0.0001	0.0	0.0
6. 2. 1	EVAP CANISTER	101	0	0	0.0064	0.0	0.0
6. 2. 2	EVAP HOSES	99	0	0	0.0062	0.0	0.0

Table 4-4. SALES VOLUME FACTORS (Continued)

PART CODE	PART NAME	SALES DATA OEM SALES	GARAGE SALES	WAREHOUSE SALES	SALES VOLUME FACTORS OEM SALES	GARAGE SALES	WAREHOUSE SALES
6. 2. 3	EVAP FRSH AIR	271	0	18460	0.0171	0.0	0.0030
6. 2. 4	EVAP VPRLIG SEP	97	0	0	0.0061	0.0	0.0
6. 2. 5	EVAP VAPOR CONTR	49	0	0	0.0031	0.0	0.0
6. 2. 6	FUEL TANK/CAP	98	0	0	0.0062	0.0	0.0
6. 3. 1	AI MANIFOLD	96	0	0	0.0061	0.0	0.0
6. 3. 2	AI HOSES	50	0	8748	0.0032	0.0	0.0014
6. 3. 3	AI AIR FILTER	50	0	0	0.0032	0.0	0.0
6. 3. 4	AI CHECKVALVES	84	0	0	0.0053	0.0	0.0
6. 3. 5	AI BYPASS/DVRTR	50	0	2636	0.0032	0.0	0.0004
6. 3. 6	AI GULP VALVES	0	0	0	0.0	0.0	0.0
6. 3. 7	AI PUMP/BELTS	50	0	716	0.0032	0.0	0.0001
6. 4. 1	EGR VALVES	75	0	5800	0.0047	0.0	0.0009
6. 4. 2	EGR HOSES/SEALS	72	0	0	0.0045	0.0	0.0
6. 4. 3	EGR THERMO VALVE	62	0	0	0.0039	0.0	0.0
6. 4. 4	EGR SOLENOID VLV	27	0	0	0.0017	0.0	0.0
6. 4. 5	EGR TEMP SWITCH	13	0	0	0.0008	0.0	0.0
6. 4. 6	EGR SPEED/TRANS	11	0	0	0.0007	0.0	0.0
6. 4. 7	EGR TIME DELAY	13	0	0	0.0008	0.0	0.0
6. 4. 8	EGR VAC AMP	21	0	3000	0.0013	0.0	0.0005
6. 4. 9	EGR VAC REDUCER	1	0	0	0.0001	0.0	0.0
6. 4.10	EGR CARB SPACER	11	0	0	0.0007	0.0	0.0
6. 4.11	EGR BACKPRES SEN	4	0	0	0.0003	0.0	0.0
6. 4.12	EGR CHECKVALVE	1	0	0	0.0001	0.0	0.0
6. 5. 1	TCS VAC SOLENOID	31	0	5620	0.0020	0.0	0.0009
6. 5. 2	TCS VAC HOSES	33	0	0	0.0021	0.0	0.0
6. 5. 3	TCS TIME DELAY	21	0	0	0.0013	0.0	0.0
6. 5. 4	TCS CEC VALVE	2	0	0	0.0001	0.0	0.0
6. 5. 5	TCS THERMO VALVE	5	0	0	0.0003	0.0	0.0
6. 5. 6	TCS TRANS SWITCH	33	0	0	0.0021	0.0	0.0
6. 5. 7	TCS REVERSE RELY	0	0	0	0.0	0.0	0.0
6. 5. 8	TCS TEMP SWITCH	38	0	5300	0.0024	0.0	0.0009
6. 6. 1	SCS VACUUM SOLEN	2	0	0	0.0001	0.0	0.0
6. 6. 2	SCS VACUM LINE	2	0	0	0.0001	0.0	0.0
6. 6. 3	SCS TIME DELAY	0	0	0	0.0	0.0	0.0
6. 6. 4	SCS SPEED SWITCH	2	0	0	0.0001	0.0	0.0
6. 6. 5	SCS THERMO VALVE	1	0	0	0.0001	0.0	0.0

Table 4-4. SALES VOLUME FACTORS (Continued)

PART CODE	PART NAME	SALES DATA OEM SALES	SALES DATA GARAGE SALES	SALES DATA WAREHOUSE SALES	SALES VOLUME FACTORS OEM SALES	SALES VOLUME FACTORS GARAGE SALES	SALES VOLUME FACTORS WAREHOUSE SALES
6. 7. 1	OSAC VAC ORIFICE	12	0	0	0.0008	0.0	0.0
6. 7. 2	OSAC VAC HOSES	12	0	0	0.0008	0.0	0.0
6. 7. 3	OSAC THERMO VALV	0	0	0	0.0	0.0	0.0
6. 7. 4	OSAC VAC BYPASS	5	0	0	0.0003	0.0	0.0
6. 7. 5	OSAC TEMP SENSOR	5	0	0	0.0003	0.0	0.0
6. 8. 1	ESC ELEC MODULE	5	0	0	0.0003	0.0	0.0
6. 8. 2	ESC HOSES	4	0	0	0.0003	0.0	0.0
6. 8. 3	ESC VAC VALVES	4	0	0	0.0003	0.0	0.0
6. 8. 4	ESC TEMP SWITCH	4	0	0	0.0003	0.0	0.0
6. 8. 5	ESC SPEED SWITCH	7	0	0	0.0004	0.0	0.0
6. 9. 1	CAT BODY	0	0	0	0.0	0.0	0.0
6. 9. 2	CAT ACTIVE MEDIA	0	0	0	0.0	0.0	0.0
6. 9. 3	CAT INERTMEDIA	0	0	0	0.0	0.0	0.0
6. 9. 4	CAT SHELL	0	0	0	0.0	0.0	0.0
6.10. 1	HEAT RISER	60	0	6446	0.0038	0.0	0.0011
6.10. 2	ELEC ASSIST CHKE	29	0	0	0.0018	0.0	0.0
6.10. 3	STAGED PULLDOWN	6	0	0	0.0004	0.0	0.0
6.10. 4	DECEL VALVE	4	0	3024	0.0003	0.0	0.0005
6.10. 5	DIST VACDECL VLV	1	0	0	0.0001	0.0	0.0
6.10. 6	DIST START SOLEN	2	0	0	0.0001	0.0	0.0
6.10. 7	THERMO VAC VALV	20	0	20000	0.0013	0.0	0.0033
7. 1. 0	COOLING THERMST	101	16139	0	0.0064	0.0148	0.0
7. 2. 0	ELECTRICAL SYSTM	100	0	0	0.0063	0.0	0.0
7. 3. 1	HIGH PERF EXHAST	9	1000	396	0.0006	0.0009	0.0001
7. 3. 2	EXHAUST MANIFOLD	173	46941	600	0.0109	0.0431	0.0001
8. 1. 0	DISTR VACUUM VLV	0	0	0	0.0	0.0	0.0

- Sales or production volume of each engine family.
- Cumulative scrappage of vehicles by model-year.
- Number of each component installed in a single unit from each engine family.
- Number of replacements of each component recommended during the certification design life.

Some component categories were assigned different after-market sales volume factors than were used as OEM factors. These components were either classed only as OEM or after-market, or the after-market usage would have been substantially different than OEM usage, i.e., certain specialty equipment not intended for OEM replacement. The following after-market sales volume factors were different than the OEM sales volume:

- Idle mixture and timing adjustments were deleted, i.e., assigned zero sales volume, since they are not physical components subject to after-market replacement.
- Carburetor rebuilding kits were assigned the OEM carburetor sales volume factor.
- Specialty, i.e., performance, carburetors were assigned 5 percent of the new carburetor sales volume factor.
- Mechanical advance was assigned 5 percent of the OEM distributor sales volume factor to reflect specialty modifications to the centrifugal advance curve.
- CD electronic ignition retrofit systems were assigned 5 percent of the OEM distributor sales volume factor.

- Intake manifolds were assigned 5 percent of the OEM engine sales volume factor.
- Turbochargers and superchargers were each assigned 1 percent of the OEM engine sales volume factor.
- Specialty cams, camshafts, headers, and valves were assigned 5 percent of the OEM sales volume factor.
- After-market catalyst systems were assigned zero sales volume since they are expected to remain an OEM supplied replacement component.

4.2.4.2 Garage Sales Volume Factors

These sales volume factors were based on sales reported in the 1975 Service Job Analysis (Ref. 106). The categories reflected general service actions and, with some exceptions, did not report sales volumes by individual component categories. For those component categories with reported sales volume, the actual number in thousands was used. Sales volume factors of most other categories were assigned values of zero. However, some factors were assigned values on the basis of engineering judgment and data from the warehouse sales survey. These factors and the assumed values are discussed below:

- Specialty, i.e., performance, carburetors were assigned 5 percent of the new installed carburetor sales.
- Individual carburetor components except jets and carburetor kits were assigned 10 percent of the overhauled carburetors.
- Condensers were assigned the same sales volume factor as points, since these components are generally replaced at the same time.

- Caps, rotors, and coils were assigned 25 percent of the total tune-up sales volume.
- Distributors and distributor components were assigned 5 percent of total tune-up sales volume.
- Replacement EI trigger components were assigned the sum of trigger wheel and pole piece replacements.
- Spark plug replacements were assigned the sum of new replacement and regapped plugs.
- Cams, and camshafts, were both assigned the sum of new and reground camshafts.
- Valve guides, seals, and exhaust valves were assigned the sum of valve replacements and valve grinding jobs.
- Rings were assigned the number of replacement sets installed.
- Pistons were assigned 50 percent of the sum of crankshafts, rod bearings and main bearings.
- Head gaskets were assigned the sum of conditioned cylinder blocks and valve jobs.
- PCV filters were assigned 50 percent of the air filter replacements.
- All other components were assigned sales volume factors of zero.

4.2.4.3 Warehouse Sales Volume Factors

These sales volume factors were based on a limited survey of 25 warehouse distributors. Five responses were received which represented approximately 1 percent of the membership of the Automotive Warehouse Distributors Association. In addition, the sales of OEM Products, Inc., a distributor of emission control components was added to the warehouse sales survey results. OEM Products, Inc., claims to distribute components to 1 percent of the warehouse distributors. It was, therefore, felt that a direct sum of the six surveys was as accurate as any type of weighted sum.

The results of the survey were used directly for all components explicitly listed. Some component categories were not included, however. The following criteria was used to assign nonzero sales volume factors to these components.

- Specialty, i.e., performance, carburetors were assigned 5 percent of the new replacement carburetor sales volume.
- Pumps for fuel injection systems were assigned 1 percent of total fuel pump sales.
- All vacuum solenoid sales were assigned to TCS solenoid category.
- Air injection pump sales were assigned to the AI pump and belt category.
- All other components were assigned zero sales volume.

4.3 RANKINGS OF EMISSION-CRITICAL AFTER-MARKET COMPONENTS

The rankings of emission-critical after-market components are shown in Tables 4-5 through 4-7. These rankings are abstracted from the tables shown in Appendix A which contain detailed rankings for the six combinations of model-year group and sales volume data source. Tables 4-5 through 4-7 present independent rank-ordered lists for HC, including evaporative emissions, CO, NO_x, smoke, and a composite ranking based on the absolute value of the criticality indices regardless of pollutant.

In general, the order of the rankings depended on model-year group and sales volume although the same components generally ranked in the top 25. Most components were critical

Table 4-5. AFTER-MARKET PART CRITICALITY RANKING
(Automotive Parts Study - EPA Contract 68-01-1957)
WAREHOUSE SALES VOLUME AND EARLY MODEL EMISSION FACTORS

HC	CO	NO_x	SMOKE (Diesel)	COMPOSITE
Spark Plugs	Rebuilding Kits	Thermal Vac Valve	Valve Lifter/Spring	Spark Plugs
Ignition Wires	Choke Mechanism	Spark Delay Valve	Valve Seals	Rebuilding Kits
Rebuilding Kits	Rebuilt Carburetor	EGR Valves	Exhaust Valves	Ignition Wires
Rebuilt Carburetor	New Carburetor	Rebuilt Carburetor	Air Cleaner Element	Choke Mechanism
Rotor	Air Cleaner Element	Specialty Carburetor	FI Throttle Valve	Rebuilt Carburetor
Cap	Valve Lifter/Spring	New Carburetor	Valve Guides	New Carburetor
Choke Mechanism	PCV Valve	EGR Vacuum Amplifier	Head Gaskets	Rotor
New Carburetor	Valve Seals	TCS Vacuum Solenoid	Piston Rings	Cap
Valve Lifter/Spring	Exhaust Valves	TCS Temp Switch	Camshafts	Air Cleaner Element
Points	Specialty Carburetor	Mechanical Advance	Valve Cam Lobes	Valve Lifter/Springs
Valve Seals	Vacuum Break Valve	Exhaust Manifold	FI Hi Pres Pump	Thermal Vacuum Valve
Exhaust Valves	PCV Freshair Filter	High Perf Exhaust		PCV Valve
Specialty Carburetor	Idle Stop Solenoid			Spark Delay Valve
Coil	Throttle Dashpot			Points
Condenser	Decel Valve			EGR Valves
PCV Valve	AI Hoses			Valve Seals
Air Cleaner Element	Valve Guides			Exhaust Valves
Spark Delay Valve	Head Gaskets			Specialty Carburetor
Fuel Filter	Piston Rings			Vacuum Break Valves
Distributor Drive	Camshafts			PCV Fresh Air Filter
EVAP Fresh Air	Vacuum Advance			Coil
AI Hoses	AI Pump/Belts			Idle Stop Solenoid
Valve Guides	Intake Manifold			Condenser
Head Gaskets	Mechanical Advance			EGR Vacuum Amplifier
Piston Rings	Valve Cam Lobes			Throttle Dashpot

Table 4-6. AFTER-MARKET PART CRITICALITY RANKING
(Automotive Parts Study - EPA Contract No. 68-01-1957)
GARAGE SALES VOLUME AND EARLY MODEL EMISSION FACTORS

HC	CO	NO_x	SMOKE (Diesel)	COMPOSITE
Spark Plugs	Rebuilding Kits	Exhaust Manifold	Valve Lifter/Spring	Spark Plugs
Ignition Wires	Float and Valve	Rebuilt Carburetor	Exhaust Valves	Ignition Wires
Cap	Air Cleaner Element	Specialty Carburetor	Air Cleaner Element	Rebuilding Kits
Rotor	PCV Valve	New Carburetor	Valve Seals	Float and Valve
Rebuilding Kits	Valve Lifter/Spring	High Perf Exhaust	Piston Rings	Cap
Float and Valve	Rebuilt Carburetor		Valve Guides	Rotor
Points	Exhaust Valves		Head Gaskets	Air Cleaner Element
Valve Lifter/Springs	Valve Seals		Valve Cam Lobes	PCV Valve
Exhaust Valves	New Carburetor		Camshafts	Points
Rebuilt Carburetor	Piston Rings		FI Hi Pres Pump	Valve Lifter/Springs
Valve Seals	Exhaust Manifold			Rebuilt Carburetor
Condenser	Valve Guides			Exhaust Valves
Mag/Opt Triggers	Specialty Carburetor			Valve Seals
EI Control Circuit	Head Gasket			New Carburetor
New Carburetor	Valve Cam Lobes			Condenser
PCV Valve	Camshafts			Mag/Opt Triggers
Piston Rings	High Perf Exhaust			EI Control Circuit
Air Cleaner Element	FI Hi Pres Pump			Piston Rings
Exhaust Manifold	Idle Stop Solenoid			Exhaust Manifold
Fuel Filter	Throttle Dashpot			Fuel Filter
Valve Guides	Throttle Positioner			Valve Guides
Specialty Carburetor	Metering Jets			Specialty Carburetor
Head Gaskets	Metering Rods			Head Gaskets
Valve Cam Lobes	Vacuum Break Valve			Valve Cam Lobes
Camshafts	Choke Mechanism			Camshafts

Table 4-7. AFTER-MARKET PART CRITICALITY RANKING
(Automotive Parts Study - EPA Contract 68-01-1957)
OEM SALES VOLUME AND LATE MODEL EMISSION FACTORS

HC	CO	NO_x	SMOKE (Diesel)	COMPOSITE
Spark Plugs	Rebuilding Kits	EGR Valves	Valve Lifter/Springs	Spark Plugs
Ignition Wires	Float and Valve	EGR Thermal Valve	Valve Seals	Ignition Wires
Rebuilding Kits	Choke Mechanism	Spark Delay Valve	Exhaust Valves	Rebuilding Kits
Float and Valve	Power Valves	EGR Vacuum Amplifier	Air Cleaner Element	Float and Valve
Choke Mechanism	Rebuilt Carburetor	Thermal Vacuum Valve	MFI Valves	Choke Mechanism
Power Valves	New Carburetor	EGR Hoses/Seals	Valve Guides	Power Valves
EVAP Canister	Accelerator Pump	TCS Temp Switch	Piston Rings	Valve Lifter/Springs
Rebuilt Carburetor	Metering Rods	TCS Trans Switch	Head Gaskets	Rebuilt Carburetor
Heat Riser	Air Cleaner Element	TCS Vacuum Solenoid	FI Throttle Valve	EGR Valves
PCV Valve	Metering Jets	EGR Solenoid Valve	Valve Cam Lobes	Valve Seals
Rotor	PCV Valve	Rebuilt Carburetor	FI Pres Sens/Reg	Exhaust Valves
Cap	Spark Plugs	TCS Time Delay	Supercharger	New Carburetor
New Carburetor	Vacuum Break Valve	OSAC Vacuum Orifice	PCV Oil Separator	Accelerator Pumps
Vacuum Break Valve	AI Hoses	Specialty Carburetor	Camshafts	EVAP Canister
TAC Vacuum Motor	AI Pump/Belts	EGR Carb Spacer	Turbocharger	Heat Riser
TAC Vacuum Hoses	PCV Fresh Air Filter	TCS Thermal Valve	FI Dist Manifold	Metering Rods
PCV Fresh/Air Filter	Specialty Carburetor	New Carburetor	FI Hi Pres Pump	Air Cleaner Element
PCV Hoses	Vacuum Advance	EGR Backpres Sensor		EGR Thermal Vac Valve
EVAP Hoses	AI Bypass/Diverter	EGR Temp Switch		Metering Jets
Valve Lifter/Springs	Valve Lifter/Springs	EGR Time Delay		PCV Valve
Idle Stop Solenoid	Idle Stop Solenoid	EGR Speed/Trans Sen		Rotor
EVAP Fresh Air Filter	Ignition Wires	OSAC Vacuum Bypass		Cap
TAC Shroud	Valve Seals	ESC Speed Switch		Vacuum Break Valve
TAC Thermostat	Exhaust Valves	ESC Elec Module		TAC Vacuum Motor
AI Hoses	AI Manifold	Exhaust Manifold		TAC Vacuum Hoses

to more than one pollutant, although not necessarily to the same degree. Critical after-market components for HC and CO typically included the following:

- Primary ignition components such as points, condenser, and coil.
- Secondary ignition components such as spark plugs and wires, and distributor caps and rotors.
- Carburetion components such as chokes, power valves, metering rods, floats and needle valves.
- Induction components such as air filter elements.
- After-market carburetors and carburetor rebuilding kits.
- Mechanical components such as piston rings and valve train components.

Emissions of NO_x were dependent on the performance of NO_x control systems, including the EGR valve and control components, and carburetion or vacuum control components which can affect vacuum signals for EGR valve operation or timing advance.

Smoke emissions were related to basic engine components on diesel engines. These components included engine valves and valve train components, piston rings, air cleaner, and fuel injection valves and control equipment.

Some components can cause emissions failures but were not ranked in the top 25 critical components. Table 4-8 summarizes those components which were found to cause a failure of one or more emission standard if defective or not-OEM equivalent. This list includes those components shown in Table 3-1 and Appendix B for which one or more emission increase factor had a value of at least 1.0. As

Table 4-8. AFTER-MARKET COMPONENTS WHICH CAN CAUSE AN EMISSION FAILURE IF IMPROPERLY INSTALLED OR DEFECTIVE

PART OR COMPONENT	EMISSIONS FAILURE			
	HC	CO	NO_x	Smoke
Carburetor System				
New Carburetor	x	x		
Rebuilt Carburetors	x	x		
Idle Stop Solenoid	x	x		
Throttle Dashpot		x		
Throttle Positioner		x		
Metering Jets		x		
Metering Rods		x		
Vacuum Break Valves		x		
Choke Mechanism	x	x		
Power Valves	x	x		
Float and Valve		x		
Heat Riser	x	x		
Idle Enrichment System	x	x		
Electric Assisted Choke	x	x		
Staged Choke Pulldown	x	x		
Ignition System				
Points	x			
Condenser/Capacitor	x			
Distributor Cap	x			
Distributor Rotor	x			
Mechanical Advance Mechanism		x		
Vacuum Advance Mechanism		x		
Distributor Drive Mechanism	x			
Magnetic or Optical Triggers	x			
Spark Plugs	x			
Ignition Wires	x			
Coil - Inductive	x			
Ballast Resistor	x			
Spark Delay Valve			x	
Air Induction System				
Thermostatically-Controlled Air Inlet	x			
Vacuum Motor and Hoses	x			
Air Cleaner Element	x	x		x
Turbochargers and Superchargers				x
Intake Manifolds	x	x	x	

Table 4-8. AFTER-MARKET COMPONENTS WHICH CAN CAUSE AN EMISSION FAILURE IF IMPROPERLY INSTALLED OR DEFECTIVE (Cont'd)

PART OR COMPONENT	EMISSIONS FAILURE			
	HC	CO	NO_x	Smoke
Fuel Injection System				
Fuel Pressure Sensors/Regulators		x		x
Throttle Linkage and Valve				x
Injection Valves				x
Air Sensors/Switches	x	x		
Temperature Sensors/Switches	x	x		
Injectors		x		
Triggering Switches	x			
Starting Valve	x	x		
Engine System				
Valve Lifters and Springs	x	x		x
Cams	x	x		x
Valves, Guides and Seats	x	x		x
Seals	x	x		x
Rings	x	x		x
Gaskets	x	x		x
Camshafts	x	x		x
Emission Control System*				
PCV Valve	x	x		
PCV Hoses	x			
PCV Fresh Air Filter	x	x		
AI Distribution Manifold	x	x		
AI Hoses	x	x		
AI Inlet Filter	x	x		
AI Check Valves	x	x		
AI Bypass/Diverter Valves	x	x		
AI Gulp Valves	x	x		
AI Pump	x	x		
EVAP Canister Body and Carbon Media	x			
EVAP Hoses	x			
EVAP Fresh Air Filter	x			
EVAP Vapor/Liquid Separator	x			
EVAP System Vapor Control Valves	x			
EVAP Fuel Tank Cap	x			
EGR Valves or Orifices			x	
EGR Hoses, Gaskets, Seals			x	
EGR Temperature-Controlled Valve			x	
EGR Solenoid-Controlled Valve			x	

*These components are not all available in the after-market at this time but may become available in the future.

Table 4-8. AFTER-MARKET COMPONENTS WHICH CAN CAUSE AN EMISSION FAILURE IF IMPROPERLY INSTALLED OR DEFECTIVE (Cont'd)

PART OR COMPONENT	EMISSIONS FAILURE			
	HC	CO	NO_x	Smoke
Emission Control System (Cont'd)				
EGR Temperature Switch			x	
EGR Speed/Transmission Switch			x	
EGR Time Delay Control			x	
EGR Vacuum Amplifier			x	
EGR Vacuum Reducing Valve			x	
EGR Carburetor Spacer			x	
EGR Back Pressure Sensor			x	
EGR Check Valve			x	
TCS Vacuum Solenoid			x	
TCS Vacuum Lines and Hoses		x	x	
TCS Time Delay Control	x		x	
TCS CEC Valve	x	x		
TCS Temperature Control Valve			x	
TCS Transmission Switch			x	
TCS Reversing Relay			x	
SCS Vacuum Solenoid			x	
SCS Vacuum Lines		x		
SCS Time Delay Control			x	
SCS Speed Sensing Switch			x	
SCS Temperature-Controlled Valve			x	
OSAC Vacuum Orifice Valve			x	
OSAC Vacuum Hoses		x		
OSAC Thermal Valve			x	
OSAC Vacuum Bypass Valve			x	
OSAC Temperature Sensor			x	
ESC Electronic Module			x	
ESC Hoses		x		
ESC Vacuum Valves			x	
ESC Temperature Sensing			x	
ESC Speed Sensing Switch			x	
Heat Riser	x			
Decel Valve	x	x		
Distributor Vacuum Deceleration Valve			x	
Distributor Starting Solenoid	x	x		
Thermal Vacuum Valve			x	

can be seen from Table 4-8, most of the components would result in a failure of one or more standards if defective.

As with the OEM components, the criticality rankings of after-market components were sensitive to changes in the input parameters. The criticality rankings were generally dependent on which sales volume factors were used. The garage sales rankings emphasized ignition, carburetion, and mechanical component criticality. The OEM sales ranking included more specialized emission control components. The warehouse sales rankings reflected primarily ignition and carburetion components. In all rankings, however, the lowest ranked components were several orders of magnitude lower in criticality than the highest ranked components and the top 5 to 10 components were generally the same although their order may have been different.

The rankings of critical after-market components presented above may be compared with a ranking developed from factors estimated by the Automative Liaison Council's Automotive Products Emissions Committee (ALC-APEC) which is shown in Table 4-9. The ALC-APEC rankings do not include all individual components considered above and consider failures resulting from defects rather than misapplication or improper installation. Except for catalysts which were not included, the ALC-APEC rankings were generally similar to the after-market part criticality rankings developed above.

Table 4-9. AUTOMOTIVE PART CRITICALITY RANKING
(Automotive Liaison Council-Automotive Products Emissions Committee)

HC	CO	NO_x	COMPOSITE
Catalyst	Catalyst	EGR System	Catalyst
Spark Plugs	Air Cleaner	Catalyst	Spark Plugs
Points	Spark Plugs	Spark Plugs	Carburetor
PCV System	Points	Distributor Advance	Air Cleaner
Air Cleaner	Air Injection	Emission Control Components	Air Injection
EGR System	Thermal Reactor	Air Cleaner	Thermal Reactor
Carburetor	Carburetor	Carburetor	EGR System
EVAP System	PCV System	Points	Emission Control Component
Thermal Reactor	EGR System	PCV System	Points
Air Injection	Emission Control Component	Thermostatic Air Cleaner	Distributor Advance
Emission Control Component	Distributor Advance	Exhaust System	PCV System
Distributor Advance	Thermostatic Air Cleaner	Air Injection	Thermostatic Air Cleaner
Exhaust Valves	Exhaust Valves	Thermal Reactor	Distributor
Thermostatic Air Cleaner	Exhaust System	EVAP System	Exhaust Valves
Exhaust System	EVAP System	Distributor	EVAP System
Distributor	Distributor	Exhaust Valves	Exhaust System

Section 5

CRITICAL PARAMETERS

This section discusses the critical parameters of the most emission-critical after-market components. Critical parameters were defined to include factors or specifications of the part, component, or system which directly affect the emissions of one or more pollutants, or which indirectly affect emissions by affecting the operation of other critical components; i.e., vacuum control valves. The critical factors or specifications were generally classified as one or more of the following:

- Dimensions.
- Materials.
- Flow curve (flow volume or rate as a function of pressure or vacuum signals).
- Movement characteristics (length, direction, and speed of travel or actuation signal).
- Electrical properties (resistance, capacitance, inductance, voltage, current, voltage rise time and dielectric strength).
- Thermodynamic properties (conductivity, operating temperature, thermal expansion).

Although discussed individually, these characterists are generally interrelated; i.e., thermal conductivity, depends on materials while flow curves depend on dimensions.

Critical parameters were determined for the five most critical after-market components for each pollutant. The five most critical components were selected from all three criticality rankings shown in Tables 4-5, 4-6, and 4-7 in order to encompass as many of the components as possible. Table 5-1 summarizes the components selected and their critical parameters. Each of these components is discussed below.

5.1 CARBURETION SYSTEM COMPONENTS

The following carburetion system components were among the five most critical in at least one ranking.

- Carburetors
  - New replacement
  - Rebuilt replacement
  - Speciality (performance)

- Carburetor Components
  - Rebuilding kit
  - Choke thermostat
  - Float and needle valve
  - Power valve

5.1.1 Carburetors

All three subgroups of assembled carburetors have the same critical performance parameters. These are related to the flow curve of the carburetor and the air fuel ratio as a function of air flow rate and vacuum. The fuel metering rate is controlled by the venturi vacuum at the point were fuel is admitted. Power enrichment either by vacuum diaphragm operated valves or by metering rod movement should occur under similar speed and load conditions for the after-market carburetor as for the OEM carburetor.

Table 5-1. SUMMARY OF CRITICAL PARAMETERS OF EMISSION-CRITICAL AFTER-MARKET PARTS

SYSTEM/COMPONENT	CRITICAL PARAMETERS					
	Dimensions	Materials	Flow Curve	Movement	Electrical	Thermodynamic
Carburetion System						
Rebuilding Kits	x	x				
Rebuilt Carburetors	x		x			
New Carburetors	x		x			
Specialty Carburetors	x		x			
Choke Thermostats	x	x		x		x
Float and Valves	x		x	x		
Power Valves	x	x	x	x		
Ignition System						
Spark Plugs	x	x			x	x
Wires		x			x	x
Rotors	x	x			x	
Caps	x	x			x	
Induction System						
Air Cleaner Elements	x	x	x			
Mechanical System						
Exhaust Manifolds	x	x	x			x
Headers	x		x			x
Valve Lifters/Springs	x	x		x		
Exhaust Valves	x	x				x
Valve Seals	x	x				x
Piston Rings	x	x				x
Fuel Injection System						
MFI Valves	x		x	x		
FI Throttle Valves	x		x	x		
Emission Control System						
EGR Valves	x	x	x	x		x
Thermal Vacuum Valves	x	x	x	x		x
EGR Vacuum Amplifiers			x	x		
Spark Delay Valves			x	x		

The venturi vacuum depression and, therefore, the fuel metering rate and air fuel ratio are controlled by the air velocity through the carburetor. This is dependent on the dimensions (i.e., cross sectional area) of the carburetor throats as well as the physical construction of the fuel jet orifices, vacuum required for diaphragm actuation, and mechanical adjustments. This requires that the carburetor's design flow range be compatible with that of the engine, and that components of the carburetor be generally equivalent in dimension, adjustment, and operation as the OEM carburetor.

In addition to the fuel metering and air fuel ratio characteristics, the after-market carburetor must have equivalent vacuum signals at the EGR, venturi, and or spark advance ports as the OEM carburetor in order to produce OEM equivalent vacuum advance and EGR operation. Differences in these characteristics can significantly affect emissions performance, particularly of NO_x.

5.1.2 Carburetor Components

Critical parameters of carburetor components vary by component. However, the dimensions of all the selected components are critical to their proper function and, consequently, their emissions performance. In establishing their critical performance parameters, it was assumed that each would be individually installed as an after-market part in an OEM carburetor.

5.1.2.1 Rebuilding Kit

In addition to dimensional equivalence, several components require similar materials as the OEM components; or materials which have similar properties. In particular, componets such as gaskets and vacuum diaphragms which are distributed in carburetor rebuilding kits should be made from similar materials as the OEM components to ensure that compression, sealing, and response or resistance to vacuum, liquids (gasoline, water, or oil), vapors (fuel vapors, smoke), and environmental conditions (temperature) are equivalent to the OEM components.

5.1.2.2 Choke Thermostat

The choke thermostat depends on dimensional equivalence to the OEM part and an equivalent coefficient of thermal expansion to ensure that the same rotation of the choke plate occurs over a specified temperature range. Thermodynamic properties of the thermostat are governed by the materials used to make the coil spring.

5.1.2.3 Float and Needle Valve

The float and needle valve are frequently replaced as a set. Both of these components must have dimensional equivalence to ensure that the same fuel height is maintained as with the OEM components. This includes installing the needle valve, valve seat, and float arm in identical locations of the float chamber as with the OEM components.

5.1.2.4 Power Valve

After-market power valves generally involve replacement of vacuum diaphragms. The replacement diaphragm and return springs, if replaced, should result in the same carburetor metering as the OEM components. This requires that the components have similar elasticity and spring coefficients so that the valve's response to carburetor vacuum signals is the same as for the OEM power valve. The critical parameters for power valve are, therefore, dimensions, materials, and flow curve.

5.2 IGNITION SYSTEM COMPONENTS

Four components of the ignition system ranked among the five most critical components:

- Spark plugs
- Wires
- Rotors
- Caps

5.2.1 Spark Plugs

Spark plugs were the most critical after-market component for HC emissions in all the rankings. This is due to the high sales volume of spark plugs and the substantial effect a plug failure has on HC emissions in particular. The spark plug is critically dependent on gap length and relative position in the cylinder. These two parameters are determined by dimensional equivalence of an after-market spark plug to the OEM plug.

In general, the durability of spark plugs depends on how long the gap remains within the allowable tolerance. Changes in gap length are caused either by plug fouling or electrical erosion of the electrode. In both cases, the plug degrades until the required firing voltage is higher than the available voltage, or the firing time is too short to ignite the charge. The rate of plug fouling is, in turn, controlled by the operating temperature of the plug which depends on materials of construction, design heat range, and installation technique.

5.2.2 Wires

Wires were critically related to HC emissions in all rankings. The performance of ignition wires depends on their ability to deliver the required firing voltage to the spark plug. The important properties of wires are, therefore, electrical properties such as conductivity, capacitance, and the dielectric strength of the insulation around the wire and which covers the connectors at each end. These properties are controlled by selection of the materials used for the wires and, to a lesser extent, by the dimensions (length and diameter) of the conductor and insulation.

Wires typically perform satisfactorily after installation regardless of quality. The durability of the wire, however, depends on the materials and the ability of the wire to resist heat stress and vibration.

5.2.3 Rotors

Distributor rotors must have dimensional equivalence to the OEM rotor. This is required to ensure proper electrode registration between the rotor terminals and the terminals on the cap. In addition, the configuration and materials of construction must prevent arcing of the high voltage through or across the body of the rotor to ground represented by the distributor shaft and body. Failure to maintain proper dimensions, registration and arc resistance will result in shorter useful life of the rotor and/or cap and changes in the available firing voltages, spark initiation or duration.

5.2.4 Caps

After-market distributor caps must also be dimensionally equivalent to the electrodes and terminals of the OEM cap. Overall dimensions and configuration may be different, however, provided that electrical properties of conductivity and arc resistance are equivalent to the OEM cap.

5.3 AIR INDUCTION SYSTEM COMPONENTS

The only air induction system component which ranked among the five most critical components was the air cleaner element. The critical parameter of the air cleaner is the flow curve. The flow curve is dependent on both the cross sectional area and the pressure drop across the filter media. Factors which affect these parameters include the element's external dimensions and configuration, and the depth, density, and nature of the filtering media. Differences in these factors, however, can result in the same flow curve.

5.4 MECHANICAL SYSTEM COMPONENTS

Six mechanical components ranked among the five most critical components. Two components (exhaust manifolds and headers) ranked high in NO_x emission-criticality only because there were only five NO_x emissions-related components with nonzero garage sales volume factors. The other four components were internal engine components (valve lifters/ springs, exhaust valves, valve seals, and piston rings).

5.4.1 Exhaust Manifolds and Headers

Exhaust manifolds and headers are generally associated with OEM replacement and performance modifications, respectively. Both components, however, involve flow curves as critical parameters. The exhaust back pressure at the cylinder exhaust valves as a function of exhaust flow rate. Manifolds sold as OEM replacement must have dimensional and possibly material equivalence to the OEM manifold. The headers, however, generally are not equivalent to OEM manifold in any respect.

5.4.2 Internal Engine Components

The valve train components and piston rings requires dimensional equivalence to the OEM components. To ensure equivalent durability, similar material and fabrication techniques are also necessary. Failure to maintain equivalent dimensions and physical properties of valve train components may result in changes in timing, duration, and rate of valve opening. Non-OEM equivalent piston rings may result in low cylinder compression, excessive oil burning or plug fouling, or excessive crankcase blowby.

5.5 FUEL INJECTION SYSTEM

Two fuel injection components ranked high in smoke emission-criticality; injection valves and throttle valves. Both of these components require dimensional equivalence to the OEM component in order to be installed in a diesel engine. Both of the components also require equivalent flow curves to ensure that the same rate of fueling occurs for given engine speed and load.

5.6 EMISSION CONTROL SYSTEM COMPONENTS

Four emission control components were among the five most NO_x emission-critical components; one of the components is the EGR valve. Three of the components modulate vacuum signals actuating EGR operation or timing advance. The components were the following:

- EGR valve
- Thermal vacuum value
- EGR vacuum amplifier
- Spark delay valve

5.6.1 EGR Valve

The EGR valve opens a passage between the intake and exhaust manifolds. The valve is actuated by a vacuum diaphragm and return spring. The critical parameter of the EGR valve is the flow curve of recirculated exhaust gas as a function of carburetor flow rate and venturi vacuum. Non-OEM equivalent vacuum diaphragm or spring operation will result in different exhaust gas recirculation rate and may affect either engine performance NO_x emissions.

5.6.2 Thermal Vacuum Valve

The thermal vacuum valve opens or closes vacuum ports in response to coolant temperature. The performance of the valve depends on the thermal conductivity and heat capacity of the soft solder plug in the base of the valve, and the ball valves and springs controlling the vacuum signal. Equivalent performance is generally provided by dimensional and material equivalence of the OEM and after-market components.

5.6.3 EGR Vacuum Amplifier

The EGR vacuum amplifier is a vacuum switch which regulates a manifold vacuum signal in response to weaker venturi vacuum signals. The operation of the EGR valve depends on the diaphragm and spring tension of the vacuum amplifier switch. These parameters are regulated by the dimensions and material of the component.

5.6.4 Spark Delay Valve

The spark delay valve is an in-line air bleed which restricts airflow in one direction. The valve typically consists of a restricted orifice and check valve. The critical parameter of the spark delay valve is the porosity or leak down rate in both flow directions. These factors are generally governed by materials and dimensions, however, alternative designs can yield the same flow curve.

Section 6

RECOMMENDED TESTING

Components that were recommended for testing are discussed in this section. No heavy-duty diesel components were recommended due to the relatively low criticality of smoke-related components compared to the gaseous pollutants. The 25 after-market components selected for testing are discussed in paragraph 6.1. The test protocol recommended for the 25 components is discussed in paragraph 6.2.

6.1 SELECTION OF COMPONENTS

The after-market components selected for testing primarily include fundamental ignition and carburetion components which affect vehicle performance and emissions. Data on some of these components have been reported in the literature. However, controlled experiments involving after-market component installation on catalyst-equipped vehicles were generally not reported. Some components recommended for testing may be included as OEM components in on-going or planned restorative maintenance and characterization programs and, therefore, may be subsequently deleted.

Components have been chosen from those which appear on either Table 4-5 or 4-7 since these rankings provided the best estimate of current and future criticality. Table 4-5 was based on the pre-catalyst emission increase factors and warehouse distributor sales volumes. Table 4-7 was based on the OEM sales volume factors and post-1975 emission increase factors.

Table 6-1 summarizes the components recommended for testing. Several components have more than one basic operating design. One each of these multiple configurations should be tested where appropriate.

6.1.1 Carburetion System Components

Carburetion components are critical to both HC and CO emissions. Carburetor replacement may also be critical to NO_x if EGR or timing advance vacuum signals differ from the OEM carburetor. The following carburetion components were recommended for testing on both air injection and nonair injection-equipped vehicles:

- New carburetors
- Rebuilt carburetors
- Specialty carburetors
- Choke thermostats
- Floats and valves
- Power valves
- Metering jets
- Dashpots
- Carburetor rebuilding kits

The other major carburetor components (gaskets, accelerator pumps, throttle positioners, and idle adjustments) are not recommended for testing due to their low criticality as after-market components or because they have been recommended for testing as OEM components.

At least four representative units from each recommended component category should be tested on each selected vehicle. Each component would be installed in accordance with the vehicle and/or component manufacturer's

Table 6-1. AFTER-MARKET COMPONENTS RECOMMENDED FOR TESTING

COMPONENT	TEST CONDITIONS
Carburetion System	
New Carburetor	OEM - After-market
Rebuilt Carburetor	OEM - After-market
Specialty Carburetor	OEM - After-market
Carburetor Rebuilding Kit	OEM - Rebuilding Kit
Choke Thermostat	OEM - After-market
Float and Valve	OEM - After-market
Metering Jet	Lean - OEM - Rich
Dashpot	OEM - After-market
Ignition System	
Spark Plugs	OEM - After-market
Ignition Wires	OEM - After-market
Points	OEM - After-market
Condenser	OEM - After-market
Coil	OEM - After-market
Distributor Cap	OEM - After-market
Distributor Rotor	OEM - After-market
Vacuum Advance Unit	OEM - After-market
Retrofit CD Electronic Ignition	OEM - After-market
Optical/Magnetic Retrofit EI Distributor System	OEM - After-market
Replacement Distributor	OEM - After-market
Engine System	
Valve Lifters/Springs	OEM - After-market
Intake Manifold/Headers	OEM - After-market
Emission Control System	
PCV Valve	OEM - After-market
Decel Valve	OEM - After-market
Spark Delay Valve	OEM - After-market
Thermal Vacuum Valve	OEM - After-market

instructions. Prior to installing each component, the test vehicle would receive a baseline test with all engine, ignition and carburetion components inspected and set to specification. The test of the after-market component would then provide a measure of the emissions resulting from a direct replacement of the OEM component with the recommended after-market component.

OEM metering jets may be replaced with nonequivalent after-market jets. The OEM jet may be replaced with a larger jet in order to improve driveability and performance. Although unlikely, it is also possible that the OEM jet would be replaced by a smaller jet to improve fuel economy. Therefore, four jet sizes are recommended for each vehicle selected for testing: OEM supplied jet, two larger jet sizes (0.010" and 0.020"), and one smaller jet size (0.005"). This range of metering jets should include the probable range of jet size changes.

The emissions performance of carburetor rebuilding kits are highly dependent on the thoroughness and competence of the mechanic performing the repair. In order to minimize the chance of error in rebuilding the carburetor, each test vehicle would be sent to the same reputable independent service garage. The mechanics would be aware that a study of carburetor rebuilding practices was being performed. Representative carburetors from each major carburetor manufacturer should be included.

6.1.2 Ignition System Components

Ignition components are critically related to HC and CO emissions. Some components may also affect NO_x emissions. The following after-market ignition system components are recommended for testing on both air injection and nonair injection-equipped vehicles:

- Spark plugs
- Ignition wires
- Points
- Condenser
- Coil
- Distributor caps
- Distributor rotors
- Vacuum advance units
- Electronic ignition (CD) retrofit systems
- Optical/magnetic retrofit EI systems
- Replacement distributor

All of the above components are direct replacements to OEM components. Therefore, each selected vehicle would be tested with the OEM component installed and all ignition and carburetion components set to manfacturers. The after-market component would then be installed and all ignition and carburetion component specifications rechecked and reset, if necessary, to specification. Several after-market components representative of each category should be tested.

6.1.3 Air Induction System

No after-market air induction components are recommended for testing since they ranked low in emissions criticality.

6.1.4 Fuel Injection System

No fuel injection components are recommended for testing since they ranked low in emissions criticality. Fuel injection is used on only a small percentage of the current U.S. vehicle population.

6.1.5 Mechanical Components

Two after-market engine components are recommended for testing: replacement valve lifters and springs, and a combination of specialty intake manifold and exhaust headers. Valve lifters and springs ranked relatively high in criticality due to high after-market sales volume. These components, however, are usually not replaced during the emissions warranty period. Two engines are recommended to be tested with the OEM valve components installed and then with the replacement after-market components installed.

One representative combination of specialty intake manifold and exhaust headers is recommended for testing. Although these components rank relatively low in emissions criticality, they do represent typical performance modifications which can be expected on post-1975 model-year vehicles.

6.1.6 Emission Control Components

The following emission control components are recommended for testing due to their expected impact on emissions and availability in the after-market. Although they are generally considered to be OEM distributed components, after-market sources do exist.

- PCV valve
- Decel valve
- Spark delay valve
- Thermal vacuum valve

The selected vehicles would be tested with OEM components and then with the recommended replacement component installed. Several different sources of each component should be used if available.

6.2 TEST PROTOCOL

The after-market components selected for testing would all be subjected to the following general test protocol:

- Select representative test vehicles.
- Set all components to nominal specifications.
- Precondition test vehicle.
- Perform baseline tests with OEM components.
- Replace OEM component with after-market components.
- Precondition test vehicle.
- Perform tests with after-market components.
- Perform restorative maintenance.
- Precondition test vehicle.
- Perform baseline test.
- Retest or perform additional restorative maintenance if second baseline emissions differ by more than 25 percent for HC, CO, and NO_x from first baseline test.

Various aspects of the test protocol are discussed in the following paragraphs.

6.2.1 Vehicle Selection

Test vehicles would be selected to represent typical weight classes and engine sizes equipped with the specific component to be evaluated. Where applicable, one vehicle with each of the following catalyst emission control systems should be tested for each component:

- Pelleted catalyst with air
- Pelleted catalyst without air
- Monolith catalyst with air
- Monolith catalyst without air

Testing is not recommended on pre-1975 model-year or noncatalyst-equipped vehicles since they represent small and decreasing fractions of the vehicle population. In addition, the majority of existing data on after-market equipment is based on pre-catalyst vehicles.

6.2.2 Preconditioning

Preconditioning should be performed by accumulating 300 miles of freeway driving followed by approximately 10 minutes of surface street driving, or the first 505 seconds of the LA-4 driving schedule. Each vehicle would be preconditioned prior both to the baseline and after-market test. Preconditioning and cold soak would be performed in accordance with 40 CFR 85.076-12b for vehicles receiving the FTP.

6.2.3 Test Fuel

All preconditioning and testing would be performed with tank fuel.

6.2.4 Inspection and Maintenance

Each vehicle would be fully inspected prior to each test series to ensure that the basic engine adjustments are correct, that the ignition and carburetor systems are functioning normally, and that all vacuum, vapor, and air hoses are correctly routed and connected. During each test series, only the specific component under study would be adjusted or disabled. Carburetor or mechanical component replacements would be performed by reputable independent garages under contractor supervision.

6.2.5 Emission Tests

Ideally, the full FTP should be used to clearly define emission changes resulting from component defects since the criteria for emission-criticality includes failure of one or more of the FTP emission standards. However, FTP testing is expensive and, for those component defects which cause large emission increases, a short inspection test is probably adequate and cost-effective to confirm that emissions have increased significantly. Therefore, a short test sequence is recommended for most components, with FTP testing recommended only for carburetion components and those components which have significant effects on cold start operation.

6.2.5.1 Short Tests

Considerable data on the relationship between various short tests and the FTP have been, and are currently being, developed by the EPA. Although numerical relationships between short tests and the FTP are not precise, significant emission increases on short tests indicate a probable FTP failure. However, a vehicle which passes a short test may still fail the FTP.

In order to minimize the possible errors of omission by the short test, the following two short tests are recommended:

- Clayton Key Mode Test
- Federal 9-Mode CVS Test

The Key Mode test is recommended because it provides modal emission results. The Federal 9-Mode is recommended since it simulates the FTP. A separate idle test is not recommended, however, since the Clayton Key Mode test includes an idle mode. Each of the selected components would be tested using these cycles. An emission increase of 100 percent in any mode or in the Federal 9-Mode composite would constitute a significant increase. As an alternative criteria, the EPA Project Officer could establish failure limits for each test.

The components listed below are recommended for testing using the short tests only. These components are expected to have significant affect on hot running emissions in addition to cold start emissions which would be detected by the short tests. If increases are not observed, it is likely that FTP emissions would not be significantly altered by the defective component. These components include the following:

- <u>Carburetion System</u>
  Float and valve
  Power valve
  Metering jet
  Dashpot

- <u>Ignition System</u>
  Spark plugs
  Wires
  Cap
  Rotor
  Points
  Coil
  Condenser
  Vacuum advance
  Electronic ignition systems
  Replacement distributors

- <u>Engine Mechanical System</u>
  Valve lifters and springs
  Intake manifold/headers

- <u>Emission Control System</u>
  PCV valve
  Spark delay valve
  EGR valve
  Thermal vacuum valve

6.2.5.2 FTP Tests

Several carburetor components have a significant effect on cold start or cold running emissions. Defects in these components may cause an FTP emissions failure, but not necessarily affect short test emissions which are measured when the vehicle and catalyst are warmed up. The following components would receive the FTP in addition to the short test:

- Choke
- Specialty carburetor
- New replacement carburetor
- Rebuilt carburetor
- Carburetor rebuilding kit
- PCV valve

6.2.5.3 Test Procedures

The FTP should be performed in accordance with 40 CFR 85.076-12b. The Federal 9-Mode test should be performed in accordance with 40 CFR 85.076-12b (4) except for the cold-start driving schedule, accumulated mileage, and calibrations. The Key Mode test should be performed using

NDIR analyzers for HC, CO, and NO_x emissions and the appropriate speed and power absorption for the vehicle weight.

During the road driving and dynamometer driving, a general driveability data sheet should be filled out by the test driver giving a general description of the vehicle's performance under baseline and defect conditions. This provides data on the symptoms and detectability of the defects to the vehicle operator.

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Appendix A

CRITICALITY INDEX RANKINGS

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - OEM SALES VOLUME

PRINCIPAL RANKING - HC

EARLY MODEL

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
2. 5. 0	SPARK PLUGS	1	0.189E+00	67	0.0	61	0.0	46	0.0
2. 6. 0	IGNITION WIRES	2	0.677E-01	68	0.0	62	0.0	47	0.0
1. 3. 8	REBUILDING KITS	3	0.786E-02	1	0.393E-01	48	0.0	31	0.0
5. 1. 1	VALVE LIFTER/SPR	4	0.709E-02	5	0.709E-02	89	0.0	1	0.709E-02
5. 1. 4	VALVE SEALS	5	0.411E-02	7	0.411E-02	92	0.0	2	0.411E-02
5. 1. 5	EXHAUST VALVES	6	0.411E-02	8	0.411E-02	93	0.0	3	0.411E-02
1. 3. 9	FLOAT AND VALVE	7	0.337E-02	2	0.168E-01	49	0.0	32	0.0
1. 3. 4	CHOKE MECHANISM	8	0.334E-02	3	0.167E-01	44	0.0	27	0.0
1. 3. 6	POWER VALVES	9	0.334E-02	4	0.167E-01	46	0.0	29	0.0
6. 2. 1	EVAP CANISTER	10	0.318E-02	88	0.0	102	0.0	71	0.0
1. 1. 2	REBUILT CARB	11	0.290E-02	6	0.562E-02	11	0.281E-03	19	0.0
2. 3. 2	ROTOR	12	0.187E-02	63	0.0	56	0.0	39	0.0
2. 3. 1	CAP	13	0.185E-02	62	0.0	55	0.0	38	0.0
1. 1. 1	NEW CARB	14	0.174E-02	9	0.337E-02	17	0.168E-03	18	0.0
6. 1. 2	PCV HOSES	15	0.107E-02	87	0.0	99	0.0	69	0.0
6. 2. 2	EVAP HOSES	16	0.107E-02	89	0.0	103	0.0	72	0.0
2. 1. 0	POINTS	17	0.728E-03	60	0.0	53	0.0	36	0.0
6. 2. 3	EVAP FRSH AIR	18	0.569E-03	90	0.0	104	0.0	73	0.0
2. 7. 0	COIL	19	0.562E-03	69	0.0	63	0.0	48	0.0
2. 9. 0	BALLAST RESISTOR	20	0.562E-03	71	0.0	65	0.0	50	0.0
5. 1. 3	VALVE GUIDES	21	0.411E-03	18	0.411E-03	91	0.0	6	0.411E-03
5. 2. 0	PISTON RINGS	22	0.411E-03	19	0.411E-03	94	0.0	7	0.411E-03
6. 2. 6	FUEL TANK/CAP	23	0.371E-03	93	0.0	107	0.0	76	0.0
6. 2. 4	EVAP VPRLIG SEP	24	0.367E-03	91	0.0	105	0.0	74	0.0
2. 3. 5	DISTRIBUTOR DRIV	25	0.312E-03	64	0.0	58	0.0	42	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - OEM SALES VOLUME

PRINCIPAL RANKING - CO

EARLY MODEL

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
1. 3. 8	REBUILDING KITS	3	0.786E-02	1	0.393E-01	48	0.0	31	0.0
1. 3. 9	FLOAT AND VALVE	7	0.337E-02	2	0.168E-01	49	0.0	32	0.0
1. 3. 4	CHOKE MECHANISM	8	0.334E-02	3	0.167E-01	44	0.0	27	0.0
1. 3. 6	POWER VALVES	9	0.334E-02	4	0.167E-01	46	0.0	29	0.0
5. 1. 1	VALVE LIFTER/SPR	4	0.709E-02	5	0.709E-02	89	0.0	1	0.709E-02
1. 1. 2	REBUILT CARB	11	0.290E-02	6	0.562E-02	11	0.281E-03	19	0.0
5. 1. 4	VALVE SEALS	5	0.411E-02	7	0.411E-02	92	0.0	2	0.411E-02
5. 1. 5	EXHAUST VALVES	6	0.411E-02	8	0.411E-02	93	0.0	3	0.411E-02
1. 1. 1	NEW CARB	14	0.174E-02	9	0.337E-02	17	0.168E-03	18	0.0
1. 3. 5	ACCELERATOR PUMP	35	0.168E-03	10	0.337E-02	45	0.0	28	0.0
1. 3. 2	METERING RODS	40	0.117E-03	11	0.235E-02	42	0.0	25	0.0
3. 2. 0	AIR CLEANER ELEM	42	0.106E-03	12	0.211E-02	73	0.0	4	0.528E-03
1. 3. 1	METERING JETS	43	0.103E-03	13	0.205E-02	41	0.0	24	0.0
6. 1. 1	PCV VALVE	32	0.195E-03	14	0.195E-02	98	0.0	68	0.0
1. 3. 3	VAC BRK VALVE	34	0.170E-03	15	0.170E-02	43	0.0	26	0.0
6. 1. 3	PCV FRSHAIR FLTR	41	0.108E-03	16	0.108E-02	100	0.0	70	0.0
1. 2. 1	IDLE STPSOLENOID	45	0.709E-04	17	0.709E-03	38	0.0	21	0.0
5. 1. 3	VALVE GUIDES	21	0.411E-03	18	0.411E-03	91	0.0	6	0.411E-03
5. 2. 0	PISTON RINGS	22	0.411E-03	19	0.411E-03	94	0.0	7	0.411E-03
1. 1. 3	SPECIALTY CARB	29	0.205E-03	20	0.397E-03	14	0.199E-03	20	0.0
6. 3. 2	AI HOSES	27	0.221E-03	21	0.221E-03	109	0.0	78	0.0
6. 3. 7	AI PUMP/BELTS	28	0.221E-03	22	0.221E-03	114	0.0	83	0.0
4.12. 0	FI STARTING VALV	55	0.284E-04	23	0.142E-03	87	0.0	65	0.0
1. 2. 2	THROTTLE DASHPOT	68	0.132E-04	24	0.132E-03	39	0.0	22	0.0
5. 4. 1	HEAD GASKETS	44	0.981E-04	25	0.981E-04	96	0.0	8	0.981E-04

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - OEM SALES VOLUME

PRINCIPAL RANKING - NOX

EARLY MODEL

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
6. 4. 1	EGR VALVES	115	0.0	95	0.0	1	0.463E-02	84	0.0
6. 4. 3	EGR THERMO VALVE	116	0.0	97	0.0	2	0.211E-02	86	0.0
2. 3. 7	SPARK DELAY VLV	38	0.122E-03	65	0.0	3	0.122E-02	44	0.0
6. 4. 8	EGR VAC AMP	52	0.357E-04	102	0.0	4	0.715E-03	91	0.0
6.10. 7	THERMO VAC VALV	54	0.340E-04	131	0.0	5	0.681E-03	129	0.0
6. 4. 2	EGR HOSES/SEALS	57	0.227E-04	96	0.0	6	0.454E-03	85	0.0
6. 5. 8	TCS TEMP SWITCH	60	0.216E-04	112	0.0	7	0.431E-03	103	0.0
6. 5. 6	TCS TRANS SWITCH	63	0.187E-04	110	0.0	8	0.374E-03	101	0.0
6. 5. 1	TCS VAC SOLENOID	64	0.176E-04	107	0.0	9	0.352E-03	96	0.0
6. 4. 4	EGR SOLENOID VLV	117	0.0	98	0.0	10	0.306E-03	87	0.0
1. 1. 2	REBUILT CARB	11	0.290E-02	6	0.562E-02	11	0.281E-03	19	0.0
6. 5. 3	TCS TIME DELAY	69	0.119E-04	108	0.0	12	0.238E-03	98	0.0
6. 7. 1	OSAC VAC ORIFICE	62	0.204E-04	117	0.0	13	0.204E-03	109	0.0
1. 1. 3	SPECIALTY CARB	29	0.205E-03	20	0.397E-03	14	0.199E-03	20	0.0
6. 4.10	EGR CARB SPACER	122	0.0	104	0.0	15	0.187E-03	93	0.0
6. 5. 5	TCS THERMO VALVE	72	0.851E-05	109	0.0	16	0.170E-03	100	0.0
1. 1. 1	NEW CARB	14	0.174E-02	9	0.337E-02	17	0.168E-03	18	0.0
6. 4.11	EGR BACKPRES SEN	123	0.0	105	0.0	18	0.159E-03	94	0.0
6. 4. 5	EGR TEMP SWITCH	118	0.0	99	0.0	19	0.148E-03	88	0.0
6. 4. 7	EGR TIME DELAY	120	0.0	101	0.0	20	0.148E-03	90	0.0
6. 4. 6	EGR SPEED/TRANS	119	0.0	100	0.0	21	0.125E-03	89	0.0
6. 7. 4	OSAC VAC BYPASS	73	0.851E-05	119	0.0	22	0.851E-04	112	0.0
6. 8. 5	ESC SPEED SWITCH	79	0.397E-05	124	0.0	23	0.794E-04	118	0.0
6. 8. 1	ESC ELEC MODULE	85	0.284E-05	121	0.0	24	0.567E-04	114	0.0
7. 3. 2	EXHAUST MANIFOLD	49	0.545E-04	30	0.545E-04	25	0.545E-04	133	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - OEM SALES VOLUME

PRINCIPAL RANKING - SMOKE

EARLY MODEL

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
5. 1. 1	VALVE LIFTER/SPR	4	0.709E-02	5	0.709E-02	89	0.0	1	0.709E-02
5. 1. 4	VALVE SEALS	5	0.411E-02	7	0.411E-02	92	0.0	2	0.411E-02
5. 1. 5	EXHAUST VALVES	6	0.411E-02	8	0.411E-02	93	0.0	3	0.411E-02
3. 2. 0	AIR CLEANER ELEM	42	0.106E-03	12	0.211E-02	73	0.0	4	0.528E-03
4. 5. 0	MFI VALVES	107	0.0	80	0.0	81	0.0	5	0.454E-03
5. 1. 3	VALVE GUIDES	21	0.411E-03	18	0.411E-03	91	0.0	6	0.411E-03
5. 2. 0	PISTON RINGS	22	0.411E-03	19	0.411E-03	94	0.0	7	0.411E-03
5. 4. 1	HEAD GASKETS	44	0.981E-04	25	0.981E-04	96	0.0	8	0.981E-04
5. 1. 2	VALVE CAM LOBES	61	0.210E-04	36	0.210E-04	90	0.0	9	0.210E-04
4. 4. 0	FI THROTTLE VALV	106	0.0	79	0.0	80	0.0	10	0.156E-04
4. 3. 0	FI PRES SENS/REG	91	0.170E-05	38	0.170E-04	79	0.0	11	0.936E-05
6. 1. 4	PCV OIL SEPARATR	53	0.352E-04	32	0.340E-04	101	0.0	12	0.340E-05
3. 5. 0	SUPERCHARGER	77	0.567E-05	42	0.113E-04	76	0.0	13	0.312E-05
5. 5. 0	CAMSHAFTS	83	0.284E-05	50	0.284E-05	97	0.0	14	0.284E-05
3. 4. 0	TURBOCHARGER	88	0.189E-05	48	0.378E-05	75	0.0	15	0.104E-05
4. 8. 0	FI DIST MANIFOLD	99	0.420E-06	55	0.315E-06	37	0.315E-06	16	0.315E-06
4. 2. 0	FI HI PRES PUMP	100	0.630E-07	56	0.630E-07	78	0.0	17	0.630E-07
1. 1. 1	NEW CARB	14	0.174E-02	9	0.337E-02	17	0.168E-03	18	0.0
1. 1. 2	REBUILT CARB	11	0.290E-02	6	0.562E-02	11	0.281E-03	19	0.0
1. 1. 3	SPECIALTY CARB	29	0.205E-03	20	0.397E-03	14	0.199E-03	20	0.0
1. 2. 1	IDLE STPSOLENOID	45	0.709E-04	17	0.709E-03	38	0.0	21	0.0
1. 2. 2	THROTTLE DASHPOT	68	0.132E-04	24	0.132E-03	39	0.0	22	0.0
1. 2. 3	THRTTL POSITIONR	75	0.662E-05	28	0.662E-04	40	0.0	23	0.0
1. 3. 1	METERING JETS	43	0.103E-03	13	0.205E-02	41	0.0	24	0.0
1. 3. 2	METERING RODS	40	0.117E-03	11	0.235E-02	42	0.0	25	0.0

AUTCMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - GARAGE SALES

PRINCIPAL RANKING - HC

EARLY MODEL

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
2. 5. 0	SPARK PLUGS	1	0.266E+00	42	0.0	31	0.0	39	0.0
2. 6. 0	IGNITICN WIRES	2	0.127E+00	43	0.0	32	0.0	40	0.0
2. 3. 1	CAP	3	0.168E-01	34	0.0	23	0.0	31	0.0
2. 3. 2	ROTOR	4	0.168E-01	35	0.0	24	0.0	32	0.0
1. 3. 8	REBUILDING KITS	5	0.950E-02	1	0.475E-01	16	0.0	24	0.0
1. 3. 9	FLOAT AND VALVE	6	0.410E-02	2	0.205E-01	17	0.0	25	0.0
2. 1. 0	POINTS	7	0.281E-02	32	0.0	21	0.0	29	0.0
5. 1. 1	VALVE LIFTER/SPR	8	0.240E-02	5	0.240E-02	60	0.0	1	0.240E-02
5. 1. 5	EXHAUST VALVES	9	0.159E-02	7	0.159E-02	64	0.0	2	0.159E-02
1. 1. 2	REBUILT CARB	10	0.109E-02	6	0.212E-02	2	0.106E-03	12	0.0
5. 1. 4	VALVE SEALS	11	0.109E-02	8	0.109E-02	63	0.0	4	0.109E-02
2. 2. 0	CONDENSER	12	0.561E-03	33	0.0	22	0.0	30	0.0
2. 4. 0	MAG/OPT TRIGGERS	13	0.447E-03	41	0.0	30	0.0	38	0.0
2.10. 0	EI CONTRCL CIRCT	14	0.447E-03	47	0.0	36	0.0	44	0.0
1. 1. 1	NEW CARB	15	0.388E-03	9	0.750E-03	4	0.375E-04	11	0.0
6. 1. 1	PCV VALVE	16	0.295E-03	4	0.295E-02	69	0.0	67	0.0
5. 2. 0	PISTON RINGS	17	0.278E-03	10	0.278E-03	65	0.0	5	0.278E-03
3. 2. 0	AIR CLEANER ELEM	18	0.244E-03	3	0.487E-02	43	0.0	3	0.122E-02
7. 3. 2	EXHAUST MANIFOLD	19	0.215E-03	11	0.215E-03	1	0.215E-03	133	0.0
1. 4. 0	FUEL FILTER	20	0.167E-03	31	0.0	20	0.0	28	0.0
5. 1. 3	VALVE GUIDES	21	0.109E-03	12	0.109E-03	62	0.0	6	0.109E-03
1. 1. 3	SPECIALTY CARB	22	0.448E-04	13	0.867E-04	3	0.433E-04	13	0.0
5. 4. 1	HEAD GASKETS	23	0.224E-04	14	0.224E-04	67	0.0	7	0.224E-04
5. 1. 2	VALVE CAM LOBES	24	0.721E-05	15	0.721E-05	61	0.0	8	0.721E-05
5. 5. 0	CAMSHAFTS	25	0.721E-05	16	0.721E-05	68	0.0	9	0.721E-05

AUTCMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - GARAGE SALES

PRINCIPAL RANKING - CO

EARLY MODEL

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
1. 3. 8	REBUILDING KITS	5	0.950E-02	1	0.475E-01	16	0.0	24	0.0
1. 3. 9	FLOAT AND VALVE	6	0.410E-02	2	0.205E-01	17	0.0	25	0.0
3. 2. 0	AIR CLEANER ELEM	18	0.244E-03	3	0.487E-02	43	0.0	3	0.122E-02
6. 1. 1	PCV VALVE	16	0.295E-03	4	0.295E-02	69	0.0	67	0.0
5. 1. 1	VALVE LIFTER/SPR	8	0.240E-02	5	0.240E-02	60	0.0	1	0.240E-02
1. 1. 2	REBUILT CARB	10	0.109E-02	6	0.212E-02	2	0.106E-03	12	0.0
5. 1. 5	EXHAUST VALVES	9	0.159E-02	7	0.159E-02	64	0.0	2	0.159E-02
5. 1. 4	VALVE SEALS	11	0.109E-02	8	0.109E-02	63	0.0	4	0.109E-02
1. 1. 1	NEW CARB	15	0.388E-03	9	0.750E-03	4	0.375E-04	11	0.0
5. 2. 0	PISTON RINGS	17	0.278E-03	10	0.278E-03	65	0.0	5	0.278E-03
7. 3. 2	EXHAUST MANIFOLD	19	0.215E-03	11	0.215E-03	1	0.215E-03	133	0.0
5. 1. 3	VALVE GUIDES	21	0.109E-03	12	0.109E-03	62	0.0	6	0.109E-03
1. 1. 3	SPECIALTY CARB	22	0.448E-04	13	0.867E-04	3	0.433E-04	13	0.0
5. 4. 1	HEAD GASKETS	23	0.224E-04	14	0.224E-04	67	0.0	7	0.224E-04
5. 1. 2	VALVE CAM LOBES	24	0.721E-05	15	0.721E-05	61	0.0	8	0.721E-05
5. 5. 0	CAMSHAFTS	25	0.721E-05	16	0.721E-05	68	0.0	9	0.721E-05
7. 3. 1	HIGH PERF EXHAST	26	0.917E-06	17	0.917E-06	5	0.917E-06	132	0.0
4. 2. 0	FI HI PRES PUMP	27	0.101E-07	18	0.101E-07	48	0.0	10	0.101E-07
1. 2. 1	IDLE STPSCLENOID	28	0.0	19	0.0	6	0.0	14	0.0
1. 2. 2	THROTTLE DASHPOT	29	0.0	20	0.0	7	0.0	15	0.0
1. 2. 3	THRTTL POSITIONR	30	0.0	21	0.0	8	0.0	16	0.0
1. 3. 1	METERING JETS	31	0.0	22	0.0	9	0.0	17	0.0
1. 3. 2	METERING RODS	32	0.0	23	0.0	10	0.0	18	0.0
1. 3. 3	VAC BRK VALVE	33	0.0	24	0.0	11	0.0	19	0.0
1. 3. 4	CHOKE MECHANISM	34	0.0	25	0.0	12	0.0	20	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - GARAGE SALES

PRINCIPAL RANKING - NOX

EARLY MODEL

PART CODE	PART NAME	----- HC ----- RANK	CI	----- CO ----- RANK	CI	----- NOX ----- RANK	CI	---- SMOKE ---- RANK	CI
7. 3. 2	EXHAUST MANIFOLD	19	0.215E-03	11	0.215E-03	1	0.215E-03	133	0.0
1. 1. 2	REBUILT CARB	10	0.109E-02	6	0.212E-02	2	0.106E-03	12	0.0
1. 1. 3	SPECIALTY CARB	22	0.448E-04	13	0.867E-04	3	0.433E-04	13	0.0
1. 1. 1	NEW CARB	15	0.388E-03	9	0.750E-03	4	0.375E-04	11	0.0
7. 3. 1	HIGH PERF EXHAST	26	0.917E-06	17	0.917E-06	5	0.917E-06	132	0.0
1. 2. 1	IDLE STPSOLENOID	28	0.0	19	0.0	6	0.0	14	0.0
1. 2. 2	THROTTLE DASHPOT	29	0.0	20	0.0	7	0.0	15	0.0
1. 2. 3	THRTTL POSITIONR	30	0.0	21	0.0	8	0.0	16	0.0
1. 3. 1	METERING JETS	31	0.0	22	0.0	9	0.0	17	0.0
1. 3. 2	METERING RODS	32	0.0	23	0.0	10	0.0	18	0.0
1. 3. 3	VAC BRK VALVE	33	0.0	24	0.0	11	0.0	19	0.0
1. 3. 4	CHOKE MECHANISM	34	0.0	25	0.0	12	0.0	20	0.0
1. 3. 5	ACCELERATOR PUMP	35	0.0	26	0.0	13	0.0	21	0.0
1. 3. 6	POWER VALVES	36	0.0	27	0.0	14	0.0	22	0.0
1. 3. 7	GASKETS	37	0.0	28	0.0	15	0.0	23	0.0
1. 3. 8	REBUILDING KITS	5	0.950E-02	1	0.475E-01	16	0.0	24	0.0
1. 3. 9	FLOAT AND VALVE	6	0.410E-02	2	0.205E-01	17	0.0	25	0.0
1. 3.10	IDLE ADJUSTMENT	38	0.0	29	0.0	18	0.0	26	0.0
1. 3.11	IDLE ENRICHMENT	39	0.0	30	0.0	19	0.0	27	0.0
1. 4. 0	FUEL FILTER	20	0.167E-03	31	0.0	20	0.0	28	0.0
2. 1. 0	POINTS	7	0.281E-02	32	0.0	21	0.0	29	0.0
2. 2. 0	CONDENSER	12	0.561E-03	33	0.0	22	0.0	30	0.0
2. 3. 1	CAP	3	0.168E-01	34	0.0	23	0.0	31	0.0
2. 3. 2	ROTOR	4	0.168E-01	35	0.0	24	0.0	32	0.0
2. 3. 3	MECH ADVANCE	40	0.0	36	0.0	25	0.0	33	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - GARAGE SALES

PRINCIPAL RANKING - SMOKE

EARLY MODEL

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
5. 1. 1	VALVE LIFTER/SPR	8	0.240E-02	5	0.240E-02	60	0.0	1	0.240E-02
5. 1. 5	EXHAUST VALVES	9	0.159E-02	7	0.159E-02	64	0.0	2	0.159E-02
3. 2. 0	AIR CLEANER ELEM	18	0.244E-03	3	0.487E-02	43	0.0	3	0.122E-02
5. 1. 4	VALVE SEALS	11	0.109E-02	8	0.109E-02	63	0.0	4	0.109E-02
5. 2. 0	PISTON RINGS	17	0.278E-03	10	0.278E-03	65	0.0	5	0.278E-03
5. 1. 3	VALVE GUIDES	21	0.109E-03	12	0.109E-03	62	0.0	6	0.109E-03
5. 4. 1	HEAD GASKETS	23	0.224E-04	14	0.224E-04	67	0.0	7	0.224E-04
5. 1. 2	VALVE CAM LOBES	24	0.721E-05	15	0.721E-05	61	0.0	8	0.721E-05
5. 5. 0	CAMSHAFTS	25	0.721E-05	16	0.721E-05	68	0.0	9	0.721E-05
4. 2. 0	FI HI PRES PUMP	27	0.101E-07	18	0.101E-07	48	0.0	10	0.101E-07
1. 1. 1	NEW CARB	15	0.388E-03	9	0.750E-03	4	0.375E-04	11	0.0
1. 1. 2	REBUILT CARB	10	0.109E-02	6	0.212E-02	2	0.106E-03	12	0.0
1. 1. 3	SPECIALTY CARB	22	0.448E-04	13	0.867E-04	3	0.433E-04	13	0.0
1. 2. 1	IDLE STPSOLENOID	28	0.0	19	0.0	6	0.0	14	0.0
1. 2. 2	THROTTLE DASHPOT	29	0.0	20	0.0	7	0.0	15	0.0
1. 2. 3	THRTTL POSITIONR	30	0.0	21	0.0	8	0.0	16	0.0
1. 3. 1	METERING JETS	31	0.0	22	0.0	9	0.0	17	0.0
1. 3. 2	METERING RODS	32	0.0	23	0.0	10	0.0	18	0.0
1. 3. 3	VAC BRK VALVE	33	0.0	24	0.0	11	0.0	19	0.0
1. 3. 4	CHOKE MECHANISM	34	0.0	25	0.0	12	0.0	20	0.0
1. 3. 5	ACCELERATOR PUMP	35	0.0	26	0.0	13	0.0	21	0.0
1. 3. 6	POWER VALVES	36	0.0	27	0.0	14	0.0	22	0.0
1. 3. 7	GASKETS	37	0.0	28	0.0	15	0.0	23	0.0
1. 3. 8	REBUILDING KITS	5	0.950E-02	1	0.475E-01	16	0.0	24	0.0
1. 3. 9	FLOAT AND VALVE	6	0.410E-02	2	0.205E-01	17	0.0	25	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - WAREHOUSE SALES

PRINCIPAL RANKING - HC

EARLY MODEL

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
2. 5. 0	SPARK PLUGS	1	0.446E+00	49	0.0	36	0.0	40	0.0
2. 6. 0	IGNITICN WIRES	2	0.340E-01	50	0.0	37	0.0	41	0.0
1. 3. 8	REBUILDING KITS	3	0.169E-01	1	0.846E-01	23	0.0	25	0.0
1. 1. 2	REBUILT CARB	4	0.608E-02	3	0.118E-01	4	0.589E-03	13	0.0
2. 3. 2	ROTOR	5	0.539E-02	44	0.0	31	0.0	33	0.0
2. 3. 1	CAP	6	0.459E-02	43	0.0	30	0.0	32	0.0
1. 3. 4	CHOKE MECHANISM	7	0.384E-02	2	0.192E-01	19	0.0	21	0.0
1. 1. 1	NEW CARB	8	0.379E-02	4	0.733E-02	6	0.367E-03	12	0.0
5. 1. 1	VALVE LIFTER/SPR	9	0.272E-02	6	0.272E-02	65	0.0	1	0.272E-02
2. 1. 0	POINTS	10	0.146E-02	41	0.0	28	0.0	30	0.0
5. 1. 4	VALVE SEALS	11	0.919E-03	8	0.919E-03	68	0.0	2	0.919E-03
5. 1. 5	EXHAUST VALVES	12	0.919E-03	9	0.919E-03	69	0.0	3	0.919E-03
1. 1. 3	SPECIALTY CARB	13	0.442E-03	10	0.856E-03	5	0.428E-03	14	0.0
2. 7. 0	COIL	14	0.426E-03	51	0.0	38	0.0	42	0.0
2. 2. 0	CONDENSER	15	0.293E-03	42	0.0	29	0.0	31	0.0
6. 1. 1	PCV VALVE	16	0.161E-03	7	0.161E-02	74	0.0	67	0.0
3. 2. 0	AIR CLEANER ELEM	17	0.155E-03	5	0.310E-02	48	0.0	4	0.776E-03
2. 3. 7	SPARK DELAY VLV	18	0.148E-03	47	0.0	2	0.148E-02	38	0.0
1. 4. 0	FUEL FILTER	19	0.105E-03	40	0.0	27	0.0	29	0.0
2. 3. 5	DISTRIBUTCR DRIV	20	0.105E-03	45	0.0	33	0.0	36	0.0
6. 2. 3	EVAP FRSH AIR	21	0.100E-03	79	0.0	80	0.0	73	0.0
6. 3. 2	AI HOSES	22	0.100E-03	16	0.100E-03	85	0.0	78	0.0
5. 1. 3	VALVE GUIDES	23	0.919E-04	17	0.919E-04	67	0.0	6	0.919E-04
5. 4. 1	HEAD GASKETS	24	0.910E-04	18	0.910E-04	72	0.0	7	0.910E-04
5. 2. 0	PISTON RINGS	25	0.901E-04	19	0.901E-04	70	0.0	8	0.901E-04

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - WAREHOUSE SALES

PRINCIPAL RANKING - CO

EARLY MODEL

PART CODE	PART NAME	----- HC ----- RANK	CI	----- CO ----- RANK	CI	----- NOX ----- RANK	CI	---- SMOKE ---- RANK	CI
1. 3. 8	REBUILDING KITS	3	0.169E-01	1	0.846E-01	23	0.0	25	0.0
1. 3. 4	CHOKE MECHANISM	7	0.384E-02	2	0.192E-01	19	0.0	21	0.0
1. 1. 2	REBUILT CARB	4	0.608E-02	3	0.118E-01	4	0.589E-03	13	0.0
1. 1. 1	NEW CARB	8	0.379E-02	4	0.733E-02	6	0.367E-03	12	0.0
3. 2. 0	AIR CLEANER ELEM	17	0.155E-03	5	0.310E-02	48	0.0	4	0.776E-03
5. 1. 1	VALVE LIFTER/SPR	9	0.272E-02	6	0.272E-02	65	0.0	1	0.272E-02
6. 1. 1	PCV VALVE	16	0.161E-03	7	0.161E-02	74	0.0	67	0.0
5. 1. 4	VALVE SEALS	11	0.919E-03	8	0.919E-03	68	0.0	2	0.919E-03
5. 1. 5	EXHAUST VALVES	12	0.919E-03	9	0.919E-03	69	0.0	3	0.919E-03
1. 1. 3	SPECIALTY CARB	13	0.442E-03	10	0.856E-03	5	0.428E-03	14	0.0
1. 3. 3	VAC BRK VALVE	28	0.787E-04	11	0.787E-03	18	0.0	20	0.0
6. 1. 3	PCV FRSHAIR FLTR	31	0.495E-04	12	0.495E-03	76	0.0	69	0.0
1. 2. 1	IDLE STPSOLENOID	33	0.407E-04	13	0.407E-03	13	0.0	15	0.0
1. 2. 2	THROTTLE DASHPOT	36	0.210E-04	14	0.210E-03	14	0.0	16	0.0
6.10. 4	DECEL VALVE	37	0.133E-04	15	0.133E-03	129	0.0	126	0.0
6. 3. 2	AI HOSES	22	0.100E-03	16	0.100E-03	85	0.0	78	0.0
5. 1. 3	VALVE GUIDES	23	0.919E-04	17	0.919E-04	67	0.0	6	0.919E-04
5. 4. 1	HEAD GASKETS	24	0.910E-04	18	0.910E-04	72	0.0	7	0.910E-04
5. 2. 0	PISTON RINGS	25	0.901E-04	19	0.901E-04	70	0.0	8	0.901E-04
5. 5. 0	CAMSHAFTS	26	0.901E-04	20	0.901E-04	73	0.0	9	0.901E-04
2. 3. 4	VACUUM ADVANCE	62	0.0	21	0.251E-04	32	0.0	35	0.0
6. 3. 7	AI PUMP/BELTS	41	0.819E-05	22	0.819E-05	90	0.0	83	0.0
3. 3. 0	INTAKE MANIFOLD	44	0.653E-05	23	0.653E-05	49	0.0	52	0.0
2. 3. 3	MECH ADVANCE	45	0.588E-05	24	0.588E-05	10	0.588E-04	34	0.0
5. 1. 2	VALVE CAM LOBES	46	0.500E-05	25	0.500E-05	66	0.0	10	0.500E-05

AUTCMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - WAREHOUSE SALES

PRINCIPAL RANKING - NOX

EARLY MODEL

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
6.10. 7	THERMO VAC VALV	27	0.882E-04	131	0.0	1	0.176E-02	129	0.0
2. 3. 7	SPARK DELAY VLV	18	0.148E-03	47	0.0	2	0.148E-02	38	0.0
6. 4. 1	EGR VALVES	92	0.0	87	0.0	3	0.928E-03	84	0.0
1. 1. 2	REBUILT CARB	4	0.608E-02	3	0.118E-01	4	0.589E-03	13	0.0
1. 1. 3	SPECIALTY CARB	13	0.442E-03	10	0.856E-03	5	0.428E-03	14	0.0
1. 1. 1	NEW CARB	8	0.379E-02	4	0.733E-02	6	0.367E-03	12	0.0
6. 4. 8	EGR VAC AMP	38	0.132E-04	94	0.0	7	0.265E-03	91	0.0
6. 5. 1	TCS VAC SOLENOID	40	0.826E-05	99	0.0	8	0.165E-03	96	0.0
6. 5. 8	TCS TEMP SWITCH	42	0.779E-05	106	0.0	9	0.156E-03	103	0.0
2. 3. 3	MECH ADVANCE	45	0.588E-05	24	0.588E-05	10	0.588E-04	34	0.0
7. 3. 2	EXHAUST MANIFOLD	50	0.490E-06	28	0.490E-06	11	0.490E-06	133	0.0
7. 3. 1	HIGH PERF EXHAST	52	0.647E-07	30	0.647E-07	12	0.647E-07	132	0.0
1. 2. 1	IDLE STPSOLENOID	33	0.407E-04	13	0.407E-03	13	0.0	15	0.0
1. 2. 2	THROTTLE DASHPOT	36	0.210E-04	14	0.210E-03	14	0.0	16	0.0
1. 2. 3	THRTTL POSITIONR	53	0.0	31	0.0	15	0.0	17	0.0
1. 3. 1	METERING JETS	54	0.0	32	0.0	16	0.0	18	0.0
1. 3. 2	METERING RODS	55	0.0	33	0.0	17	0.0	19	0.0
1. 3. 3	VAC BRK VALVE	28	0.787E-04	11	0.787E-03	18	0.0	20	0.0
1. 3. 4	CHOKE MECHANISM	7	0.384E-02	2	0.192E-01	19	0.0	21	0.0
1. 3. 5	ACCELERATOR PUMP	56	0.0	34	0.0	20	0.0	22	0.0
1. 3. 6	POWER VALVES	57	0.0	35	0.0	21	0.0	23	0.0
1. 3. 7	GASKETS	58	0.0	36	0.0	22	0.0	24	0.0
1. 3. 8	REBUILDING KITS	3	0.169E-01	1	0.846E-01	23	0.0	25	0.0
1. 3. 9	FLOAT AND VALVE	59	0.0	37	0.0	24	0.0	26	0.0
1. 3.10	IDLE ADJUSTMENT	60	0.0	38	0.0	25	0.0	27	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - WAREHOUSE SALES

PRINCIPAL RANKING - SMOKE

EARLY MODEL

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
5. 1. 1	VALVE LIFTER/SPR	9	0.272E-02	6	0.272E-02	65	0.0	1	0.272E-02
5. 1. 4	VALVE SEALS	11	0.919E-03	8	0.919E-03	68	0.0	2	0.919E-03
5. 1. 5	EXHAUST VALVES	12	0.919E-03	9	0.919E-03	69	0.0	3	0.919E-03
3. 2. 0	AIR CLEANER ELEM	17	0.155E-03	5	0.310E-02	48	0.0	4	0.776E-03
4. 4. 0	FI THROTTLE VALV	70	0.0	64	0.0	55	0.0	5	0.970E-04
5. 1. 3	VALVE GUIDES	23	0.919E-04	17	0.919E-04	67	0.0	6	0.919E-04
5. 4. 1	HEAD GASKETS	24	0.910E-04	18	0.910E-04	72	0.0	7	0.910E-04
5. 2. 0	PISTON RINGS	25	0.901E-04	19	0.901E-04	70	0.0	8	0.901E-04
5. 5. 0	CAMSHAFTS	26	0.901E-04	20	0.901E-04	73	0.0	9	0.901E-04
5. 1. 2	VALVE CAM LOBES	46	0.500E-05	25	0.500E-05	66	0.0	10	0.500E-05
4. 2. 0	FI HI PRES PUMP	51	0.183E-06	29	0.183E-06	53	0.0	11	0.183E-06
1. 1. 1	NEW CARB	8	0.379E-02	4	0.733E-02	6	0.367E-03	12	0.0
1. 1. 2	REBUILT CARB	4	0.608E-02	3	0.118E-01	4	0.589E-03	13	0.0
1. 1. 3	SPECIALTY CARB	13	0.442E-03	10	0.856E-03	5	0.428E-03	14	0.0
1. 2. 1	IDLE STPSOLENOID	33	0.407E-04	13	0.407E-03	13	0.0	15	0.0
1. 2. 2	THROTTLE DASHPOT	36	0.210E-04	14	0.210E-03	14	0.0	16	0.0
1. 2. 3	THRTTL POSITIONR	53	0.0	31	0.0	15	0.0	17	0.0
1. 3. 1	METERING JETS	54	0.0	32	0.0	16	0.0	18	0.0
1. 3. 2	METERING RODS	55	0.0	33	0.0	17	0.0	19	0.0
1. 3. 3	VAC BRK VALVE	28	0.787E-04	11	0.787E-03	18	0.0	20	0.0
1. 3. 4	CHOKE MECHANISM	7	0.384E-02	2	0.192E-01	19	0.0	21	0.0
1. 3. 5	ACCELERATOR PUMP	56	0.0	34	0.0	20	0.0	22	0.0
1. 3. 6	POWER VALVES	57	0.0	35	0.0	21	0.0	23	0.0
1. 3. 7	GASKETS	58	0.0	36	0.0	22	0.0	24	0.0
1. 3. 8	REBUILDING KITS	3	0.169E-01	1	0.846E-01	23	0.0	25	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - OEM SALES VOLUME

PRINCIPAL RANKING - HC

LATE MODELS

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
2. 5. 0	SPARK PLUGS	1	0.189E+00	12	0.189E-02	61	0.0	46	0.0
2. 6. 0	IGNITION WIRES	2	0.677E-01	22	0.677E-03	62	0.0	47	0.0
1. 3. 8	REBUILDING KITS	3	0.786E-02	1	0.393E-01	48	0.0	31	0.0
1. 3. 9	FLOAT AND VALVE	4	0.337E-02	2	0.168E-01	49	0.0	32	0.0
1. 3. 4	CHOKE MECHANISM	5	0.334E-02	3	0.167E-01	44	0.0	27	0.0
1. 3. 6	POWER VALVES	6	0.334E-02	4	0.167E-01	46	0.0	29	0.0
6. 2. 1	EVAP CANISTER	7	0.318E-02	90	0.0	102	0.0	71	0.0
1. 1. 2	REBUILT CARB	8	0.290E-02	5	0.562E-02	11	0.281E-03	19	0.0
6.10. 1	HEAT RISER	9	0.238E-02	27	0.238E-03	127	0.0	123	0.0
6. 1. 1	PCV VALVE	10	0.195E-02	11	0.195E-02	98	0.0	68	0.0
2. 3. 2	ROTOR	11	0.187E-02	37	0.936E-04	56	0.0	39	0.0
2. 3. 1	CAP	12	0.185E-02	38	0.927E-04	55	0.0	38	0.0
1. 1. 1	NEW CARB	13	0.174E-02	6	0.337E-02	17	0.168E-03	18	0.0
1. 3. 3	VAC BRK VALVE	14	0.170E-02	13	0.170E-02	43	0.0	26	0.0
3. 1. 3	TAC VAC MOTOR	15	0.141E-02	31	0.141E-03	70	0.0	55	0.0
3. 1. 4	TAC VAC HOSES	16	0.141E-02	32	0.141E-03	71	0.0	56	0.0
6. 1. 3	PCV FRSHAIR FLTR	17	0.108E-02	16	0.108E-02	100	0.0	70	0.0
6. 1. 2	PCV HOSES	18	0.107E-02	52	0.312E-04	99	0.0	69	0.0
6. 2. 2	EVAP HOSES	19	0.107E-02	53	0.312E-04	103	0.0	72	0.0
5. 1. 1	VALVE LIFTER/SPR	20	0.709E-03	20	0.709E-03	89	0.0	1	0.709E-02
1. 2. 1	IDLE STPSOLENOID	21	0.709E-03	21	0.709E-03	38	0.0	21	0.0
6. 2. 3	EVAP FRSH AIR	22	0.569E-03	91	0.0	104	0.0	73	0.0
3. 1. 1	TAC SHROUD	23	0.550E-03	79	0.0	68	0.0	53	0.0
3. 1. 2	TAC THERMOSTAT	24	0.550E-03	80	0.0	69	0.0	54	0.0
6. 3. 2	AI HOSES	25	0.441E-03	14	0.110E-02	109	0.0	78	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - OEM SALES VOLUME

PRINCIPAL RANKING - CO

LATE MODELS

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
1. 3. 8	REBUILDING KITS	3	0.786E-02	1	0.393E-01	48	0.0	31	0.0
1. 3. 9	FLOAT AND VALVE	4	0.337E-02	2	0.168E-01	49	0.0	32	0.0
1. 3. 4	CHOKE MECHANISM	5	0.334E-02	3	0.167E-01	44	0.0	27	0.0
1. 3. 6	POWER VALVES	6	0.334E-02	4	0.167E-01	46	0.0	29	0.0
1. 1. 2	REBUILT CARB	8	0.290E-02	5	0.562E-02	11	0.281E-03	19	0.0
1. 1. 1	NEW CARB	13	0.174E-02	6	0.337E-02	17	0.168E-03	18	0.0
1. 3. 5	ACCELERATOR PUMP	38	0.168E-03	7	0.337E-02	45	0.0	28	0.0
1. 3. 2	METERING RODS	42	0.117E-03	8	0.235E-02	42	0.0	25	0.0
3. 2. 0	AIR CLEANER ELEM	44	0.106E-03	9	0.211E-02	73	0.0	4	0.704E-03
1. 3. 1	METERING JETS	45	0.103E-03	10	0.205E-02	41	0.0	24	0.0
6. 1. 1	PCV VALVE	10	0.195E-02	11	0.195E-02	98	0.0	68	0.0
2. 5. 0	SPARK PLUGS	1	0.189E+00	12	0.189E-02	61	0.0	46	0.0
1. 3. 3	VAC BRK VALVE	14	0.170E-02	13	0.170E-02	43	0.0	26	0.0
6. 3. 2	AI HOSES	25	0.441E-03	14	0.110E-02	109	0.0	78	0.0
6. 3. 7	AI PUMP/BELTS	26	0.441E-03	15	0.110E-02	114	0.0	83	0.0
6. 1. 3	PCV FRSHAIR FLTR	17	0.108E-02	16	0.108E-02	100	0.0	70	0.0
1. 1. 3	SPECIALTY CARB	29	0.404E-03	17	0.993E-03	14	0.199E-03	20	0.0
2. 3. 4	VACUUM ADVANCE	102	0.0	18	0.936E-03	57	0.0	41	0.0
6. 3. 5	AI BYPASS/DVRTR	32	0.315E-03	19	0.788E-03	112	0.0	81	0.0
5. 1. 1	VALVE LIFTER/SPR	20	0.709E-03	20	0.709E-03	89	0.0	1	0.709E-02
1. 2. 1	IDLE STPSOLENOID	21	0.709E-03	21	0.709E-03	38	0.0	21	0.0
2. 6. 0	IGNITION WIRES	2	0.677E-01	22	0.677E-03	62	0.0	47	0.0
5. 1. 4	VALVE SEALS	27	0.411E-03	23	0.411E-03	92	0.0	2	0.411E-02
5. 1. 5	EXHAUST VALVES	28	0.411E-03	24	0.411E-03	93	0.0	3	0.411E-02
6. 3. 1	AI MANIFOLD	43	0.109E-03	25	0.272E-03	108	0.0	77	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - OEM SALES VOLUME

PRINCIPAL RANKING - NOX

LATE MODELS

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
6. 4. 1	EGR VALVES	115	0.0	96	0.0	1	0.463E-02	84	0.0
6. 4. 3	EGR THERMO VALVE	116	0.0	98	0.0	2	0.211E-02	86	0.0
2. 3. 7	SPARK DELAY VLV	40	0.122E-03	77	0.0	3	0.122E-02	44	0.0
6. 4. 8	EGR VAC AMP	55	0.357E-04	103	0.0	4	0.715E-03	91	0.0
6.10. 7	THERMO VAC VALV	56	0.340E-04	131	0.0	5	0.681E-03	129	0.0
6. 4. 2	EGR HOSES/SEALS	59	0.227E-04	97	0.0	6	0.454E-03	85	0.0
6. 5. 8	TCS TEMP SWITCH	60	0.216E-04	113	0.0	7	0.431E-03	103	0.0
6. 5. 6	TCS TRANS SWITCH	62	0.187E-04	111	0.0	8	0.374E-03	101	0.0
6. 5. 1	TCS VAC SOLENOID	63	0.176E-04	108	0.0	9	0.352E-03	96	0.0
6. 4. 4	EGR SOLENOID VLV	117	0.0	99	0.0	10	0.306E-03	87	0.0
1. 1. 2	REBUILT CARB	8	0.290E-02	5	0.562E-02	11	0.281E-03	19	0.0
6. 5. 3	TCS TIME DELAY	67	0.119E-04	109	0.0	12	0.238E-03	98	0.0
6. 7. 1	OSAC VAC ORIFICE	61	0.204E-04	118	0.0	13	0.204E-03	109	0.0
1. 1. 3	SPECIALTY CARB	29	0.404E-03	17	0.993E-03	14	0.199E-03	20	0.0
6. 4.10	EGR CARB SPACER	122	0.0	105	0.0	15	0.187E-03	93	0.0
6. 5. 5	TCS THERMO VALVE	71	0.851E-05	110	0.0	16	0.170E-03	100	0.0
1. 1. 1	NEW CARB	13	0.174E-02	6	0.337E-02	17	0.168E-03	18	0.0
6. 4.11	EGR BACKPRES SEN	123	0.0	106	0.0	18	0.159E-03	94	0.0
6. 4. 5	EGR TEMP SWITCH	118	0.0	100	0.0	19	0.148E-03	88	0.0
6. 4. 7	EGR TIME DELAY	120	0.0	102	0.0	20	0.148E-03	90	0.0
6. 4. 6	EGR SPEED/TRANS	119	0.0	101	0.0	21	0.125E-03	89	0.0
6. 7. 4	OSAC VAC BYPASS	72	0.851E-05	120	0.0	22	0.851E-04	112	0.0
6. 8. 5	ESC SPEED SWITCH	78	0.397E-05	125	0.0	23	0.794E-04	118	0.0
6. 8. 1	ESC ELEC MODULE	82	0.284E-05	122	0.0	24	0.567E-04	114	0.0
7. 3. 2	EXHAUST MANIFOLD	52	0.545E-04	47	0.545E-04	25	0.545E-04	133	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - OEM SALES VOLUME

PRINCIPAL RANKING - SMOKE

LATE MODELS

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
5. 1. 1	VALVE LIFTER/SPR	20	0.709E-03	20	0.709E-03	89	0.0	1	0.709E-02
5. 1. 4	VALVE SEALS	27	0.411E-03	23	0.411E-03	92	0.0	2	0.411E-02
5. 1. 5	EXHAUST VALVES	28	0.411E-03	24	0.411E-03	93	0.0	3	0.411E-02
3. 2. 0	AIR CLEANER ELEM	44	0.106E-03	9	0.211E-02	73	0.0	4	0.704E-03
4. 5. 0	MFI VALVES	107	0.0	83	0.0	81	0.0	5	0.454E-03
5. 1. 3	VALVE GUIDES	53	0.411E-04	48	0.411E-04	91	0.0	6	0.411E-03
5. 2. 0	PISTON RINGS	54	0.411E-04	49	0.411E-04	94	0.0	7	0.411E-03
5. 4. 1	HEAD GASKETS	70	0.981E-05	59	0.981E-05	96	0.0	8	0.981E-04
4. 4. 0	FI THROTTLE VALV	106	0.0	82	0.0	80	0.0	9	0.388E-04
5. 1. 2	VALVE CAM LOBES	85	0.210E-05	66	0.210E-05	90	0.0	10	0.210E-04
4. 3. 0	FI PRES SENS/REG	88	0.170E-05	55	0.170E-04	79	0.0	11	0.119E-04
3. 5. 0	SUPERCHARGER	74	0.567E-05	58	0.113E-04	76	0.0	12	0.397E-05
6. 1. 4	PCV OIL SEPARATR	76	0.454E-05	65	0.340E-05	101	0.0	13	0.340E-05
5. 5. 0	CAMSHAFTS	99	0.284E-06	74	0.284E-06	97	0.0	14	0.284E-05
3. 4. 0	TURBOCHARGER	86	0.189E-05	64	0.378E-05	75	0.0	15	0.132E-05
4. 8. 0	FI DIST MANIFOLD	97	0.420E-06	73	0.315E-06	37	0.315E-06	16	0.315E-06
4. 2. 0	FI HI PRES PUMP	100	0.630E-07	75	0.630E-07	78	0.0	17	0.630E-07
1. 1. 1	NEW CARB	13	0.174E-02	6	0.337E-02	17	0.168E-03	18	0.0
1. 1. 2	REBUILT CARB	8	0.290E-02	5	0.562E-02	11	0.281E-03	19	0.0
1. 1. 3	SPECIALTY CARB	29	0.404E-03	17	0.993E-03	14	0.199E-03	20	0.0
1. 2. 1	IDLE STPSCLENOID	21	0.709E-03	21	0.709E-03	38	0.0	21	0.0
1. 2. 2	THROTTLE DASHPOT	39	0.132E-03	33	0.132E-03	39	0.0	22	0.0
1. 2. 3	THRTTL POSITIONR	48	0.662E-04	42	0.662E-04	40	0.0	23	0.0
1. 3. 1	METERING JETS	45	0.103E-03	10	0.205E-02	41	0.0	24	0.0
1. 3. 2	METERING RODS	42	0.117E-03	8	0.235E-02	42	0.0	25	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - GARAGE SALES

PRINCIPAL RANKING - HC

LATE MODELS

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
2. 5. 0	SPARK PLUGS	1	0.266E+00	5	0.266E-02	31	0.0	39	0.0
2. 6. 0	IGNITICN WIRES	2	0.127E+00	7	0.127E-02	32	0.0	40	0.0
2. 3. 1	CAP	3	0.168E-01	8	0.842E-03	23	0.0	31	0.0
2. 3. 2	ROTOR	4	0.168E-01	9	0.842E-03	24	0.0	32	0.0
1. 3. 8	REBUILDING KITS	5	0.950E-02	1	0.475E-01	16	0.0	24	0.0
1. 3. 9	FLOAT AND VALVE	6	0.410E-02	2	0.205E-01	17	0.0	25	0.0
6. 1. 1	PCV VALVE	7	0.295E-02	4	0.295E-02	69	0.0	67	0.0
1. 1. 2	REBUILT CARB	8	0.109E-02	6	0.212E-02	2	0.106E-03	12	0.0
2. 4. 0	MAG/OPT TRIGGERS	9	0.447E-03	21	0.447E-05	30	0.0	38	0.0
2.10. 0	EI CONTROL CIRCT	10	0.447E-03	22	0.447E-05	36	0.0	44	0.0
1. 1. 1	NEW CARB	11	0.388E-03	10	0.750E-03	4	0.375E-04	11	0.0
2. 1. 0	POINTS	12	0.281E-03	11	0.281E-03	21	0.0	29	0.0
3. 2. 0	AIR CLEANER ELEM	13	0.244E-03	3	0.487E-02	43	0.0	2	0.162E-02
5. 1. 1	VALVE LIFTER/SPR	14	0.240E-03	12	0.240E-03	60	0.0	1	0.240E-02
7. 3. 2	EXHAUST MANIFOLD	15	0.215E-03	14	0.215E-03	1	0.215E-03	133	0.0
1. 4. 0	FUEL FILTER	16	0.167E-03	15	0.167E-03	20	0.0	28	0.0
5. 1. 5	EXHAUST VALVES	17	0.159E-03	16	0.159E-03	64	0.0	3	0.159E-02
5. 1. 4	VALVE SEALS	18	0.109E-03	17	0.109E-03	63	0.0	4	0.109E-02
1. 1. 3	SPECIALTY CARB	19	0.881E-04	13	0.217E-03	3	0.433E-04	13	0.0
2. 2. 0	CONDENSER	20	0.561E-04	18	0.561E-04	22	0.0	30	0.0
5. 2. 0	PISTON RINGS	21	0.278E-04	19	0.278E-04	65	0.0	5	0.278E-03
5. 1. 3	VALVE GUIDES	22	0.109E-04	20	0.109E-04	62	0.0	6	0.109E-03
5. 4. 1	HEAD GASKETS	23	0.224E-05	23	0.224E-05	67	0.0	7	0.224E-04
7. 3. 1	HIGH PERF EXHAST	24	0.917E-06	24	0.917E-06	5	0.917E-06	132	0.0
5. 1. 2	VALVE CAM LOBES	25	0.721E-06	25	0.721E-06	61	0.0	8	0.721E-05

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - GARAGE SALES

PRINCIPAL RANKING - CO

LATE MODELS

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
1. 3. 8	REBUILDING KITS	5	0.950E-02	1	0.475E-01	16	0.0	24	0.0
1. 3. 9	FLOAT AND VALVE	6	0.410E-02	2	0.205E-01	17	0.0	25	0.0
3. 2. 0	AIR CLEANER ELEM	13	0.244E-03	3	0.487E-02	43	0.0	2	0.162E-02
6. 1. 1	PCV VALVE	7	0.295E-02	4	0.295E-02	69	0.0	67	0.0
2. 5. 0	SPARK PLUGS	1	0.266E+00	5	0.266E-02	31	0.0	39	0.0
1. 1. 2	REBUILT CARB	8	0.109E-02	6	0.212E-02	2	0.106E-03	12	0.0
2. 6. 0	IGNITION WIRES	2	0.127E+00	7	0.127E-02	32	0.0	40	0.0
2. 3. 1	CAP	3	0.168E-01	8	0.842E-03	23	0.0	31	0.0
2. 3. 2	ROTOR	4	0.168E-01	9	0.842E-03	24	0.0	32	0.0
1. 1. 1	NEW CARB	11	0.388E-03	10	0.750E-03	4	0.375E-04	11	0.0
2. 1. 0	POINTS	12	0.281E-03	11	0.281E-03	21	0.0	29	0.0
5. 1. 1	VALVE LIFTER/SPR	14	0.240E-03	12	0.240E-03	60	0.0	1	0.240E-02
1. 1. 3	SPECIALTY CARB	19	0.881E-04	13	0.217E-03	3	0.433E-04	13	0.0
7. 3. 2	EXHAUST MANIFOLD	15	0.215E-03	14	0.215E-03	1	0.215E-03	133	0.0
1. 4. 0	FUEL FILTER	16	0.167E-03	15	0.167E-03	20	0.0	28	0.0
5. 1. 5	EXHAUST VALVES	17	0.159E-03	16	0.159E-03	64	0.0	3	0.159E-02
5. 1. 4	VALVE SEALS	18	0.109E-03	17	0.109E-03	63	0.0	4	0.109E-02
2. 2. 0	CONDENSER	20	0.561E-04	18	0.561E-04	22	0.0	30	0.0
5. 2. 0	PISTON RINGS	21	0.278E-04	19	0.278E-04	65	0.0	5	0.278E-03
5. 1. 3	VALVE GUIDES	22	0.109E-04	20	0.109E-04	62	0.0	6	0.109E-03
2. 4. 0	MAG/OPT TRIGGERS	9	0.447E-03	21	0.447E-05	30	0.0	38	0.0
2.10. 0	EI CONTROL CIRCT	10	0.447E-03	22	0.447E-05	36	0.0	44	0.0
5. 4. 1	HEAD GASKETS	23	0.224E-05	23	0.224E-05	67	0.0	7	0.224E-04
7. 3. 1	HIGH PERF EXHAST	24	0.917E-06	24	0.917E-06	5	0.917E-06	132	0.0
5. 1. 2	VALVE CAM LOBES	25	0.721E-06	25	0.721E-06	61	0.0	8	0.721E-05

AUTCMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - GARAGE SALES

PRINCIPAL RANKING - NOX

LATE MODELS

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
7. 3. 2	EXHAUST MANIFOLD	15	0.215E-03	14	0.215E-03	1	0.215E-03	133	0.0
1. 1. 2	REBUILT CARB	8	0.109E-02	6	0.212E-02	2	0.106E-03	12	0.0
1. 1. 3	SPECIALTY CARB	19	0.881E-04	13	0.217E-03	3	0.433E-04	13	0.0
1. 1. 1	NEW CARB	11	0.388E-03	10	0.750E-03	4	0.375E-04	11	0.0
7. 3. 1	HIGH PERF EXHAST	24	0.917E-06	24	0.917E-06	5	0.917E-06	132	0.0
1. 2. 1	IDLE STPSCLENOID	28	0.0	28	0.0	6	0.0	14	0.0
1. 2. 2	THROTTLE DASHPOT	29	0.0	29	0.0	7	0.0	15	0.0
1. 2. 3	THRTTL POSITIONR	30	0.0	30	0.0	8	0.0	16	0.0
1. 3. 1	METERING JETS	31	0.0	31	0.0	9	0.0	17	0.0
1. 3. 2	METERING RODS	32	0.0	32	0.0	10	0.0	18	0.0
1. 3. 3	VAC BRK VALVE	33	0.0	33	0.0	11	0.0	19	0.0
1. 3. 4	CHOKE MECHANISM	34	0.0	34	0.0	12	0.0	20	0.0
1. 3. 5	ACCELERATCR PUMP	35	0.0	35	0.0	13	0.0	21	0.0
1. 3. 6	POWER VALVES	36	0.0	36	0.0	14	0.0	22	0.0
1. 3. 7	GASKETS	37	0.0	37	0.0	15	0.0	23	0.0
1. 3. 8	REBUILDING KITS	5	0.950E-02	1	0.475E-01	16	0.0	24	0.0
1. 3. 9	FLOAT AND VALVE	6	0.410E-02	2	0.205E-01	17	0.0	25	0.0
1. 3.10	IDLE ADJUSTMENT	38	0.0	38	0.0	18	0.0	26	0.0
1. 3.11	IDLE ENRICHMENT	39	0.0	39	0.0	19	0.0	27	0.0
1. 4. 0	FUEL FILTER	16	0.167E-03	15	0.167E-03	20	0.0	28	0.0
2. 1. 0	POINTS	12	0.281E-03	11	0.281E-03	21	0.0	29	0.0
2. 2. 0	CONDENSER	20	0.561E-04	18	0.561E-04	22	0.0	30	0.0
2. 3. 1	CAP	3	0.168E-01	8	0.842E-03	23	0.0	31	0.0
2. 3. 2	ROTOR	4	0.168E-01	9	0.842E-03	24	0.0	32	0.0
2. 3. 3	MECH ADVANCE	40	0.0	40	0.0	25	0.0	33	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - GARAGE SALES

PRINCIPAL RANKING - SMOKE

LATE MODELS

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
5. 1. 1	VALVE LIFTER/SPR	14	0.240E-03	12	0.240E-03	60	0.0	1	0.240E-02
3. 2. 0	AIR CLEANER ELEM	13	0.244E-03	3	0.487E-02	43	0.0	2	0.162E-02
5. 1. 5	EXHAUST VALVES	17	0.159E-03	16	0.159E-03	64	0.0	3	0.159E-02
5. 1. 4	VALVE SEALS	18	0.109E-03	17	0.109E-03	63	0.0	4	0.109E-02
5. 2. 0	PISTON RINGS	21	0.278E-04	19	0.278E-04	65	0.0	5	0.278E-03
5. 1. 3	VALVE GUIDES	22	0.109E-04	20	0.109E-04	62	0.0	6	0.109E-03
5. 4. 1	HEAD GASKETS	23	0.224E-05	23	0.224E-05	67	0.0	7	0.224E-04
5. 1. 2	VALVE CAM LOBES	25	0.721E-06	25	0.721E-06	61	0.0	8	0.721E-05
5. 5. 0	CAMSHAFTS	26	0.721E-06	26	0.721E-06	68	0.0	9	0.721E-05
4. 2. 0	FI HI PRES PUMP	27	0.101E-07	27	0.101E-07	48	0.0	10	0.101E-07
1. 1. 1	NEW CARB	11	0.388E-03	10	0.750E-03	4	0.375E-04	11	0.0
1. 1. 2	REBUILT CARB	8	0.109E-02	6	0.212E-02	2	0.106E-03	12	0.0
1. 1. 3	SPECIALTY CARB	19	0.881E-04	13	0.217E-03	3	0.433E-04	13	0.0
1. 2. 1	IDLE STPSOLENOID	28	0.0	28	0.0	6	0.0	14	0.0
1. 2. 2	THROTTLE DASHPOT	29	0.0	29	0.0	7	0.0	15	0.0
1. 2. 3	THRTTL POSITIONR	30	0.0	30	0.0	8	0.0	16	0.0
1. 3. 1	METERING JETS	31	0.0	31	0.0	9	0.0	17	0.0
1. 3. 2	METERING RODS	32	0.0	32	0.0	10	0.0	18	0.0
1. 3. 3	VAC BRK VALVE	33	0.0	33	0.0	11	0.0	19	0.0
1. 3. 4	CHOKE MECHANISM	34	0.0	34	0.0	12	0.0	20	0.0
1. 3. 5	ACCELERATOR PUMP	35	0.0	35	0.0	13	0.0	21	0.0
1. 3. 6	POWER VALVES	36	0.0	36	0.0	14	0.0	22	0.0
1. 3. 7	GASKETS	37	0.0	37	0.0	15	0.0	23	0.0
1. 3. 8	REBUILDING KITS	5	0.950E-02	1	0.475E-01	16	0.0	24	0.0
1. 3. 9	FLOAT AND VALVE	6	0.410E-02	2	0.205E-01	17	0.0	25	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - WAREHOUSE SALES

PRINCIPAL RANKING - HC

LATE MODELS

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
2. 5. 0	SPARK PLUGS	1	0.446E+00	5	0.446E-02	36	0.0	40	0.0
2. 6. 0	IGNITION WIRES	2	0.340E-01	13	0.340E-03	37	0.0	41	0.0
1. 3. 8	REBUILDING KITS	3	0.169E-01	1	0.846E-01	23	0.0	25	0.0
1. 1. 2	REBUILT CARB	4	0.608E-02	3	0.118E-01	4	0.589E-03	13	0.0
2. 3. 2	ROTOR	5	0.539E-02	15	0.269E-03	31	0.0	33	0.0
2. 3. 1	CAP	6	0.459E-02	17	0.229E-03	30	0.0	32	0.0
1. 3. 4	CHOKE MECHANISM	7	0.384E-02	2	0.192E-01	19	0.0	21	0.0
1. 1. 1	NEW CARB	8	0.379E-02	4	0.733E-02	6	0.367E-03	12	0.0
6. 1. 1	PCV VALVE	9	0.161E-02	8	0.161E-02	74	0.0	67	0.0
1. 1. 3	SPECIALTY CARB	10	0.870E-03	7	0.214E-02	5	0.428E-03	14	0.0
1. 3. 3	VAC BRK VALVE	11	0.787E-03	9	0.787E-03	18	0.0	20	0.0
6.10. 1	HEAT RISER	12	0.663E-03	25	0.663E-04	126	0.0	123	0.0
6. 1. 3	PCV FRSHAIR FLTR	13	0.495E-03	11	0.495E-03	76	0.0	69	0.0
3. 1. 3	TAC VAC MOTOR	14	0.441E-03	26	0.441E-04	45	0.0	49	0.0
1. 2. 1	IDLE STPSOLENOID	15	0.407E-03	12	0.407E-03	13	0.0	15	0.0
3. 1. 4	TAC VAC HOSES	16	0.374E-03	29	0.374E-04	46	0.0	50	0.0
5. 1. 1	VALVE LIFTER/SPR	17	0.272E-03	14	0.272E-03	65	0.0	1	0.272E-02
3. 1. 1	TAC SHROUD	18	0.235E-03	59	0.0	43	0.0	47	0.0
1. 2. 2	THROTTLE DASHPOT	19	0.210E-03	18	0.210E-03	14	0.0	16	0.0
6. 3. 2	AI HOSES	20	0.200E-03	10	0.500E-03	85	0.0	78	0.0
3. 2. 0	AIR CLEANER ELEM	21	0.155E-03	6	0.310E-02	48	0.0	2	0.103E-02
2. 3. 7	SPARK DELAY VLV	22	0.148E-03	56	0.0	2	0.148E-02	38	0.0
2. 1. 0	POINTS	23	0.146E-03	19	0.146E-03	28	0.0	30	0.0
6.10. 4	DECEL VALVE	24	0.133E-03	20	0.133E-03	129	0.0	126	0.0
1. 4. 0	FUEL FILTER	25	0.105E-03	22	0.105E-03	27	0.0	29	0.0

AUTCMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - WAREHOUSE SALES

PRINCIPAL RANKING - CO

LATE MODELS

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
1. 3. 8	REBUILDING KITS	3	0.169E-01	1	0.846E-01	23	0.0	25	0.0
1. 3. 4	CHOKE MECHANISM	7	0.384E-02	2	0.192E-01	19	0.0	21	0.0
1. 1. 2	REBUILT CARB	4	0.608E-02	3	0.118E-01	4	0.589E-03	13	0.0
1. 1. 1	NEW CARB	8	0.379E-02	4	0.733E-02	6	0.367E-03	12	0.0
2. 5. 0	SPARK PLUGS	1	0.446E+00	5	0.446E-02	36	0.0	40	0.0
3. 2. 0	AIR CLEANER ELEM	21	0.155E-03	6	0.310E-02	48	0.0	2	0.103E-02
1. 1. 3	SPECIALTY CARB	10	0.870E-03	7	0.214E-02	5	0.428E-03	14	0.0
6. 1. 1	PCV VALVE	9	0.161E-02	8	0.161E-02	74	0.0	67	0.0
1. 3. 3	VAC BRK VALVE	11	0.787E-03	9	0.787E-03	18	0.0	20	0.0
6. 3. 2	AI HOSES	20	0.200E-03	10	0.500E-03	85	0.0	78	0.0
6. 1. 3	PCV FRSHAIR FLTR	13	0.495E-03	11	0.495E-03	76	0.0	69	0.0
1. 2. 1	IDLE STPSCLENOID	15	0.407E-03	12	0.407E-03	13	0.0	15	0.0
2. 6. 0	IGNITION WIRES	2	0.340E-01	13	0.340E-03	37	0.0	41	0.0
5. 1. 1	VALVE LIFTER/SPR	17	0.272E-03	14	0.272E-03	65	0.0	1	0.272E-02
2. 3. 2	ROTOR	5	0.539E-02	15	0.269E-03	31	0.0	33	0.0
2. 3. 4	VACUUM ADVANCE	62	0.0	16	0.251E-03	32	0.0	35	0.0
2. 3. 1	CAP	6	0.459E-02	17	0.229E-03	30	0.0	32	0.0
1. 2. 2	THROTTLE DASHPOT	19	0.210E-03	18	0.210E-03	14	0.0	16	0.0
2. 1. 0	POINTS	23	0.146E-03	19	0.146E-03	28	0.0	30	0.0
6.10. 4	DECEL VALVE	24	0.133E-03	20	0.133E-03	129	0.0	126	0.0
6. 3. 5	AI BYPASS/DVRTR	32	0.430E-04	21	0.108E-03	88	0.0	81	0.0
1. 4. 0	FUEL FILTER	25	0.105E-03	22	0.105E-03	27	0.0	29	0.0
5. 1. 4	VALVE SEALS	28	0.919E-04	23	0.919E-04	68	0.0	3	0.919E-03
5. 1. 5	EXHAUST VALVES	29	0.919E-04	24	0.919E-04	69	0.0	4	0.919E-03
6.10. 1	HEAT RISER	12	0.663E-03	25	0.663E-04	126	0.0	123	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - WAREHOUSE SALES

PRINCIPAL RANKING - NOX

LATE MODELS

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
6.10. 7	THERMO VAC VALV	30	0.882E-04	131	0.0	1	0.176E-02	129	0.0
2. 3. 7	SPARK DELAY VLV	22	0.148E-03	56	0.0	2	0.148E-02	38	0.0
6. 4. 1	EGR VALVES	92	0.0	88	0.0	3	0.928E-03	84	0.0
1. 1. 2	REBUILT CARB	4	0.608E-02	3	0.118E-01	4	0.589E-03	13	0.0
1. 1. 3	SPECIALTY CARB	10	0.870E-03	7	0.214E-02	5	0.428E-03	14	0.0
1. 1. 1	NEW CARB	8	0.379E-02	4	0.733E-02	6	0.367E-03	12	0.0
6. 4. 8	EGR VAC AMP	36	0.132E-04	95	0.0	7	0.265E-03	91	0.0
6. 5. 1	TCS VAC SOLENOID	42	0.826E-05	100	0.0	8	0.165E-03	96	0.0
6. 5. 8	TCS TEMP SWITCH	43	0.779E-05	107	0.0	9	0.156E-03	103	0.0
2. 3. 3	MECH ADVANCE	46	0.588E-05	37	0.588E-05	10	0.588E-04	34	0.0
7. 3. 2	EXHAUST MANIFOLD	49	0.490E-06	41	0.490E-06	11	0.490E-06	133	0.0
7. 3. 1	HIGH PERF EXHAST	52	0.647E-07	45	0.647E-07	12	0.647E-07	132	0.0
1. 2. 1	IDLE STPSOLENOID	15	0.407E-03	12	0.407E-03	13	0.0	15	0.0
1. 2. 2	THROTTLE DASHPOT	19	0.210E-03	18	0.210E-03	14	0.0	16	0.0
1. 2. 3	THRTTL POSITIONR	53	0.0	46	0.0	15	0.0	17	0.0
1. 3. 1	METERING JETS	54	0.0	47	0.0	16	0.0	18	0.0
1. 3. 2	METERING RODS	55	0.0	48	0.0	17	0.0	19	0.0
1. 3. 3	VAC BRK VALVE	11	0.787E-03	9	0.787E-03	18	0.0	20	0.0
1. 3. 4	CHOKE MECHANISM	7	0.384E-02	2	0.192E-01	19	0.0	21	0.0
1. 3. 5	ACCELERATOR PUMP	56	0.0	49	0.0	20	0.0	22	0.0
1. 3. 6	POWER VALVES	57	0.0	50	0.0	21	0.0	23	0.0
1. 3. 7	GASKETS	58	0.0	51	0.0	22	0.0	24	0.0
1. 3. 8	REBUILDING KITS	3	0.169E-01	1	0.846E-01	23	0.0	25	0.0
1. 3. 9	FLOAT AND VALVE	59	0.0	52	0.0	24	0.0	26	0.0
1. 3.10	IDLE ADJUSTMENT	60	0.0	53	0.0	25	0.0	27	0.0

AUTOMOTIVE PARTS STUDY - EPA CONTRACT NO. 68-01-1957

CRITICALITY INDEX RANKING - WAREHOUSE SALES

PRINCIPAL RANKING - SMOKE

LATE MODELS

PART CODE	PART NAME	HC RANK	HC CI	CO RANK	CO CI	NOX RANK	NOX CI	SMOKE RANK	SMOKE CI
5. 1. 1	VALVE LIFTER/SPR	17	0.272E-03	14	0.272E-03	65	0.0	1	0.272E-02
3. 2. 0	AIR CLEANER ELEM	21	0.155E-03	6	0.310E-02	48	0.0	2	0.103E-02
5. 1. 4	VALVE SEALS	28	0.919E-04	23	0.919E-04	68	0.0	3	0.919E-03
5. 1. 5	EXHAUST VALVES	29	0.919E-04	24	0.919E-04	69	0.0	4	0.919E-03
4. 4. 0	FI THROTTLE VALV	70	0.0	65	0.0	55	0.0	5	0.241E-03
5. 1. 3	VALVE GUIDES	38	0.919E-05	32	0.919E-05	67	0.0	6	0.919E-04
5. 4. 1	HEAD GASKETS	39	0.910E-05	33	0.910E-05	72	0.0	7	0.910E-04
5. 2. 0	PISTON RINGS	40	0.901E-05	34	0.901E-05	70	0.0	8	0.901E-04
5. 5. 0	CAMSHAFTS	41	0.901E-05	35	0.901E-05	73	0.0	9	0.901E-04
5. 1. 2	VALVE CAM LOBES	48	0.500E-06	40	0.500E-06	66	0.0	10	0.500E-05
4. 2. 0	FI HI PRES PUMP	51	0.183E-06	43	0.183E-06	53	0.0	11	0.183E-06
1. 1. 1	NEW CARB	8	0.379E-02	4	0.733E-02	6	0.367E-03	12	0.0
1. 1. 2	REBUILT CARB	4	0.608E-02	3	0.118E-01	4	0.589E-03	13	0.0
1. 1. 3	SPECIALTY CARB	10	0.870E-03	7	0.214E-02	5	0.428E-03	14	0.0
1. 2. 1	IDLE STPSOLENOID	15	0.407E-03	12	0.407E-03	13	0.0	15	0.0
1. 2. 2	THROTTLE DASHPOT	19	0.210E-03	18	0.210E-03	14	0.0	16	0.0
1. 2. 3	THRTTL POSITIONR	53	0.0	46	0.0	15	0.0	17	0.0
1. 3. 1	METERING JETS	54	0.0	47	0.0	16	0.0	18	0.0
1. 3. 2	METERING RODS	55	0.0	48	0.0	17	0.0	19	0.0
1. 3. 3	VAC BRK VALVE	11	0.787E-03	9	0.787E-03	18	0.0	20	0.0
1. 3. 4	CHOKE MECHANISM	7	0.384E-02	2	0.192E-01	19	0.0	21	0.0
1. 3. 5	ACCELERATOR PUMP	56	0.0	49	0.0	20	0.0	22	0.0
1. 3. 6	POWER VALVES	57	0.0	50	0.0	21	0.0	23	0.0
1. 3. 7	GASKETS	58	0.0	51	0.0	22	0.0	24	0.0
1. 3. 8	REBUILDING KITS	3	0.169E-01	1	0.846E-01	23	0.0	25	0.0

Appendix B

CRITICALITY INDEX INPUT PARAMETER VALUES

PART NAME	EMISSION INCREASE FACTORS: GASOLINE							DIESEL (SMOKE)					PROBABILITY FACTORS		SALES VOLUME FACTORS		
		PRE-1975			POST-1975			PRE-1974		POST-1974							
	EVAP	HC	CO	NOX	HC	CO	NOX	ACCEL	LUG	ACCEL	LUG	PEAK	EARLY FAIL	NO REPL	OEM	GARAGE	WAREHOUSE
NEW CARB	0.1	1.0	2.0	0.1	1.0	2.0	0.1	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0062	0.0014	0.0136
REBUILT CARB	0.1	1.0	2.0	0.1	1.0	2.0	0.1	0.0	0.0	0.0	0.0	0.0	0.50	0.90	0.0062	0.0024	0.0131
SPECIALTY CARB	0.1	1.0	2.0	1.0	2.0	5.0	1.0	0.0	0.0	0.0	0.0	0.0	0.70	0.90	0.0003	0.0001	0.0007
IDLE STPSOLENOID	0.0	0.1	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.50	0.0047	0.0	0.0027
THROTTLE DASHPOT	0.0	0.1	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.50	0.0009	0.0	0.0014
THRTTL POSITIONR	0.0	0.1	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.50	0.0004	0.0	0.0
METERING JETS	0.0	0.1	2.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0114	0.0	0.0
METERING RODS	0.0	0.1	2.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0043	0.0	0.0
VAC BRK VALVE	0.0	0.1	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0063	0.0	0.0029
CHOKE MECHANISM	0.0	2.0	10.0	0.0	2.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0062	0.0	0.0071
ACCELERATOR PUMP	0.0	0.1	2.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0062	0.0	0.0
POWER VALVES	0.0	2.0	10.0	0.0	2.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0062	0.0	0.0
GASKETS	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0062	0.0	0.0
REBUILDING KITS	0.0	2.0	10.0	0.0	2.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.70	0.90	0.0062	0.0075	0.0134
FLOAT AND VALVE	0.0	2.0	10.0	0.0	2.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0062	0.0076	0.0
IDLE ADJUSTMENT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IDLE ENRICHMENT	0.0	0.1	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0002	0.0	0.0
FUEL FILTER	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0240	0.0333	0.0211
POINTS	0.0	1.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.50	0.10	0.0146	0.0561	0.0293
CONDENSER	0.0	1.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.10	0.0043	0.0561	0.0293
CAP	0.0	2.0	0.0	0.0	2.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.50	0.0062	0.0561	0.0153
ROTOR	0.0	2.0	0.0	0.0	2.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.50	0.0062	0.0561	0.0180
MECH ADVANCE	0.0	0.1	0.1	1.0	0.1	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.30	0.50	0.0003	0.0	0.0004
VACUUM ADVANCE	0.0	0.0	0.1	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.50	0.0062	0.0	0.0017
DISTRIBUTOR DRIV	0.0	1.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0062	0.0	0.0021
DUAL DIAPHM DIST	0.0	0.0	0.1	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0003	0.0	0.0
SPARK DELAY VLV	0.0	0.1	0.0	1.0	0.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.50	0.90	0.0027	0.0	0.0033
MAG/OPT TRIGGERS	0.0	10.0	0.0	0.0	10.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.10	0.0020	0.0045	0.0001
SPARK PLUGS	0.0	10.0	0.0	0.0	10.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.70	0.10	0.2700	0.3802	0.6374
IGNITION WIRES	0.0	10.0	0.0	0.0	10.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.50	0.0451	0.0849	0.0226
COIL	0.0	1.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0062	0.0	0.0047
CAPACITIVE DISCH	0.0	1.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.10	0.0003	0.0	0.0002
BALLAST RESISTOR	0.0	1.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0062	0.0	0.0
EI CONTROL CIRCT	0.0	10.0	0.0	0.0	10.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.10	0.0020	0.0045	0.0006
IGN TIMING ADJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0062	0.0158	0.0
TAC SHROUD	0.0	0.1	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0061	0.0	0.0026

PART NAME	EMISSION INCREASE FACTORS												PROBABILITY FACTORS		SALES VOLUME FACTORS		
	GASOLINE							DIESEL(SMOKE)									
		PRE-1975			POST-1975			PRE-1974		POST-1974							
	EVAP	HC	CO	NOX	HC	CO	NOX	ACCEL	LUG	ACCEL	LUG	PEAK	EARLY FAIL	NO REPL	OEM	GARAGE	WAREHOUSE
TAC THERMOSTAT	0.0	0.1	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0061	0.0	0.0011
TAC VAC MOTOR	0.0	0.1	0.0	0.0	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0052	0.0	0.0016
TAC VAC HOSES	0.0	0.1	0.0	0.0	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0052	0.0	0.0014
TAC FRESH AIR IN	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0001	0.0	0.0001
AIR CLEANER ELEM	0.0	0.1	2.0	0.0	0.1	2.0	0.0	1.0	0.0	1.0	0.0	1.0	0.10	0.50	0.0211	0.0487	0.0310
INTAKE MANIFOLD	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.50	0.90	0.0003	0.0	0.0001
TURBOCHARGER	0.0	1.0	2.0	0.0	1.0	2.0	0.0	1.0	0.1	1.0	0.1	1.0	0.10	0.30	0.0001	0.0	0.0
SUPERCHARGER	0.0	1.0	2.0	0.0	1.0	2.0	0.0	1.0	0.1	1.0	0.1	1.0	0.30	0.30	0.0001	0.0	0.0
MFI ACCUMULATOR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.01	0.90	0.0	0.0	0.0
FI HI PRES PUMP	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.10	0.10	0.0001	0.0000	0.0002
FI PRES SENS/REG	0.0	0.1	1.0	0.0	0.1	1.0	0.0	1.0	0.1	1.0	0.1	1.0	0.30	0.90	0.0001	0.0	0.0
FI THROTTLE VALV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.1	2.0	0.1	2.0	0.50	0.90	0.0001	0.0	0.0004
MFI VALVES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	2.00	0.90	0.0003	0.0	0.0
EFI AIR SENS/SWH	0.0	1.0	5.0	0.0	1.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.10	0.0	0.0	0.0
EFI TEMPSENS/SWH	0.0	1.0	5.0	0.0	1.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0	0.0	0.0
FI DIST MANIFOLD	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.10	0.50	0.0001	0.0	0.0
EFI INJECTORS	0.0	0.1	2.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.50	0.90	0.0001	0.0	0.0
EFI TRIGGER SWCH	0.0	2.0	0.1	0.1	2.0	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.30	0.10	0.0	0.0	0.0
EFI CONTROL CIRC	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.10	0.10	0.0	0.0	0.0
FI STARTING VALV	0.0	1.0	5.0	0.0	1.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.50	0.90	0.0001	0.0	0.0
FI IDLE ADJUST	0.0	0.1	1.0	0.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	2.0	0.50	0.30	0.0	0.0	0.0
VALVE LIFTER/SPR	0.0	1.0	1.0	0.0	0.1	0.1	0.0	1.0	1.0	1.0	1.0	1.0	0.30	0.50	0.0473	0.0160	0.0181
VALVE CAM LOBES	0.0	1.0	1.0	0.0	0.1	0.1	0.0	1.0	1.0	1.0	1.0	1.0	0.01	0.90	0.0023	0.0008	0.0006
VALVE GUIDES	0.0	1.0	1.0	0.0	0.1	0.1	0.0	1.0	1.0	1.0	1.0	1.0	0.01	0.90	0.0457	0.0122	0.0102
VALVE SEALS	0.0	1.0	1.0	0.0	0.1	0.1	0.0	1.0	1.0	1.0	1.0	1.0	0.10	0.90	0.0457	0.0122	0.0102
EXHAUST VALVES	0.0	1.0	1.0	0.0	0.1	0.1	0.0	1.0	1.0	1.0	1.0	1.0	0.10	0.90	0.0457	0.0177	0.0102
PISTON RINGS	0.0	1.0	1.0	0.0	0.1	0.1	0.0	1.0	1.0	1.0	1.0	1.0	0.01	0.90	0.0457	0.0309	0.0100
PISTON/RODS	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.10	0.0457	0.0	0.0029
HEAD GASKETS	0.0	1.0	1.0	0.0	0.1	0.1	0.0	1.0	1.0	1.0	1.0	1.0	0.01	0.90	0.0109	0.0025	0.0101
CAMSHAFTS	0.0	1.0	1.0	0.0	0.1	0.1	0.0	1.0	1.0	1.0	1.0	1.0	0.01	0.90	0.0003	0.0008	0.0100
PCV VALVE	0.0	0.1	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.30	0.0216	0.0328	0.0179
PCV HOSES	10.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0062	0.0	0.0
PCV FRSHAIR FLTR	0.0	0.1	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.70	0.0154	0.0	0.0071
PCV OIL SEPARATR	0.1	1.0	1.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.30	0.90	0.0001	0.0	0.0
EVAP CANISTER	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.50	0.0064	0.0	0.0
EVAP HOSES	10.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0062	0.0	0.0

PART NAME	EMISSION INCREASE FACTORS												PROBABILITY FACTORS		SALES VOLUME FACTORS		
	GASOLINE							DIESEL(SMOKE)									
		-- PRE-1975 --			-- POST-1975 --			PRE-1974		--- POST-1974 ---							
	EVAP	HC	CO	NOX	HC	CO	NOX	ACCEL	LUG	ACCEL	LUG	PEAK	EARLY FAIL	NO REPL	OEM	GARAGE	WAREHOUSE
EVAP FRSH AIR	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0171	0.0	0.0030
EVAP VPRLIG SEP	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0061	0.0	0.0
EVAP VAPOR CONTR	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0031	0.0	0.0
FUEL TANK/CAP	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0062	0.0	0.0
AI MANIFOLD	0.0	1.0	1.0	0.0	2.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.90	0.0061	0.0	0.0
AI HOSES	0.0	1.0	1.0	0.0	2.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.70	0.0032	0.0	0.0014
AI AIR FILTER	0.0	0.1	0.1	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.70	0.0032	0.0	0.0
AI CHECKVALVES	0.0	0.1	0.1	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0053	0.0	0.0
AI BYPASS/DVRTR	0.0	0.1	0.1	0.0	2.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0032	0.0	0.0004
AI GULP VALVES	0.0	0.1	0.1	0.0	2.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0	0.0	0.0
AI PUMP/BELTS	0.0	1.0	1.0	0.0	2.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.70	0.0032	0.0	0.0001
EGR VALVES	0.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.70	0.70	0.0047	0.0	0.0009
EGR HOSES/SEALS	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0045	0.0	0.0
EGR THERMO VALVE	0.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0039	0.0	0.0
EGR SOLENOID VLV	0.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0017	0.0	0.0
EGR TEMP SWITCH	0.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0008	0.0	0.0
EGR SPEED/TRANS	0.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0007	0.0	0.0
EGR TIME DELAY	0.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0008	0.0	0.0
EGR VAC AMP	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0013	0.0	0.0005
EGR VAC REDUCER	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0001	0.0	0.0
EGR CARB SPACER	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0007	0.0	0.0
EGR BACKPRES SEN	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.70	0.90	0.0003	0.0	0.0
EGR CHECKVALVE	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0001	0.0	0.0
TCS VAC SOLENOID	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0020	0.0	0.0009
TCS VAC HOSES	0.0	0.1	0.1	0.0	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0021	0.0	0.0
TCS TIME DELAY	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0013	0.0	0.0
TCS CEC VALVE	0.0	2.0	2.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0001	0.0	0.0
TCS THERMO VALVE	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0003	0.0	0.0
TCS TRANS SWITCH	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0021	0.0	0.0
TCS REVERSE RELY	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0	0.0	0.0
TCS TEMP SWITCH	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0024	0.0	0.0009
SCS VACUUM SOLEN	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0001	0.0	0.0
SCS VACUM LINE	0.0	0.1	0.1	0.0	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0001	0.0	0.0
SCS TIME DELAY	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0	0.0	0.0
SCS SPEED SWITCH	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0001	0.0	0.0
SCS THERMO VALVE	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0001	0.0	0.0

PART NAME	EMISSION INCREASE FACTORS												PROBABILITY FACTORS		SALES VOLUME FACTORS		
	GASOLINE							DIESEL(SMOKE)									
		PRE-1975			POST-1975			PRE-1974		POST-1974							
	EVAP	HC	CO	NOX	HC	CO	NOX	ACCEL	LUG	ACCEL	LUG	PEAK	EARLY FAIL	NO REPL	OEM	GARAGE	WAREHOUSE
OSAC VAC ORIFICE	0.0	0.1	0.0	1.0	0.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0008	0.0	0.0
OSAC VAC HOSES	0.0	0.1	0.1	0.0	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0008	0.0	0.0
OSAC THERMO VALV	0.0	0.1	0.0	1.0	0.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0	0.0	0.0
OSAC VAC BYPASS	0.0	0.1	0.0	1.0	0.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0003	0.0	0.0
OSAC TEMP SENSOR	0.0	0.1	0.0	1.0	0.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0003	0.0	0.0
ESC ELEC MODULE	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0003	0.0	0.0
ESC HOSES	0.0	0.1	0.1	0.0	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0003	0.0	0.0
ESC VAC VALVES	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0003	0.0	0.0
ESC TEMP SWITCH	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0003	0.0	0.0
ESC SPEED SWITCH	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0004	0.0	0.0
CAT BODY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAT ACTIVE MEDIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAT INERTMEDIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAT SHELL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HEAT RISER	0.0	0.1	0.0	0.0	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.70	0.90	0.0038	0.0	0.0011
ELEC ASSIST CHKE	0.0	0.1	0.1	0.0	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.90	0.0018	0.0	0.0
STAGED PULLDOWN	0.0	0.1	0.1	0.0	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0004	0.0	0.0
DECEL VALVE	0.0	0.1	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0003	0.0	0.0005
DIST VACDECL VLV	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0001	0.0	0.0
DIST START SOLEN	0.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0001	0.0	0.0
THERMO VAC VALV	0.0	0.1	0.0	2.0	0.1	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0013	0.0	0.0033
COOLING THERMST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0064	0.0148	0.0
ELECTRICAL SYSTM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0063	0.0	0.0
HIGH PERF EXHAST	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.10	0.10	0.0006	0.0009	0.0001
EXHAUST MANIFOLD	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.10	0.50	0.0109	0.0431	0.0001
DISTR VACUUM VLV	0.0	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.30	0.90	0.0	0.0	0.0

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This final report documents the methodology and results of Phase II of the Investigation of the Effect of Automotive Parts on Vehicle and Engine Emissions. This study was performed for the Environmental Protection Agency, Office of Mobile Source Enforcement, under Contract No. 68-01-1957. The primary objective of this study was to identify engine and emission control system components which are critical in causing excessive emissions of one or more regulated pollutants. Phase II of the study investigated the emission-criticality of after-market equipment not installed or distributed by the original engine or vehicle manufacturers.

A computer model was developed to calculate and rank-order an index representing the criticality of each component type. Separate rankings were developed for HC, CO, NO_x and smoke (heavy-duty diesel engines) emissions using three independent sets of input data. The index for each component type was calculated from the product of four factors representing the emission increase resulting from a component failure, the probability of component failure, the probability of component repair, and the sales volume of the component.

The values of these factors were established based on data obtained from a search of technical literature and engineering analysis of system and component design or operating characteristics. The study was performed without emission or performance testing. However, a series of tests on 25 of the most emission-critical components was recommended to develop or refine data on emission increases and symptoms of failure.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

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