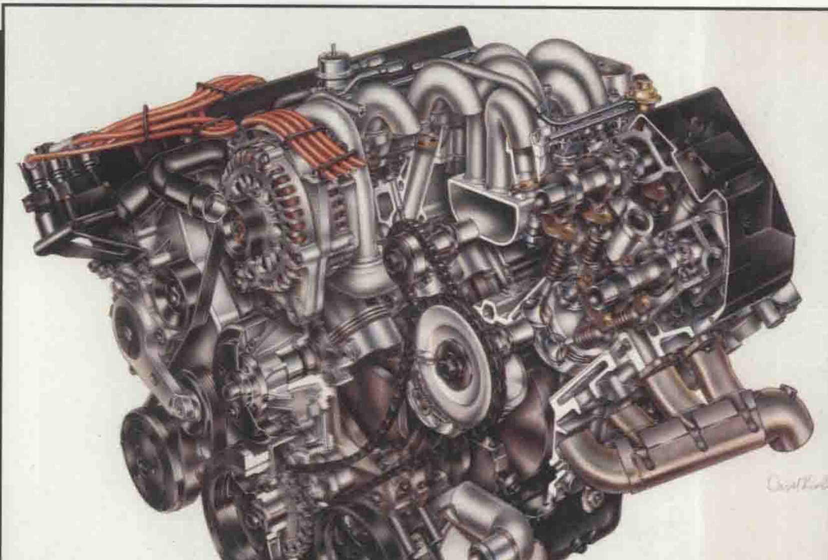
FUEL SYSTEMS AND EMISSION CONTROLS 3RD EDITION



CLASSROOM MANUAL

Fuel Systems and Emission Controls

Third Edition

By Chek-Chart

Richard K. DuPuy, *Editor*
Alan Ahlstrand,
Kalton C. Lahue, *Contributing Editors*

HarperCollins*CollegePublishers*

Acknowledgments

In producing this series of textbooks for automobile technicians, Chek-Chart has drawn extensively on the technical and editorial knowledge of the nation's carmakers and suppliers. Automotive design is a technical, fast-changing field, and we gratefully acknowledge the help of the following companies and organizations in allowing us to present the most up-to-date information and illustrations possible. These companies and organizations are not responsible for any errors or omissions in the instructions or illustrations, or for changes in procedures or specifications made by the carmakers or suppliers, contained in this book or in any other Chek-Chart product:

Automotive Diagnostics
  Allen Testproducts
  Bear Equipment
Borg-Warner Corporation
Caldo Automotive Supply
Champion Spark Plug Company
Chrysler Motors Corporation
Ford Motor Company
Fram Corporation, An Allied Signal Company
Don Mullens, Dan Sylvester, and Bryan Wilson;
  General Motors Training Center, Burbank, CA
Ellen Clark; AC-Delco, Los Angeles, CA
General Motors Corporation
  Delco-Remy Division
  Rochester Products Division
  Saginaw Steering Gear Division
  Buick Motor Division
  Cadillac Motor Car Division
  Chevrolet Motor Division
  Oldsmobile Division
  Pontiac Division
Jaguar Cars, Inc.
Mazda Motor Corporation
Nissan Motors
Robert Bosch Corporation
Snap-on Tools Corporation, and
  Sun Electric Corporation
Toyota Motor Company
Volkswagen of America

The authors have made every effort to ensure that the material in this book is as accurate and up-to-date as possible. However, neither Chek-Chart nor any related companies can be held responsible for mistakes or omission, or for changes in procedures or specifications by the carmakers or suppliers.

At Chek-Chart, Ramona Torres managed the production of this book. Type was set by Maria Glidden and Diane Maurice. Original art and photographs were produced by Dave Douglass, Gerald A. McEwan and Karen von Felten.

With respect, this work is dedicated to **Kalton C. Lahue:** 1934-1993. He wrote all the books.

Library of Congress Cataloging-in-Publication Data

Fuel systems and emission controls/by Chek-Chart;
  Richard DuPuy, editor, Virginia C. Klein, managing editor, Alan Ahlstrand, Kalton C. Lahue, contributing editors.—3rd ed.
    p. cm.
  Includes indexes.
  Contents: [1] Classroom manual — [2] Shop manual.
  ISBN 1-57932-115-1
  1. Automobiles—Fuel systems. 2. Automobiles—Fuel systems—Maintenance and repair. 3. Automobiles—Pollution control devices. 4. Automobiles—Pollution control devices—Maintenance and repair.
I. DuPuy, Richard K. II. Ahlstrand, Alan. III. Lahue, Kalton C. IV. Chek-Chart (Firm)
TL214.F8F84 1994
629.25'3—dc20 94-27859
CIP

Introduction to Fuel Systems and Emission Controls

Fuel Systems and Emission Controls is part of the Chek-Chart Automotive Series. The package for each course has two volumes, a *Classroom Manual* and a *Shop Manual*.

Other titles in this series include:

- Automatic Transmissions and Transaxles
- Automotive Brake Systems
- Automotive Heating, Ventilation, and Air Conditioning Systems
- Automotive Steering, Suspension, and Wheel Alignment
- Automotive Engine Repair and Rebuilding
- Engine Performance Diagnosis and Tune-Up
- Automotive Electrical and Electronic Systems.

Each book is written to help the instructor teach students how to become competent and knowledgeable professional automotive technicians. The two-manual texts are the core of a complete learning system that leads a student from basic theories to actual hands-on experience.

The entire series is job-oriented, especially designed for students who intend to work in the car service profession. A student will be able to use the knowledge gained from these books and from the instructor to get and keep a job. Learning the material and techniques in these volumes is a giant leap toward a satisfying, rewarding career.

The books are divided into *Classroom Manuals* and *Shop Manuals* for an improved presentation of the descriptive information and study lessons, along with the representative testing, repair, and overhaul procedures. The manuals are designed to be used together: the descriptive material in the *Classroom Manual* corresponds to the application material in the *Shop Manual*.

Each book is divided into several parts, and each of these parts is complete by itself. Instructors will find the chapters to be complete, readable, and well thought-out. Students will benefit from the many learning aids included, as well as from the thoroughness of the presentation.

The series was researched, written, and produced by the editorial and production staffs of Chek-Chart. For over 65 years, Chek-Chart has provided car and equipment manufacturers' service specifications to the automotive service field. Chek-Chart's complete, up-to-date automotive data bank was used extensively in preparing this textbook series.

Because of the comprehensive material, the hundreds of high-quality illustrations, and the inclusion of the latest automotive technology, instructors and students alike will find that these books keep their value over the years. In fact, they will form the core of the master technician's professional library.

How To Use This Book

Why Are There Two Manuals?

Unless you are familiar with the other books in this series, *Fuel Systems and Emission Controls* will not be like any other textbook you've used before. It is actually two books, the *Classroom Manual* and the *Shop Manual*. They have different purposes, and should be used together.

The *Classroom Manual* teaches you what you need to know about fuel delivery systems and components and also about emission control systems. The *Classroom Manual* will be valuable in class and at home, for study and for reference. You can use the text and illustrations for years to refresh your memory — not only about the basics of fuel systems and emission controls, but also about related topics in automotive history, physics, and technology.

In the *Shop Manual*, you learn test procedures, troubleshooting, and how to repair the systems and parts you read about in the *Classroom Manual*. The *Shop Manual* provides the practical hands-on information you need to work on fuel systems and emission controls. Use the two manuals together to fully understand how these systems work, and how to fix them when they don't work.

What Is In These Manuals?

The key features of the *Classroom Manual* make it easier for you to learn, and to remember what you learn:

- Each chapter is divided into self-contained sections for easier understanding and review. The organization shows you clearly which parts make up which systems that perform the same task differently or the same.
- Most parts and processes are fully illustrated with drawings or photographs. Important topics appear in several different ways, to make sure you can see other aspects of them.
- Important words in the *Classroom Manual* text are printed in **boldface type** and are defined on the same page and in a glossary at the end of the manual. Use these words to build the vocabulary you need to understand the text.
- Review questions are included for each chapter. Use them to test your knowledge.
- Every chapter has a brief summary at the end to help you to review for exams.
- Every few pages you will find sidebars — short blocks of "nice to know" information — in addition to the main text.

The *Shop Manual* has detailed instructions on overhaul, test, and service procedures for modern components and current fuel systems. These are easy to understand, and usually have step-by-step explanations to guide you through the procedures. The *Shop Manual* contains:

- Helpful information that tells you how to use and maintain shop tools and test equipment
- Safety precautions
- Clear illustrations and diagrams to help you locate trouble spots while you learn to read service literature
- Test procedures and troubleshooting hints that will help you work better and faster
- Tips the professionals use that are presented clearly and accurately
- A sample test at the back of the manual that is similar to those given for Automotive Service Excellence (ASE) certification; use this test to help study and prepare yourself when you are ready to be certified as a fuel system and emission controls expert.

Where Should I Begin?

If you already know something about automotive fuel systems and emission controls and know how to repair them, you will find that this book is a helpful review. If you are just starting in car repair, then the book will give you a solid foundation on which to develop professional-level skills.

Your instructor will design a course to take advantage of what you already know, and what facilities and equipment are available to work with. You may be asked to read certain chapters of these manuals out of order. That is fine. The important thing is to really understand each subject before you move on to the next.

Study the vocabulary words in boldface type. Use the review questions to help you understand the material. When you read the *Classroom Manual*, be sure to refer to your *Shop Manual* to relate the descriptive text to the service procedures. And when you are working on actual car systems and components, look back to the *Classroom Manual* to keep basic information fresh in your mind. Working on such a complicated piece of equipment as a modern car isn't always easy. Use the information in the *Classroom Manual*, the procedures in the *Shop Manual*, and the knowledge of your instructor to help you.

When you perform test procedures and overhaul equipment, you will need a complete and accurate source of manufacturers' specifications, and the techniques for pulling computer trouble codes. Most shops have either carmakers' annual shop service manuals, which lists these specifications, or an independent book such as the Chek-Chart *Car Care Guide*. This unique book is updated each year to give you service instructions, capacities, and troubleshooting tips that you need to work on specific cars.

Contents

On the Cover:
Front — The 4.6-liter DOHC V8 engine used in the Lincoln Mark VIII, courtesy of Ford Motor Company.
Rear — A cutaway of a General Motors Multec fuel injector, courtesy of the General Motors Corporation.

PART ONE

Fuel System and Emission Control Fundamentals

Chapter

1

Introduction to Fuel Systems and Emission Controls

This book is about automotive gasoline engine fuel systems. It is also about automotive emission controls. The internal combustion engine produces power by burning fuel and changing the fuel's chemical energy into thermal (heat) energy, and the thermal energy into mechanical power.

Not all the chemical energy of the gasoline gets converted into useful power — much is wasted. The engine's combustion process also produces harmful byproducts that become air pollutants when they leave the engine. An engine needs an emission control system to help it form fewer pollutants and also to reduce the discharge of pollutants it does create. Therefore, an engine's fuel system and its emission controls are closely related.

The fuel system has three important jobs. It must:

- Store liquid fuel
- Deliver liquid fuel to the carburetor (on older cars) or fuel injectors for mixing with air
- Distribute the air-fuel mixture uniformly to each engine cylinder.

Emission control requirements are important considerations in the design and operation of all parts of the fuel system. The ignition system, which provides the spark to begin combustion, plays an equally important role in emission control.

Because emission controls are a vital part of the design of an automotive gasoline engine and its fuel and ignition systems, we will begin our study of fuel systems and emission controls by examining the harmful byproducts of combustion as a major cause of air pollution.

AIR POLLUTION — A PERSPECTIVE

We can define air pollution as the introduction of contamination into the atmosphere in an amount large enough to injure human, animal, or plant life. There are many types and causes of air pollution, but they all fall into two general groups: natural and manmade. Natural pollution is caused by such things as the organic plant life cycle, forest fires, volcanic eruptions, and dust storms. While pollution from such sources is often beyond our control, we can control manmade pollution from industrial plants and automobiles.

Most urban and large industrial areas around the world suffer periodic air pollution. During the late 1940s, a unique form of air pollution was identified in the Los Angeles area. This combination of smoke and fog, which forms irritating

Figure 1-1. Have a nice day.

chemical compounds, is called **photochemical smog**, figure 1-1. As this phenomenon increased both in intensity and frequency, it posed more of a problem. California took the lead in combating it by becoming the first state to place controls on motor vehicle emissions. As smog gradually began to appear in other parts of the country, the Federal government moved into the area of regulation. To understand why, we must look at the automobile-produced elements that form air pollution and smog.

MAJOR POLLUTANTS

An internal combustion engine emits three major gaseous pollutants into the air: **hydrocarbons (HC)**, **carbon monoxide (CO)** and **oxides of nitrogen (NO_x)**, figure 1-2. In addition, an automobile engine gives off many small liquid or solid particles, such as lead, carbon, sulfur, and other **particulate matter (PM_{10})**, which contribute to pollution. By themselves, all these emissions are not smog, but simply air pollutants.

Hydrocarbons (HC)

Gasoline is a hydrocarbon compound. Unburned hydrocarbons given off by an automobile are mostly unburned fuel. Over 200 different varieties of hydrocarbon pollutants come from automotive sources. While most come from the fuel system and the engine exhaust, others are oil and gasoline fumes from the crankcase. Even a car's tires, paint, and upholstery emit tiny amounts of hydrocar-

Photochemical Smog: A combination of pollutants that forms harmful chemical compounds when acted upon by sunlight.

Hydrocarbon (HC): A chemical compound made up of hydrogen and carbon. A major pollutant given off by an internal combustion engine. Gasoline is a hydrocarbon compound.

Carbon Monoxide (CO): An odorless, colorless, tasteless poisonous gas. A major pollutant given off by an internal combustion engine.

Oxides of Nitrogen (NO_x): Chemical compounds of nitrogen given off by an internal combustion engine. They combine with hydrocarbons to produce ozone, a primary component of smog.

Particulate Matter (PM_{10}): Microscopic (10 microns or smaller) particles of materials such as lead and carbon that are given off by an internal combustion engine as pollution.

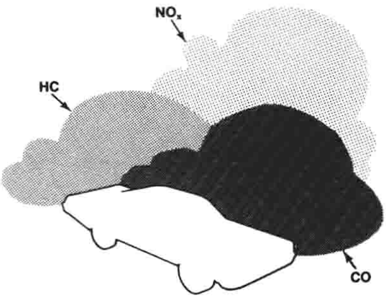


Figure 1-2. Hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x) are the three major pollutants that automobiles emit.

bons. Figure 1-3 shows the three major sources of hydrocarbon emissions from an automobile:

- Fuel system evaporation — 20 percent
- Crankcase vapors — 20 percent
- Engine exhaust — 60 percent.

Hydrocarbons are the only major automotive air pollutant that come from sources *other* than engine exhaust.

Hydrocarbons of all types are destroyed by combustion. If an automobile engine burned gasoline completely, there would be no hydrocarbons in the exhaust, only water and carbon dioxide. But when the vaporized and compressed air-fuel mixture is ignited, combustion occurs so rapidly that gasoline near the sides of the combustion chamber may not get burned. This unburned fuel then passes out with the exhaust gases. The problem is worse with engines that misfire or are not properly tuned.

Carbon Monoxide (CO)

Although not part of photochemical smog, carbon monoxide is also found in automobile exhaust in large amounts. A deadly poison, carbon monoxide is both odorless and colorless. Carbon monoxide is absorbed by the red corpuscles in the body, displacing the oxygen. In a small quantity, it causes headaches and vision difficulties. In larger quantities, it kills.

Because it is a product of incomplete combustion, the amount of carbon monoxide produced depends on the way in which hydrocarbons burn. When the air-fuel mixture burns, its hydrocarbons combine with oxygen. If the air-fuel mixture contains too much fuel, there is not enough oxygen to complete this process, so car-

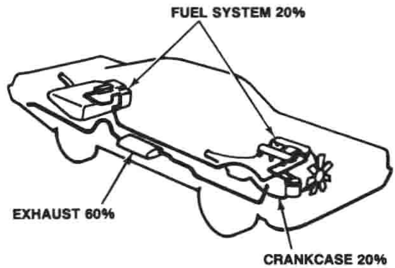


Figure 1-3. Sources of hydrocarbon emissions.

bon monoxide forms. Using an air-fuel mixture with less fuel makes combustion more complete. The leaner mixture increases the ratio of oxygen, which reduces the formation of CO by producing carbon dioxide instead.

Carbon dioxide (CO_2) is harmless, but excessive amounts of it in the atmosphere are believed to contribute to global warming, so the EPA is also monitoring CO_2 levels and views CO_2 as a pollution concern.

Oxides of Nitrogen (NO_x)

Air is about 78 percent nitrogen, 21 percent oxygen, and one percent other gases. When the combustion chamber temperature reaches 2,500°F (1,370°C) or greater, the nitrogen and oxygen in the air-fuel mixture combine to form large quantities of oxides of nitrogen (NO_x). NO_x also is formed at lower temperatures, but in far smaller amounts. By itself, NO_x is of no particular concern. But when the amount of hydrocarbons in the air reaches a certain level and the ratio of NO_x to HC is correct, the two pollutants combine chemically in the presence of sunshine to form ozone, a primary component of smog.

Lowering the engine's combustion temperature reduces NO_x formation. However, it also makes the air-fuel mixture burn less efficiently, creating large amounts of hydrocarbon and carbon monoxide. To combat this problem, automakers use various emission control systems which we will study in later chapters.

Particulate Matter (PM_{10})

Particulate matter consists of microscopic — ten microns or smaller — solid particles, such as dust, soot, and smoke, that remain in the atmosphere for a long time. Particulate matter is a prime cause of secondary pollution. For

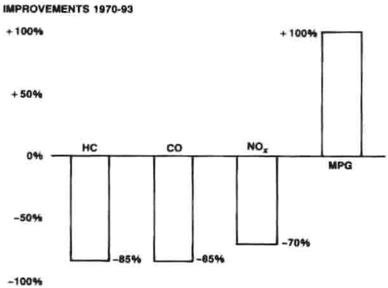


Figure 1-4. Since 1970, the average car's pollution has fallen and its fuel-efficiency has increased greatly. (Information courtesy of the U.S. Environmental Protection Agency)

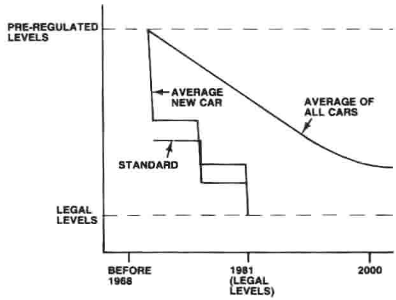


Figure 1-5. Clean air legislation has lead to dramatic decreases in the amount of pollution cars create. (Information courtesy of the U.S. Environmental Protection Agency)

example, particulates such as lead and carbon tend to collect in the atmosphere. Large amounts of these substances can injure our health.

Particulates produced by automobiles are a small percentage of the total particulates in the atmosphere. Most come from fixed sources, such as factories. While automobiles do produce particulates, the amount has decreased considerably in the past few decades because the fuel industry has eliminated additives such as lead from gasoline and changed other characteristics of the fuel. As a result, the amount of additives used in gasoline is and the types of additives are carefully controlled.

Sulfur Dioxide (SO_2)

Sulfur in gasoline and other fossil fuels (coal and oil) enters the atmosphere in the form of **sulfur dioxide (SO_2)**. As sulfur dioxide breaks down, it combines with water in the air to form corrosive sulfuric acid, which is a secondary pollutant. Starting in the 1980s, there has been a lot of publicity about this type of pollution — commonly referred to as "acid rain" — especially in the northeastern United States and in Canada.

POLLUTION AND THE AUTOMOBILE

A single car actually gives off only microscopic amounts of pollutants, but there are hundreds of millions of automobiles in use in the United States. Multiply each car's contribution toward air pollution by the number of cars and you have the potential for a staggering amount of pollution. Without emission controls, automobiles would create almost as much air pollution as all other sources combined.

Great progress has been made in reducing automobile air pollution since 1966. Hydrocarbon emissions from the engine crankcase and fuel system have been almost totally eliminated. The other 60 percent of HC emission — from the exhaust — has been lowered considerably. From 1970-1993, the HC and CO emissions of a typical car both decreased about 85 percent, figure 1-4. Figure 1-5 shows how dramatically the emissions of a typical car have fallen in the decades since regulations began.

However, some of these gains are offset by an equally dramatic increase in the number of cars on the road and the number of miles people drive their cars. The EPA estimates that vehicle travel has doubled since 1970, due in great part to urban sprawl. So, although each car pollutes less, there are many more cars contributing to pollution.

SMOG — CLIMATIC REACTION WITH AIR POLLUTANTS

Smog and air pollution are not the same thing: smog is a form of air pollution, but air pollution is not necessarily smog. Although all

Sulfur Dioxide (SO_2): Sulfur given off by processing and burning gasoline and other fossil fuels. As it decomposes, sulfur dioxide combines with water to form sulfuric acid, or "acid rain".

Figure 1-6. Smog engulfs the Los Angeles Civic Center in the 1960s. When the base of the temperature inversion is only 1,500 feet (457 meters) above ground, the inversion layer — a layer of warm air above a layer of cool air — prevents the natural dispersion of air contaminants into the upper atmosphere. (LA County)

three major pollutants are byproducts of combustion, each is created in a different way. Hydrocarbons come mostly from unburned fuel, carbon monoxide from air-fuel mixtures that contain too much fuel, and oxides of nitrogen from high combustion chamber temperatures. HC and NO_x are the two principal materials that combine in the atmosphere to form smog.

The Photochemical Reaction

Although scientists can create smog in a laboratory experiment, they do not completely understand what it is. They do know, however, that three things must be present for smog to form in the atmosphere:

- Sunlight
- Relatively still air
- A high concentration of HC and NO_x.

When these three elements co-exist, the sunlight causes a chemical reaction between the HC and NO_x that creates smog.

Temperature Inversion

Normally, air temperature decreases at higher altitudes. Warm air near the ground rises and becomes cooler by contact with the cooler air above it. When nature follows this normal pattern, smog and other pollutants are carried away. But some areas experience a natural weather pattern called a **temperature inversion**. When this occurs, a layer of warm air prevents the upward movement of cooler air near the ground. This inversion acts as a "lid" over the stagnant air. Since the air cannot rise, smog and pollution collect.

When the inversion layer is several thousand feet high, the smog can rise enough for reasonable visibility. But when the inversion layer is within a thousand feet (300 meters) of the ground, it traps the smog. This reduces visibility, making the distant landscape impossible to see, figure 1-6, and causing people to experience eye irritation, headaches, and difficulty in breathing. Temperature inversion was first noted in the Los Angeles area, which provides a classic example of this phenomenon. Sur-

California Passenger Car
New Vehicle Standards

YEAR	HC	CO	NO_x
1966-69	275 ppm	1.5%	—
1970	2.2 g/m	23 g/m	—
1971	2.2 g/m	23 g/m	4.0 g/m
1972	3.2 g/m	39 g/m	3.2 g/m
1974	3.2 g/m	39 g/m	3.0 g/m
1975-76	0.9 g/m	9 g/m	2.0 g/m
1977-79	0.41 g/m	9 g/m	1.5 g/m
1980	0.41 g/m	9 g/m	1.0 g/m
1981-92	0.41 g/m	7 g/m	0.7 g/m

Figure 1-7. This chart of California exhaust emission limits for new cars shows how standards became more stringent in the wake of the Clean Air Act. California standards are stricter than Federal. (Information courtesy of the California Air Resources Board)

rounding mountains in that area form a natural basin in which temperature inversion is present to some extent for more than 300 days a year.

AIR POLLUTION LEGISLATION AND REGULATORY AGENCIES

Once the problem of air pollution was recognized, it became the subject of intense research and investigation. By the early 1950s, scientists believed that smog in Los Angeles was caused by the photochemical process. California, as we noted earlier, became the first state to enact legislation designed to limit automotive emissions. Standards established by California one year often became U.S. Federal standards the next year.

Regulatory Agencies

The Environmental Protection Agency (EPA) is the U.S. Federal agency responsible for enforcing the Clean Air and Air Quality Acts passed by Congress. It was formed as part of the Department of Health, Education, and Welfare. The California Air Resources Board (CARB) has authority roughly parallel to that of the Federal EPA but extending only to vehicles sold in or brought into California, figure 1-7. Canadian vehicle emission standards are established by the national Ministry of Transport.

Emission Control Legislation

Beginning with the 1961 new cars, California required control over crankcase emissions. This became standard for the rest of the United States with new 1963 cars. That year, domestic automakers voluntarily equipped their new models with a blowby device which virtually eliminated crankcase emissions on all cars.

California followed by requiring that 1966 and later new cars sold within its boundaries have exhaust emission controls. The use of exhaust emission control systems was extended nationwide during the 1967-68 model years.

The first Federal air pollution research program began in 1955. In 1963, Congress passed the Clean Air Act, providing the states with money to develop air pollution control programs. This law was amended in 1965 to give the Federal government authority to set emission standards for new cars, and was amended again in 1977-78. Under this law, emission standards were first applied nationwide to 1968 models.

In addition to the Clean Air Act, the Federal government took a new approach to air pollution in 1967 with the Air Quality Act. This act and its major amendments of 1970, 1974, and 1977 instituted changes designed to turn piecemeal programs into a unified attack on pollution of all kinds. Canada attacked its own smog problem with vehicle emission requirements established by the Ministry of Transport that took effect with 1971 models.

The 1990 clean air act

In 1990, the U.S. Congress amended and updated the Clean Air Act for the first time in thirteen years. Besides making tailpipe standards more stringent and expanding vehicle Inspection and Maintenance (I/M) programs, the 1990 law focused its attention on fuel itself, in addition to vehicle technology. Some key aspects of the 1990 Clean Air Act include:

- Tighter tailpipe standards
- Carbon monoxide control
- Ozone control
- Reformulated gasoline
- Other controls.

Figure 1-8 shows a timetable for the implementation of certain provisions of the 1990 Clean Air Act.

Tighter tailpipe standards

Tailpipe standards for 1990-93 were 0.41 gram per mile (g/m) HC, 3.4 g/m CO, and 1.0 g/m NO_x. The 1990 Clean Air Act requires phasing in lower standards for HC and NO_x between 1994-96 — 0.25 g/m of non-methane HC and 0.4 g/m NO_x. The law also requires the EPA to study whether even stricter standards are nec-

Temperature Inversion: A weather pattern in which a layer, or "lid", of warm air keeps a layer of cooler air trapped beneath it.

Timetable for Implementation of Certain Provisions of the 1990 Clean Air Act

1992	Limits on maximum gasoline vapor pressure go into effect nationwide.
	Regulations for minimum oxygen content of gasoline go into effect in 39 areas.
1993	Production of vehicles requiring leaded gasoline becomes illegal.
1994	Phase-in of tighter tailpipe standards and cold-temperature CO standards for light-duty vehicles begins.
	Expansion of I/M programs begins in certain cities.
	Requirement for new cars to be equipped with onboard diagnostic systems takes effect.
1995	Reformulated gasoline must be sold in the nine smoggiest cities in the U.S.
	New warranty provisions on emission control systems take effect.
1996	Phase-in of California Pilot Program begins.
	Lead banned from use in motor vehicle fuel.
	All new vehicles must meet tighter tailpipe standards and cold-temperature CO standards.
1997	Federal "Clean Fleet" program begins in 19 states in areas with excessive ozone and CO.
2001	Second phase of California Pilot Program and Federal "Clean Fleet" program begins.

Figure 1-8. Various parts of the 1990 Clean Air Act take effect through the 1990s and in the early 21st century.

essary, feasible, and economical. If the EPA determines by 1999 to lower the standards, they will be halved beginning in the 2004 model year.

Carbon monoxide control

The EPA places primary blame for CO pollution on mobile sources (including cars and trucks, as well as other vehicles, such as bulldozers and construction equipment) in 39 U.S. cities.

Carbon monoxide emissions from cars are particularly high during cold weather, when vehicles operate less efficiently. While previous CO standards applied only at 75°F, the 1990 Clean Air Act establishes an additional CO standard of 10 g/m at 20°F. If CO levels are still excessive in six or more cities by 1997, the standard will be tightened to 3.4 g/m, to be met beginning with the 2002 model year.

The 1990 law also requires a higher oxygen content in the gasoline sold during the winter in the 39 CO-saturated cities, a requirement that took effect in 1992. Oxygen improves combustion and so reduces CO formation.

Ozone control

Ozone — the combination of HC and NO_x that is the primary component of smog — is the most widespread air quality problem in the United States. The EPA rates the following areas as having a "severe" ozone problem:

- New York City and Long Island in New York State and North New Jersey
- Baltimore, Maryland
- Muskegon, Michigan
- Chicago, Illinois; Gary, Indiana; and Lake County, Wisconsin
- Milwaukee, Wisconsin
- Houston, Galveston, and Brazoria, Texas
- San Diego, California
- Southeast Desert, California
- Ventura County, California.

Los Angeles, California receives its very own ozone rating: "extreme". Approximately 15 other cities and urban areas across the U.S. are rated as having "serious" ozone levels, and about 30 more have "moderate" ozone problems.

Gasoline vapors are a major source of HC in ozone, so the 1990 Clean Air Act calls for reducing evaporative emissions by such means as improved engine and fuel system vapor traps and wider use of systems to capture vapors during refueling in smoggy cities. In addition, the Clean Air Act places a cap on fuel volatility — reducing its tendency to evaporate.

Reformulated gasoline

The 1990 Clean Air Act established standards for the content of gasoline sold in the nine worst ozone areas. This "cleaner" gasoline must meet or exceed a certain minimum oxygen content, and it must not exceed a certain maximum level of benzene. Also, the gasoline must reduce toxic and smog-forming emissions 15 percent by 1995, and 20-25 percent by 2000, without increasing NO_x emissions. Other cities may choose to use this clean fuel, too, and the EPA expects many to do so.

Other controls

The 1990 law calls for the EPA to monitor toxic emissions such as benzene and formaldehyde and regulate them as needed. Both California and the Federal government are mandating clean car programs. The California Pilot Program requires that, starting in 1996, car manufacturers supply at least 150,000 "clean" cars for sale in California. The qualifications of a California Pilot Program clean car are that it emits no more than 0.125 g/m HC, 3.4 g/m CO, and 0.4 g/m NO_x. In 1999, the number of clean cars required goes up to 300,000.

Meanwhile, starting in 1998, the Federal government requires fleets in certain very polluted cities to have 30 percent of their new cars be clean cars. Here, a clean car is one that can use clean fuel and can meet extra-low emission