AUTOMOTIVE FUEL, LUBRICATING, AND COOLING SYSTEMS

William H. Crouse
Donald L. Anglin

Fifth Edition

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CONSTRUCTION, OPERATION, AND MAINTENANCE

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ABOUT THE AUTHORS

William H. Crouse

Behind William H. Crouse's clear technical writing is a background of sound mechanical engineering training as well as a variety of practical industrial experience. After finishing high school, he spent a year working in a tinplate mill. Summers, while still in school, he worked in General Motors plants, and for three years he worked in the Delco-Remy Division shops. Later he became Director of Field Education in the Delco-Remy Division of General Motors Corporation, which gave him an opportunity to develop and use his natural writing talent in the preparation of service bulletins and educational literature.

During the war years, he wrote a number of technical manuals for the Armed Forces. After the war, he became Editor of Technical Education Books for the McGraw-Hill Book Company. He has contributed numerous articles to automotive and engineering magazines and has written many outstanding books. He was the first Editor-in-Chief of the 15-volume McGraw-Hill Encyclopedia of Science and Technology.

William H. Crouse's outstanding work in the automotive field has earned for him membership in the Society of Automotive Engineers and in the American Society of Engineering Education.

Donald L. Anglin

Trained in the automotive and diesel service field, Donald L. Anglin has worked both as a mechanic and as a service manager. He has taught automotive courses and has also worked as curriculum supervisor and school administrator for an automotive trade school. Interested in all types of vehicle performance, he has served as a racing-car mechanic and as a consultant to truck fleets on maintenance problems.

Currently he serves as editorial assistant to William H. Crouse, visiting automotive instructors and service shops. Together they have coauthored magazine articles on automotive education and several books in the McGraw-Hill Automotive Technology Series.

Donald L. Anglin is a certified general automotive mechanic and holds many other licenses and certificates in automotive education, service, and related areas. His work in the automotive service field has earned for him membership in the American Society of Mechanical Engineers and the Society of Automotive Engineers. In addition, he is an automotive instructor at Piedmont Virginia Community College, Charlottesville, Virginia.

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AUTOMOTIVE
FUEL, LUBRICATING, AND COOLING SYSTEMS

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by William H. Crouse and * Donald L. Anglin

Automotive Chassis and Body*
  Workbook for Automotive Chassis and Body*
Automotive Electrical Equipment
  Workbook for Automotive Electrical Equipment*
Automotive Engines*
  Workbook for Automotive Engines*
Automotive Fuel, Lubricating, and Cooling Systems*
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Automotive Brakes
Automotive Electrical Systems
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Automotive Transmissions and Power Trains
Automotive Steering Systems
Automotive Suspension Systems
Engines and Fuel Systems

PREFACE

This is the fifth edition of *Automotive Fuel, Lubricating, and Cooling Systems.* The book has undergone many changes in its five editions. These changes parallel the many changes in engines, and in fuel, lubricating, and cooling systems. Engines have been improved year after year to make them more economical, more powerful, more flexible, and longer lasting. However, in recent years, the main thrust of engine design work has been directed at reducing atmospheric pollution. This has meant major changes in carburetors and fuel systems, and the introduction of new emission-control systems. Included are positive crankcase ventilating (PCV) systems, exhaust-gas recirculating (EGR) systems, vapor-recovery systems, heated-air systems, air-injection systems and thermal reactors, new types of fuel tanks, electric-assist chokes, stratified-charge engine designs, transmission-controlled vacuum advance, and catalytic converters.

This new edition covers all these developments. Included are two new chapters on automotive emission controls, with new material on catalytic converters, and information on the lubricating systems for overhead-camshaft and Wankel engines.

This fifth edition of *Automotive Fuel, Lubricating, and Cooling Systems* has been almost completely rewritten, and hundreds of new illustrations have been added. All service procedures and specifications have been updated to include the latest models and techniques. A feature of the new edition is the introduction of the metric system of measurements. When a United States Customary measurement is used, it is usually followed by its metric equivalent in brackets, for example, 0.002 inch [0.051 mm].

The *Workbook for Automotive Fuel, Lubricating, and Cooling Systems* has been specifically prepared to accompany the fifth edition of the textbook. It includes the basic service jobs on automotive fuel, lubricating, and cooling systems, as recommended by the Motor Vehicle Manufacturers Association-American Vocational Association Industry Planning Council. Together, the textbook and the workbook provide the background information and hands-on experience needed to prepare a student to become a qualified and certified automotive technician in the fields of fuel, lubricating, and cooling systems.

To assist the automotive instructor, the *Instructor's Planning Guide for Automotive Fuel, Lubricating, and Cooling Systems* is available from McGraw-Hill. The instructor's guide was prepared to help the automotive instructor do the best possible job of teaching by most effectively utilizing the textbook, workbook, and other related instructional materials. The instructor's guide contains suggestions on student motivation, classroom instruction and related shop activities, the automotive curriculum, and much more. In addition, it includes the answer key for the tests at the end of each jobsheet in the *Workbook for Automotive Fuel, Lubricating, and Cooling Systems.*

Also in the instructor's guide is a list of various related textbooks and ancillary instructional materials available from McGraw-Hill. Used singly or together, these items form a comprehensive student learning and activity package. They provide the student with meaningful learning experiences and help the student develop job competencies in automotive fuel, lubricating, and cooling systems and related fields. The instructor's guide explains how the various available materials can be used, either singly or in combination, to satisfy any teaching requirement.

WILLIAM H. CROUSE
DONALD L. ANGLIN

ACKNOWLEDGMENTS

During the preparation of this new edition of *Automotive Fuel, Lubricating, and Cooling Systems*, the authors were given invaluable aid and inspiration by many people in the automotive industry and in the field of education. The authors gratefully acknowledge their indebtedness and offer their sincere thanks to these people. All cooperated with the aim of providing accurate and complete information that would be useful in training automotive mechanics.

Special thanks are owed to the following organizations for information and illustrations that they supplied: AC Spark Plug Division of General Motors Corporation; American Motors Corporation; Autosan, Inc.; BMW Corporation; British Motor Corporation; Buick Motor Division of General Motors Corporation; Cadillac Motor Car Division of General Motors Corporation; Chevrolet Motor Division of General Motors Corporation; Chrysler Corporation; Clayton Manufacturing Company; Delco-Remy Division of General Motors Corporation; Detroit Diesel Allison Division of General Motors Corporation; Echlin Manufacturing Company; Federal-Mogul Corporation; Ford Motor Company; General Motors Corporation; Harrison Radiator Division of General Motors Corporation; Hillman Motor Car Company, Limited; Honda; Interindustry Emission Control Program; Johnson Bronze Company; Kent-Moore, Inc.; Los Angeles County Air Pollution Control District; Mercedes-Benz, Daimler-Benz Aktiengesellshaft; Muskegan Piston Ring Company; Oldsmobile Division of General Motors Corporation; Pontiac Motor Division of General Motors Corporation; Renault; Robert Bosch GmbH; Schwitzer Division, Wallace-Murray Corporation; Sealed Power Company; Service Parts Division of Dana Corporation; Sun Electric Corporation; Texaco, Incorporated; Toyo Kogyo Company, Limited; Union Carbide Corporation; Volkswagen; Waukesha Motor Company; and Young and Rubican. To all these organizations and the people who represent them, sincere thanks.

WILLIAM H. CROUSE
DONALD L. ANGLIN

TO THE STUDENT

Automotive Fuel, Lubricating, and Cooling Systems is one of eight books which are included in the McGraw-Hill Automotive Technology Series. These books cover in detail the construction, operation, and maintenance of automotive vehicles. They are designed to give you all the information you need to become successful in the automotive service business. The books satisfy the recommendations of the Motor Vehicle Manufacturers Association–American Vocational Association Industry Planning Council. The books also meet the requirements for automotive mechanics certification and state vocational educational programs and recommendations for automotive trade apprenticeship training. Furthermore, the comprehensive coverage of the subject matter in the books makes them valuable additions to the library of anyone interested in any aspect of automotive engineering, manufacturing, sales, service, and operation.

Meeting the Standards

The eight books in the McGraw-Hill Automotive Technology Series meet the standards set by the Motor Vehicle Manufacturers Association (MVMA) for an associate degree in automotive servicing and in automotive service management. These standards are described in the MVMA booklet "Community College Guide for Associate Degree Programs in Auto and Truck Service and Management." The books also cover the subjects recommended by the American National Standards Institute in their detailed standard D18.1-1972, "American National Standard for Training of Automotive Mechanics for Passenger Cars and Light Trucks."

In addition, the books cover in depth the subject matter tested by the National Institute for Automotive Service Excellence (NIASE). The tests given by NIASE are used for certifying general automotive mechanics and automotive technicians working in specific areas of specialization under the NIASE voluntary mechanic testing and certification program.

Getting Practical Experience

At the same time that you study the books, you should be getting practical experience in the shop. That is, you should handle automotive parts, automotive tools, and automotive servicing equipment and you should perform actual servicing jobs. To assist you in your shop work, there is a workbook for each book in the Automotive Technology Series. For example, the *Workbook for Automotive Fuel, Lubricating, and Cooling Systems* includes the jobs which cover every basic servicing procedure on automotive fuel, lubricating, and cooling systems. If you do every job in the workbook, you will have hands-on experience with all fuel, lubricating, and cooling system servicing work.

If you are taking an automotive mechanics course in school, you will have an instructor to guide you in your classroom and shop activities. But even if you are not taking a course, the workbook can act as an instructor. It tells you, step by step, how to do the various servicing jobs. Perhaps you can meet others who are taking a school course in automotive mechanics. You can talk over any problems you have with them. A local garage or service station is a good source of practical information. If you can get acquainted with the automotive mechanics there, you will find that they have a great deal of practical information. Watch them at work if you can. Make notes of important points for filing in a notebook.

Service Publications

While you are in the service shop, study the various publications received at the shop. Automobile manufacturers, as well as suppliers of parts, accessories, and tools, publish shop manuals, service bulletins, and parts catalogs. These help service personnel do a better job. In addition, numerous automotive magazines are published which deal with problems and methods of automotive service. All these publications will be of great value to you; study them carefully.

These activities will help you get practical experience in automotive mechanics. Sooner or later this experience, plus the knowledge that you have gained in studying the books in the McGraw-Hill Automotive Technology Series, will permit you to step into the automotive shop on a full-time basis. Or, if you are already in the shop, you will be equipped to step up to a more responsible job.

Checking Up on Yourself

You can check up on your progress in your studies by answering the questions given every few pages in the book. There are two types of tests, progress quizzes and chapter checkups, the answers to which are given at the back of the book. Each progress quiz should be taken just after you have completed the pages preceding it. The quizzes allow you to check yourself as you finish a lesson. On the other hand, the chapter checkups may cover several lessons, since they are review tests of entire chapters. Because they are review tests, you should review the entire chapter by rereading it or at least paging

through it to check important points before trying the test. If any of the questions stump you, reread the pages in the book that will give you the answer. This sort of review is valuable and will help you to remember the information you need when you work in an automotive shop.

Keeping a Notebook

Keeping a notebook is a valuable part of your training. Start it now, at the beginning of your studies of automotive fuel, lubricating, and cooling systems. Your notebook will help you in many ways. It will be a record of your progress. It will become a storehouse of valuable information you will refer to time after time. It will help you learn. And it will help you organize your training program so that it will do you the most good.

When you study a lesson in the book, have your notebook open in front of you. Start with a fresh notebook page at the beginning of each lesson. Write the lesson (or textbook page number) and date at the top of the page. As you read your lesson, jot down the important points.

In the shop, use a small scratch pad or index cards to jot down important points. You can transfer your notes to your notebook later.

You can also make sketches in your notebook showing wiring or hose diagrams, fuel systems, and so on. Save articles and illustrations from technical and hot-rod magazines and file them in your notebook. Also, save instruction sheets that come with service parts. Carburetor overhaul kits, for example, have instruction sheets explaining how to overhaul and adjust carburetors. Cement or tape these sheets to paper and file them in your notebook.

Your notebook will become a valued possession—a permanent record of what you learned about automotive fuel, lubricating, and cooling systems.

Glossary and Index

There is a glossary (a definition list) of automotive terms in the back of the book. Whenever you have any doubt about the meaning of a term or the purpose of an automotive part, you can refer to this glossary. Also, there is an index at the back of the book. This index will steer you to the page in the book where you will find the information you are seeking.

And now, good luck to you. You are studying a fascinating, complex, and admirable machine—the automobile. Your studies can lead you to success in the automotive field, a field where opportunities are nearly unlimited.

CONTENTS

chapter 1

AUTOMOTIVE FUNDAMENTALS

This chapter discusses engine operation. It supplies you with the background information you will need to understand the operation of automotive fuel, lubricating, and cooling systems.

1-1 Purpose of This Book You have shown your interest in automotive engines by starting to read this book. We hope to maintain your interest by giving you a great deal of information on engine fuel, cooling, and lubricating systems, particularly as concerns their construction, operation, and service. Regardless of what job you have or hope to have in the automotive field, the information in this book should prove of value to you. The automotive mechanic, the automotive engineer, and the people working at the higher level in automotive manufacture, sales, service, or operation should be able to do their job better if they have the information in this book at their fingertips. And naturally, this information will equip them for the bigger job ahead. The person who knows the facts and can use them in a practical way is the person who forges ahead in his or her chosen field. This book is designed to help you be that person.

1-2 Components of the Automobile Before we begin our studies of fuel, lubricating, and cooling

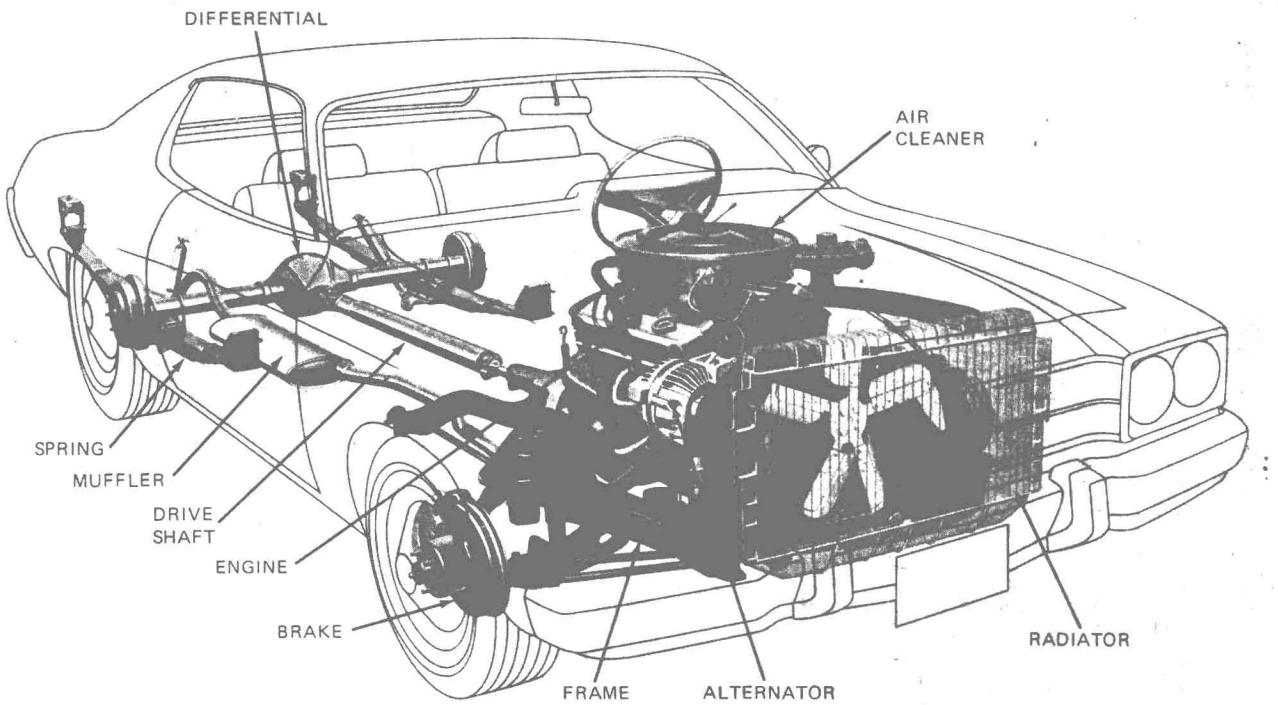

Fig. 1-1. Location of major components in the automobile. (*Young and Rubican*)

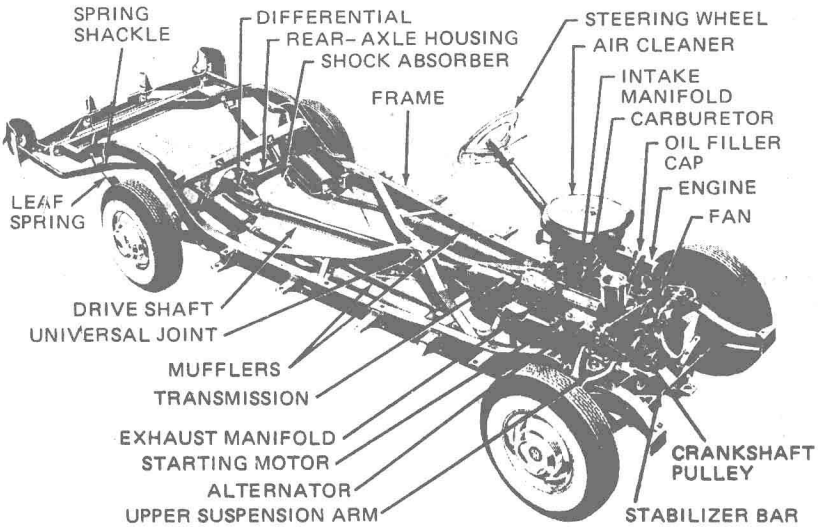

Fig. 1-2. Chassis of a passenger car. The chassis contains the source of power; the frame, which supports the engine, wheels, and body; the power train, which carries the engine power to the rear wheels; and the steering and braking systems (*Cadillac Motor Car Division of General Motors Corporation*)

systems, let us take a quick look at the complete automobile (Fig. 1-1, p. 1) and the automobile engine. The automobile consists of five basic mechanisms, or components. These are:

1. The engine, which is the source of power, including the fuel, lubricating, cooling, and electric systems
2. The frame, which supports the engine, wheels, steering and brake systems, and body
3. The power train, which carries the power from the engine (through the clutch, transmission, drive shaft, differential, and axles) to the car wheels
4. The car body
5. Car-body accessories, including heater, lights, windshield wipers, and so forth

Figure 1-2 illustrates the chassis of an automobile. The chassis is made up of the frame, engine, power train, wheels, and steering and brake systems.

1-3 Engine The engine (Figs. 1-3 to 1-5) is the source of power that makes the car move. It is usually called an *internal-combustion engine* because gasoline is burned inside the engine in the cylinders, or combustion chambers. This is in contrast to *external-combustion engines* (such as steam engines), where the combustion takes place *outside* the engine. The burning of gasoline in the engine cylinders produces the power. The power is then carried from the engine through the power train to the car wheels so that the wheels turn and the car moves.

The fuel system plays a vital part in the power-producing process since it supplies the gasoline to the engine cylinders. Before we describe how the fuel system does its job, let us review the actions that take place in the engine cylinders. Most automotive engines have six or eight cylinders. Since the

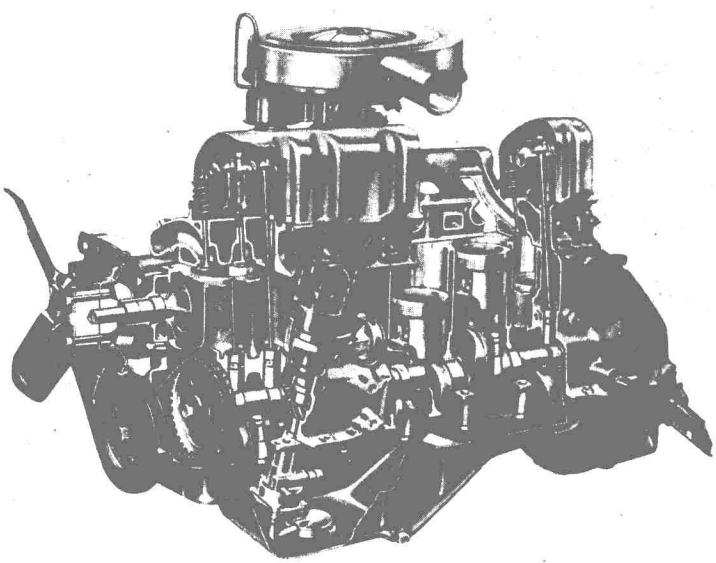

Fig. 1-3. Six-cylinder, in-line engine with overhead valves, partly cut away to show the internal construction. (*Ford Motor Company*)

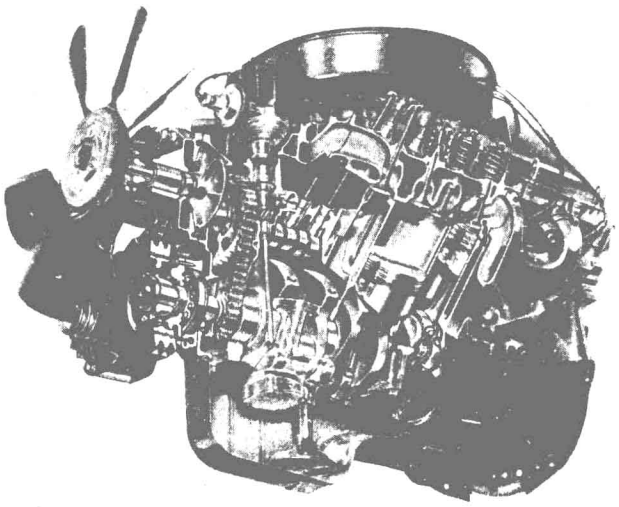

Fig. 1-4. Cutaway view of an eight-cylinder, V-type engine. (*Ford Motor Company*)

same actions occur in each cylinder, we need to examine only one cylinder of the engine.

1-4 Engine Cylinder Figures 1-3 to 1-5 show various engines, cut away so that the internal parts can be seen. As you study these pictures, you may find them somewhat confusing because they show all the basic parts of the engine, including the cylinder, pistons, valves and valve-operating mechanisms, connecting rods, crankshaft, and so on.

Let us simplify the cylinder by showing it as nothing more than a round container, closed at one end and open at the other (Fig. 1-6), like a tin can with the bottom cut out. A movable piston fits into the cylinder. The piston is slightly smaller in diameter than the cylinder, so that it can slip up inside the cylinder, as shown in Fig. 1-6*b*. Note that the cylinder is drawn as though it were transparent so that the actions in the cylinder can be seen. For the moment, you can think of the piston as a solid plug which can slide into the cylinder. This action traps air in the cylinder and compresses it (Fig. 1-6*b*). If we could combine some gasoline vapor with the

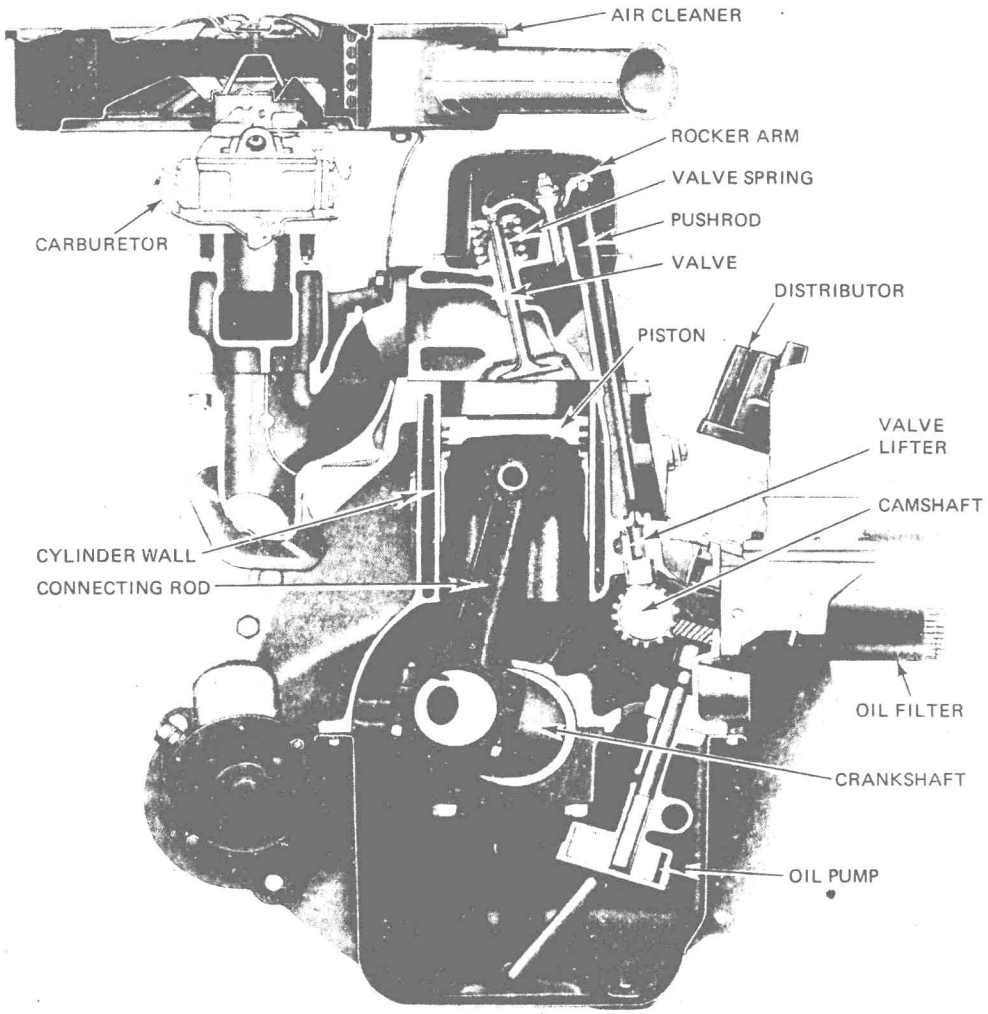

Fig. 1-5. Cross-sectional view of a six-cylinder engine. The piston is near the top of its stroke. Both the piston and the cylinder are shown cut in half. (*Ford Motor Company*)

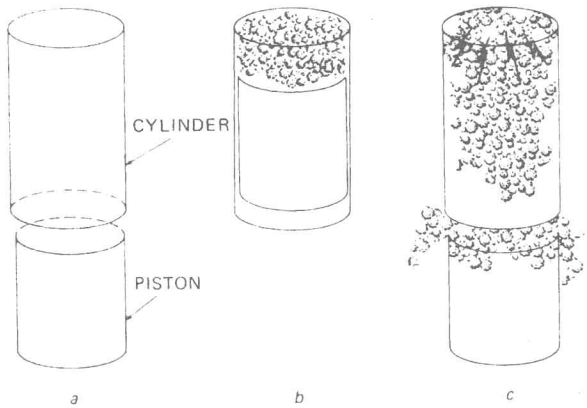

Fig. 1-6. Three steps in the actions in an engine cylinder. (*a*) The piston is a second cylinder that fits snugly into the engine cylinder. (*b*) When the piston is pushed up into the engine cylinder, air is trapped and compressed. The cylinder is drawn as though it were transparent so that the piston can be seen. (*c*) As the pressure increases because of the burning of the gasoline vapor, the piston is pushed out of the cylinder.

compressed air and then apply a lighted match or an electric spark to the air-vapor mixture, it is obvious what would happen. There would be an "explosion" that would blow the piston out of the cylinder, as shown in Fig. 1-6c.

This is actually what happens (with some modification) in each engine cylinder. a mixture of gasoline vapor and air enters the cylinder, the piston pushes up into the cylinder to compress the mixture, and then an electric spark ignites the compressed mixture so that the piston is forced downward. Of course, in the engine the piston is not blown completely out of the cylinder; the piston simply moves up and down in the cylinder—up to compress the mixture, down as the mixture burns.

⊘ 1-5 Changing Reciprocating Motion to Rotary Motion The piston moves up and down in the cylinder. This straight-line motion is called *reciprocating* motion; the piston moves in a straight line. This straight-line motion must be changed to rotary motion before it can be used to make the car wheels rotate. A connecting rod and a crank on the engine crankshaft make this change (Fig. 1-7). The crank is an offset section of the crankshaft. It swings around in a circle as the shaft rotates (Fig. 1-8). The connecting rod connects the crankpin on the crank and the piston (Figs. 1-9 and 1-10). The crank end of the connecting rod is attached to the crankpin by fastening the rod cap to the connecting rod with the rod bolts. Bearings in the rod and cap permit the crankpin to rotate freely within the rod. The piston end of the connecting rod is attached to the piston by the piston pin, or wrist pin. Bearings in the piston or in the rod to tilt back and forth freely.

Now let us see what happens as the piston moves up and down in the cylinder (Fig. 1-11). As the piston starts down, the connecting rod tilts to

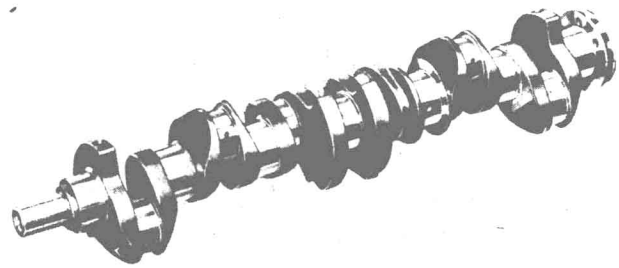

Fig. 1-7. Engine crankshaft. (*Ford Motor Company*)

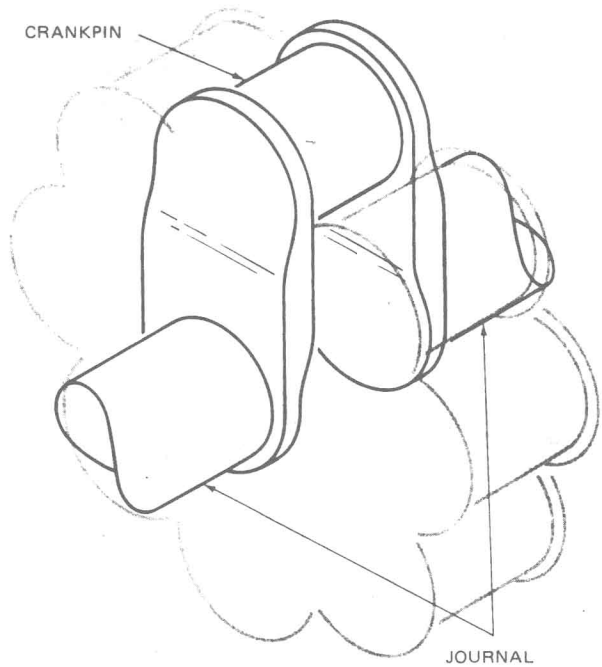

Fig. 1-8. As the crankshaft rotates, the crankpin swings in a circle around the shaft.

one side so that the lower end of the rod can follow the circular path of the crankpin. Study the sequence of action in Fig. 1-12 to see how the rod tilts first to one side and then to the other as the lower end moves in a circle with the crankpin.

⊘ 1-6 Valves There must be some means of getting the burned gasoline vapor out of the engine cylinder and of bringing fresh charges of gasoline vapor and air into the cylinder. The engine valves do this job. There are two openings, or ports, in the enclosed end of the cylinder, each containing a valve. The valves are accurately machined plugs on long stems. When they are closed, or seated (that is, moved up into the ports), the ports are sealed off and gas cannot pass through the ports. When the valve is open (as shown in Fig. 1-13), gas can pass through the port.

The valves are opened by cams on the engine camshaft (Fig. 1-14). A cam on the camshaft, as well as the rest of the valve-operating mechanism, is shown in Fig. 1-15. The cam has a high point, or lobe; every time the cam rotates, the lobe comes around

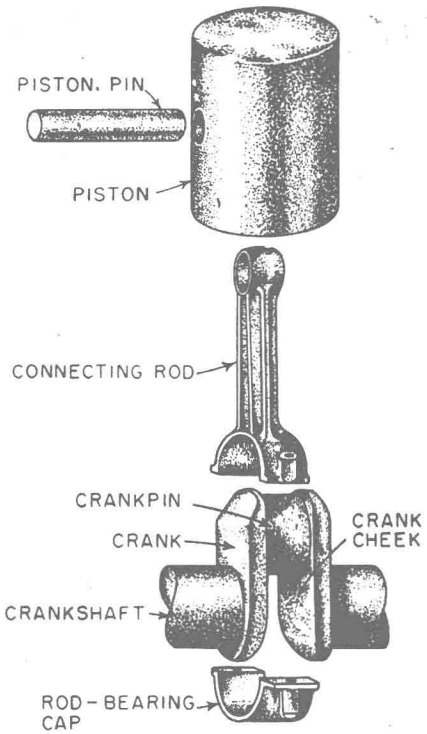

Fig. 1-9. Piston, connecting rod, piston pin, and crank of a crankshaft in disassembled view. The piston rings are not shown.

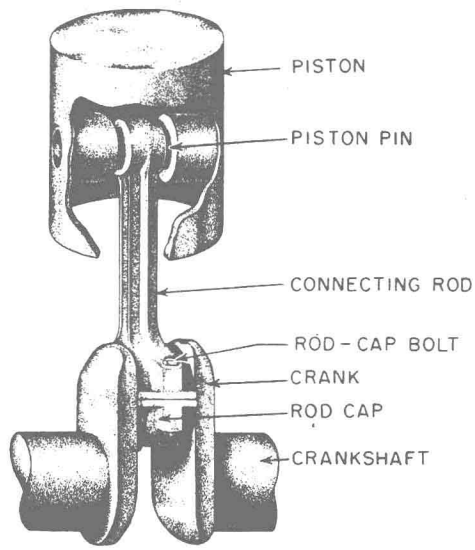

Fig. 1-10. Piston and connecting-rod assembly attached to a crankpin on a crankshaft. The piston rings are not shown. The piston is partly cut away so that you can see how it is attached to the connecting rod.

under the valve lifter and moves it upward. The lifter then carries this upward movement through the pushrod to the rocker arm. The rocker arm pivots on its support and pushes down on the valve stem, causing the valve to move down, that is, to

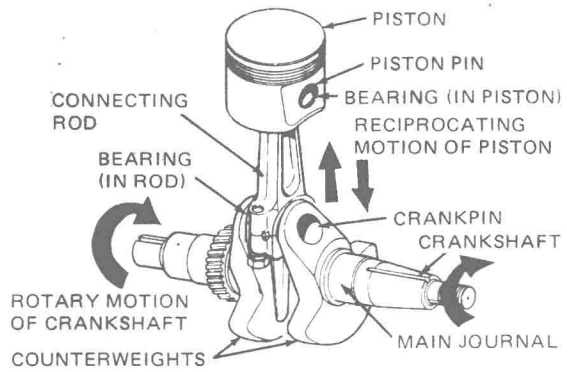

Fig. 1-11. The crankpin moves in a circle around the crankshaft while the piston moves up and down.

open. After the cam has turned enough to move the lobe out from under the lifter, the heavy valve spring pulls the valve back onto its seat. The spring is attached to the upper end of the valve stem by a spring retainer and lock. Figures 1-16 and 1-17 show how the valve train works.

There is a cam for each valve (two cams per cylinder) on the engine camshaft. The camshaft is driven off the crankshaft by gears (Fig. 1-16) or by sprockets and a chain (Fig. 1-18).

1-7 Engine Operation We have noted that the piston moves up and down in the cylinder and that the valves open and close to admit fresh charges of air and gasoline vapor and to discharge burned gases. Let us see how these actions occur. The actions can be divided into four stages, or four piston strokes. A strike occurs when the piston moves from one limiting position to the other. The upper limit of piston movement is called *top dead center*, or TDC. The lower limit of piston movement is called *bottom dead center*, or BDC. A stroke is piston movment from TDC to BDC or from BDC to TDC.

When the entire cycle of events requires four piston strokes (two crankshaft revolutions), the engine is called a *four-stroke-cycle* engine, or a *four-cycle* engine. The four strokes are *intake, compression, power,* and *exhaust.* (Two-cycle engines are also in use; in these, the entire cycle of events takes place in two strokes, or one crankshaft revolution.)

NOTE: For the sake of simplicity in the following discussion, the valves are considered to open at TDC and BDC, that is, at the upper and lower limits of piston movement. Actually, they do not. The valves open well before the piston reaches BDC. Also, the illustrations of the four strokes (Figs. 1-19 to 1-22, pp. 8 and 9) are much simplified and show the intake and exhaust valves separated and placed on either side of the cylinder. This is done so that both can be shown in the same illustration.

1-8 Intake (Fig. 1-19) On the intake stroke, the intake valve is open. The piston moves down, pulled by the rotation of the crankshaft. This piston move-

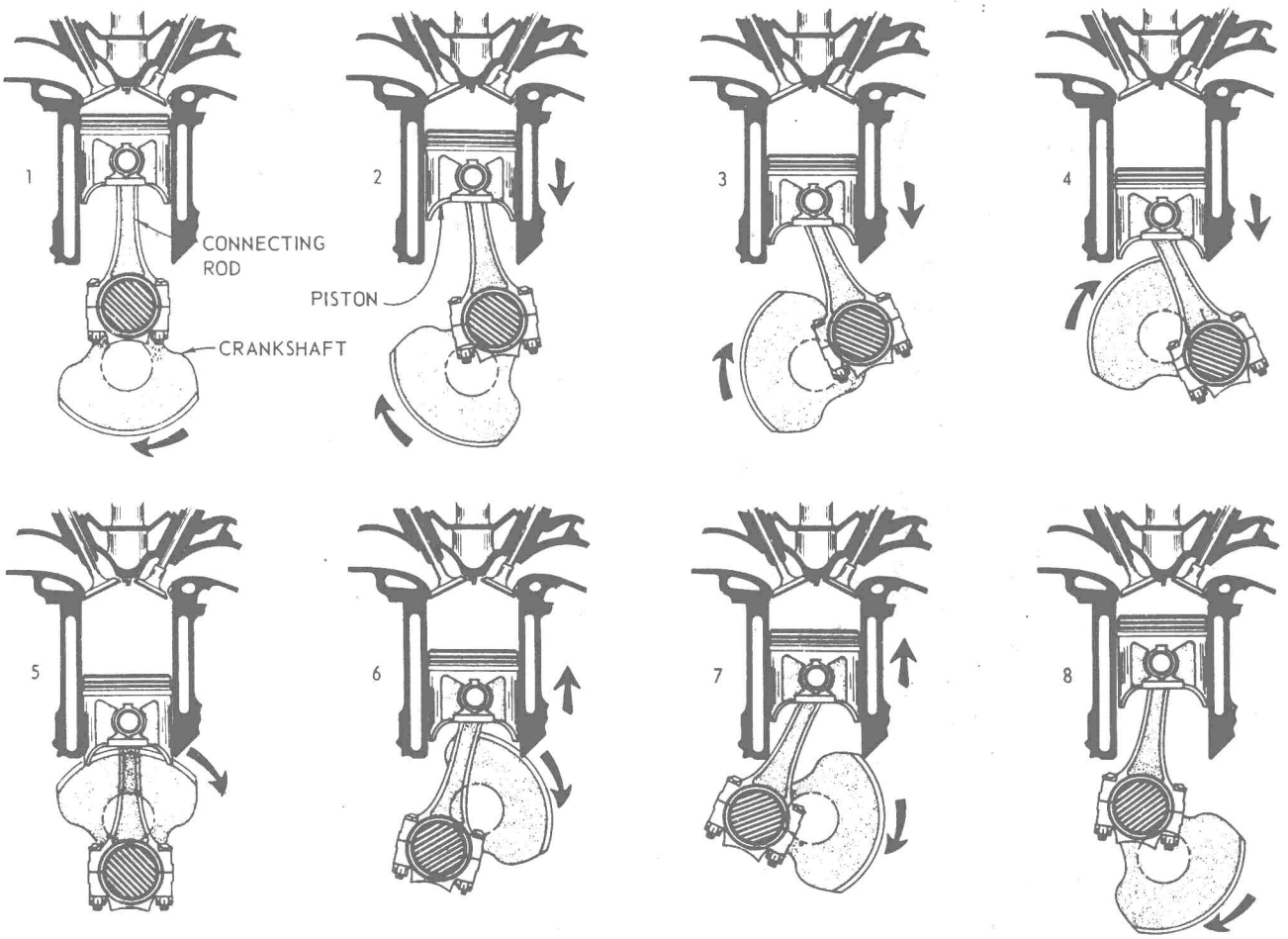

Fig. 1-12. Sequence of actions as the crankshaft completes one revolution and the piston moves from top to bottom to top again.

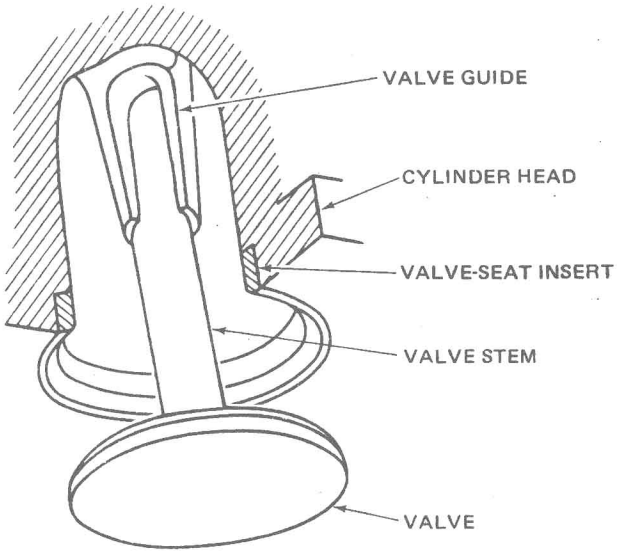

Fig. 1-13. Valve and valve seat in a cylinder head. The cylinder head and valve guide have been cut away so that the valve stem can be seen.

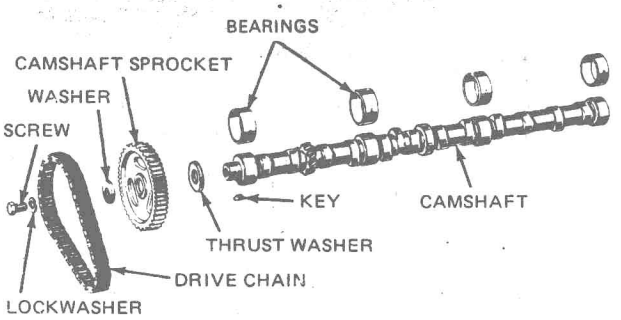

Fig. 1-14. Camshaft and related parts for a six-cylinder engine. (*Ford Motor Company*)

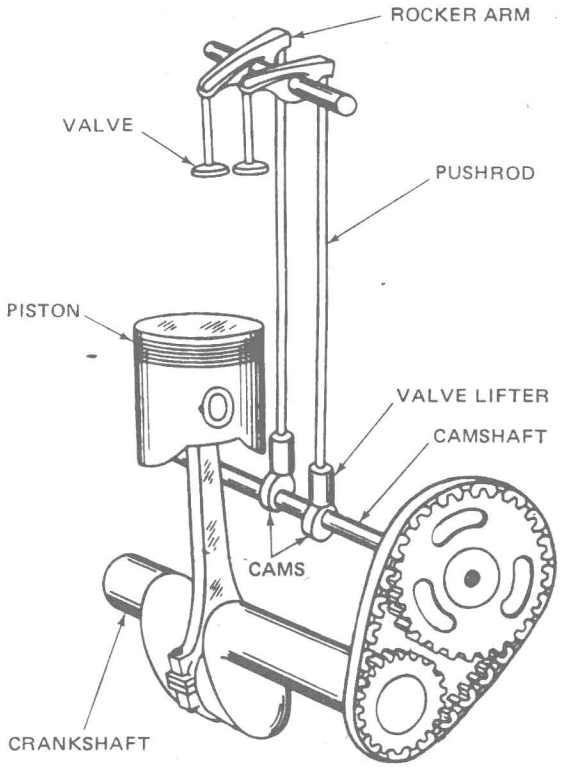

Fig. 1-15. Valve-operating mechanism for an I-head, or overhead-valve, engine. Only the essential moving parts for one cylinder are shown.

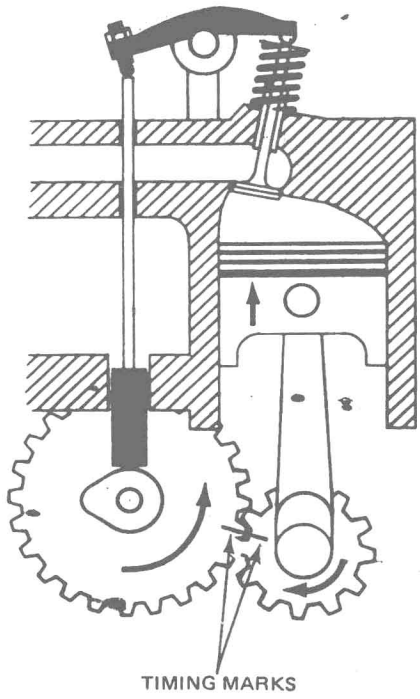

Fig. 1-17. Valve train of Fig. 1-16, showing how the valve closes when the cam lobe moves out from under the valve lifter.

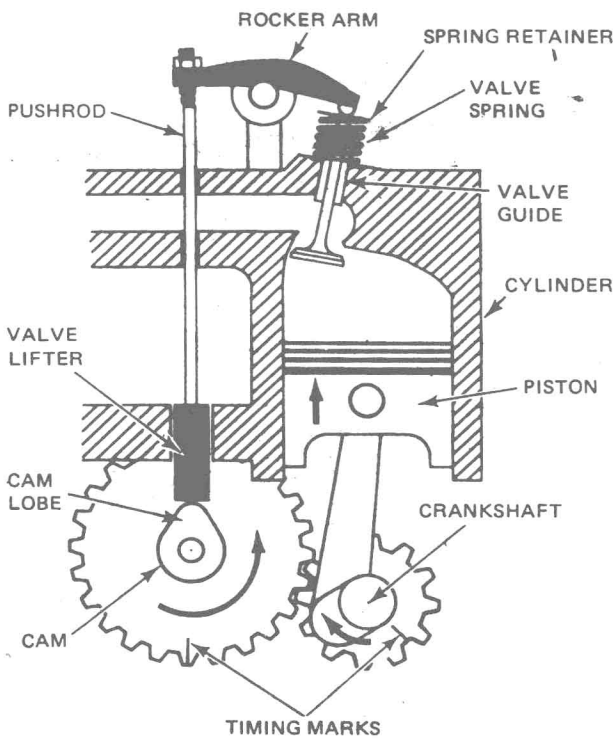

Fig. 1-16. Valve train on an engine using a pair of gears to drive the camshaft. The cam lobe has pushed the push-rod up so that the valve is opened.

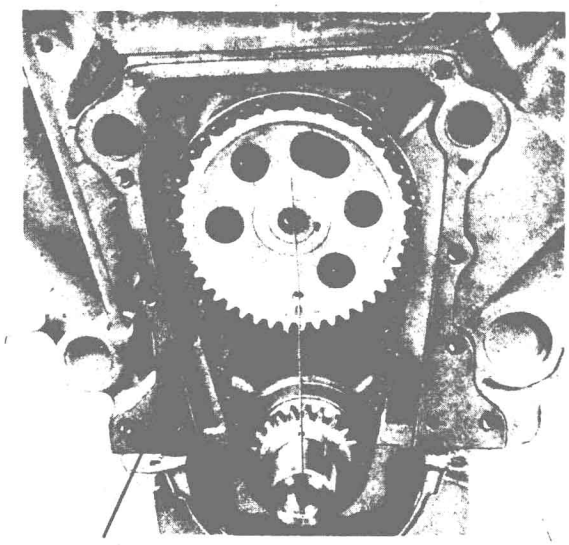

Fig. 1-18. Crankshaft and camshaft sprockets with chain drive for a V-8 engine. (*Chrysler Corporation*)