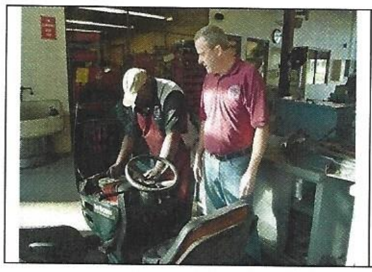


# GADSDEN TECHNICAL INSTITUTE
# CONTINUAL EDUCATION
# COVID-19 EMERGENCY LESSONS

| | |
|---|---|
| Teacher Name: | Mr. David McPhaul |
| Dates of Instruction: | April 16 – May 1, 2020 |
| Lesson(s) Title: | Chapter 3: Fasteners, Sealants, and Gaskets<br>Chapter 4: Engine Construction and Principles of Operation |
| Grade Levels: | 10 – 12; Adult |
| Subject Area: | Power Equipment Technologies |

***Assignment:*** After reading the assigned material on fasteners, sealants, gaskets engine construction and principles of operation, the student will be able to: service seals and gaskets; determine necessary action; identify lubrication systems; service and repair lubrication systems, explain the basic principles of the operation of two-stroke cycle internal combustion engines; remove, clean and inspect heads for cracks, warpage and damaged spark plug threads; remove, clean and inspect piston and rod assemblies; measure out-of-round of pistons and cylinders; measure piston skirts and ring grooves; measure the piston ring gap in cylinder bores; install piston pins according to manufacturer's specifications; check rod and piston assembly alignment.

***Lesson Instructions:***

Week of April 16 – April 23, 2020, read Chapter 3 pages 43 - 60.

Week of April 24 – May 1, 2020, read Chapter 4 pages 63 - 74.

***Practice Activities:***

Week of April 16 – April 23, 2020, answer Chapter 3 review questions 1 -25 on pages 61-62 and answer Chapter 3 workbook questions 1 – 45 on pages 19 – 24.

Week of April 24 – May 1, 2020, answer Chapter 4 review questions 1 - 18 on page 75-76 and answer Chapter 4 workbook questions 1 – 50 on pages 25 – 31.

***Instructional Materials:***

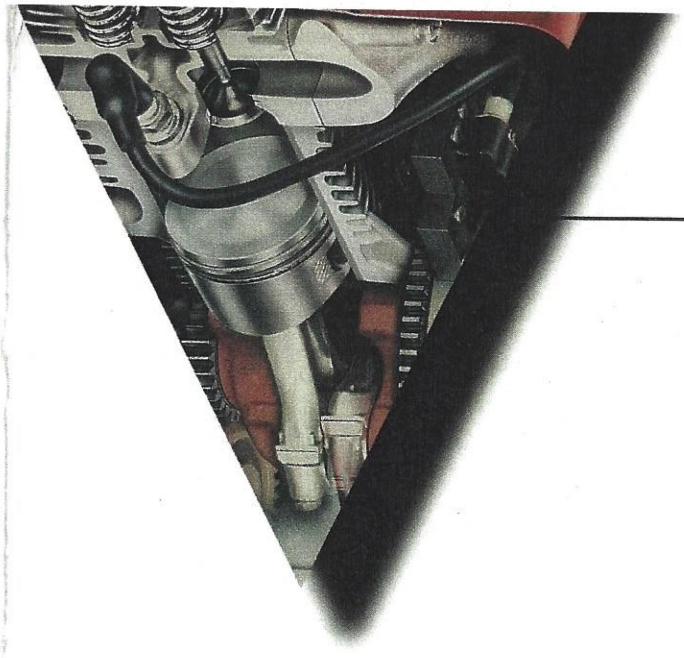
1. Chapter 3 Fasteners, Sealants, and Gaskets reading material packet.
2. Chapter 3 Fasteners, Sealants, and Gaskets workbook material packet.
3. Chapter 4 Engine Construction and Principles of Operation reading material packet.
4. Chapter 4 Engine Construction and Principles of Operation workbook material packet.

***Special Notes from Instructor:***

ALL paper work should be kept in your folder, signed and dated to reflect completion date(s) prior to bringing them to class with you on May 4, 2020. If there are any questions, I can be reached at (850) 875-8324; ext. 5113 or email mcphauld@gcpsmail.com.

**Mission Statement**

The mission of Gadsden Technical Institute is to recognize the worth and potential of each student. We are committed to providing opportunities for basic and advanced instruction in a conducive learning environment. The Center encourages academic and technical curiosity, innovation and creativity by integrating applied academic skills in all occupational areas. We strive to instill the attitudes and skills necessary to produce motivated, self-sufficient individuals who are able to function effectively in our ever-changing, complex society.



## CHAPTER 3

# Fasteners, Sealants, and Gaskets

After studying this chapter, you will be able to:

- Identify fasteners used on small gas engines and implements.
- Remove and install various fasteners correctly.
- Repair or produce internal and external threads.
- Properly select and install fasteners.
- Remove, select, and install gaskets correctly.

## Threaded Fasteners

Small gas engines and the implements for which they provide power are held together by fasteners. There are many kinds of fasteners. See **Figure 3-1.** Some are common and others are designed to perform special functions. During service fasteners may be exposed to conditions such as heating and cooling, cyclic loading, tensile and shearing loads, corrosion, and vibration.

The helical portion of a screw or bolt, or the ***helix*** in a hole that it fastens into, is called a ***thread***. A thread is an inclined plane that circles around the cylindrical bolt or hole. See **Figure 3-2.** The incline of the bolt or screw must be the same as the incline of the nut or threaded hole into which it is placed. The tightness (tension) of threaded fasteners is very important and will be discussed in the *Torque* section of this chapter.

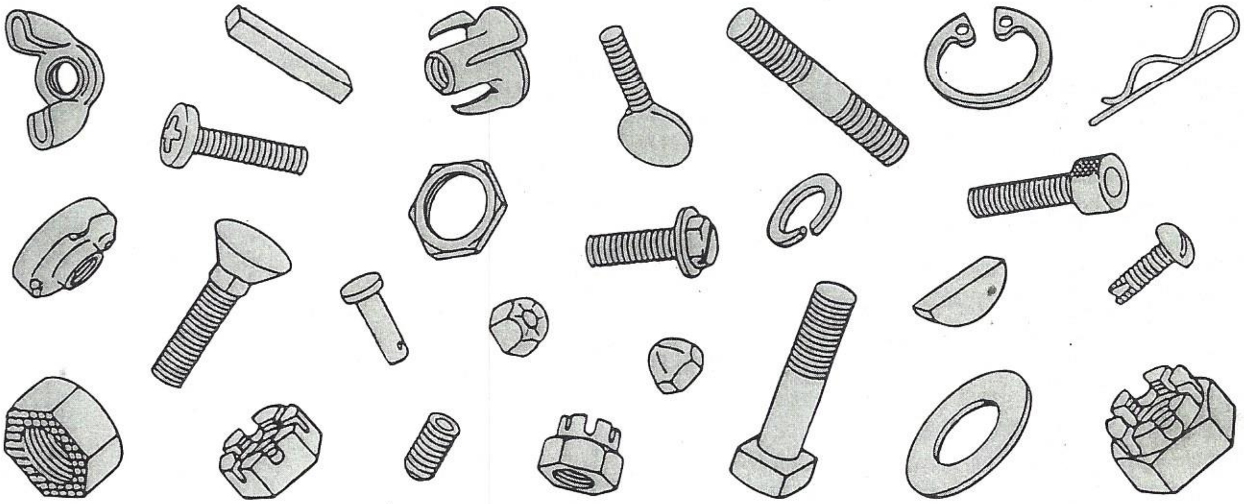


**Figure 3-1.** *There are many kinds of fasteners to hold parts together.*

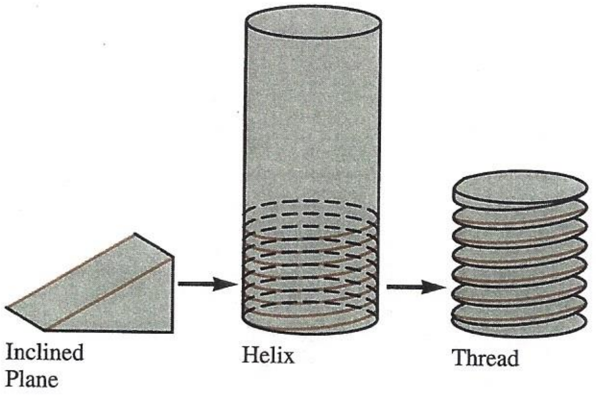


**Figure 3-2.** *A thread is an inclined plane wrapped around a cylinder and is called a helix.*

When disassembling an engine, all parts, fasteners, and washers should be noted. Care should be taken during this process, so that the correct parts, fasteners, and washers are replaced during reassembly. When fasteners are badly damaged or worn, replace them with new ones. Lightly rusted fasteners should be cleaned with a wire brush or wire wheel and examined for damage. Lightly apply oil to the thread and shank before installing bolts, nuts, or screws.

## *Screws*

***Screws*** are threaded fasteners that hold parts together by passing through one part and threading into another. See **Figure 3-3.** Flat head screws must be set into a ***countersunk*** hole so that the head will be flush with the surface. The most common angle for countersunk holes is 82 1/2°. See **Figure 3-4.** However, 60° and 100° countersinks are used for some special applications. Modern practice uses many hexagonal screw heads because of the prevalent use of hexagonal sockets and box wrenches for tightening and loosening. Round head, flat head, and other screw heads require the appropriate screwdriver or Allen wrench to turn them. The most common screw and bolt heads are shown in **Figure 3-5.** Notice that each head has a particular name that identifies the head type. Screws may be threaded all the way to the head.

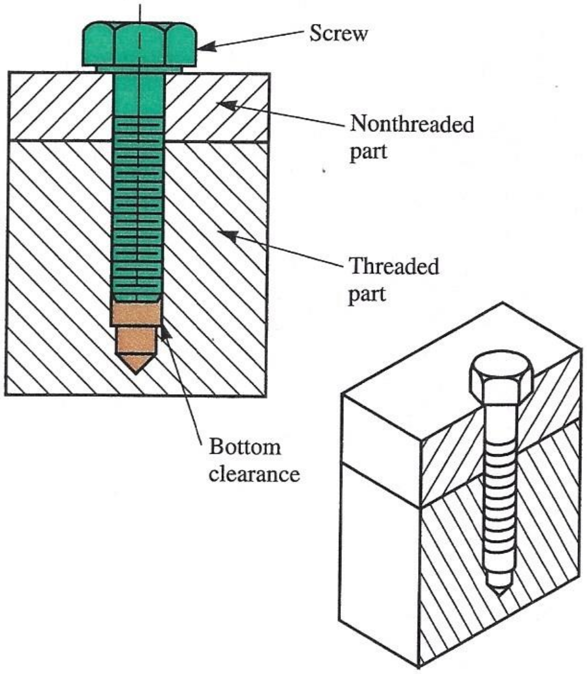


**Figure 3-3.** *Screw passes through one part and threads into mating part. Note clearance at bottom of hole.*

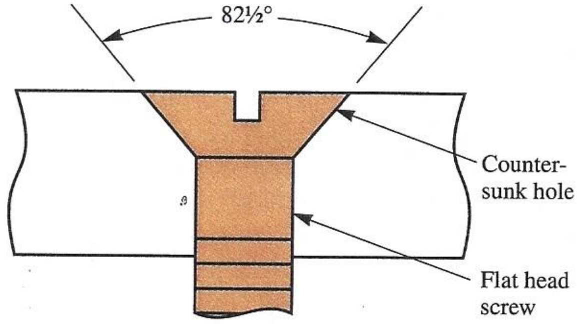


**Figure 3-4.** *Flat head screw recessed in countersunk hole to be flush with surface.*

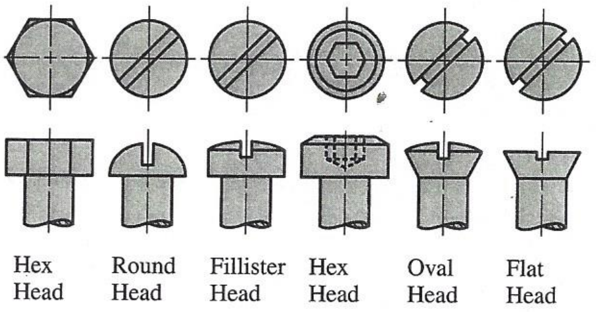


**Figure 3-5.** *Common types of bolt and screw heads.*

## Set screws

***Set screws*** are heat-treated, hardened-alloy steel fasteners, which are used to secure such things as pulleys, gears, and shafts. See **Figure 3-6.** When using set screws on a shaft it is necessary to provide a relief groove so that the part can be removed from the shaft when necessary. The common head types are square, slotted ***hexagon socket,*** and fluted socket. The set screw points may be flat, cup point, cone, half dog, or full ***dog.*** See **Figure 3-7.** Flat points are used when just clamping friction is enough to hold the part without deforming its surface. Cup and cone point set screws cut into the surface of the shaft or part to prevent its motion or rotation. Dog point set screws are designed to positively lock into a predrilled hole in a shaft matching the diameter of the dog. See **Figure 3-8.**

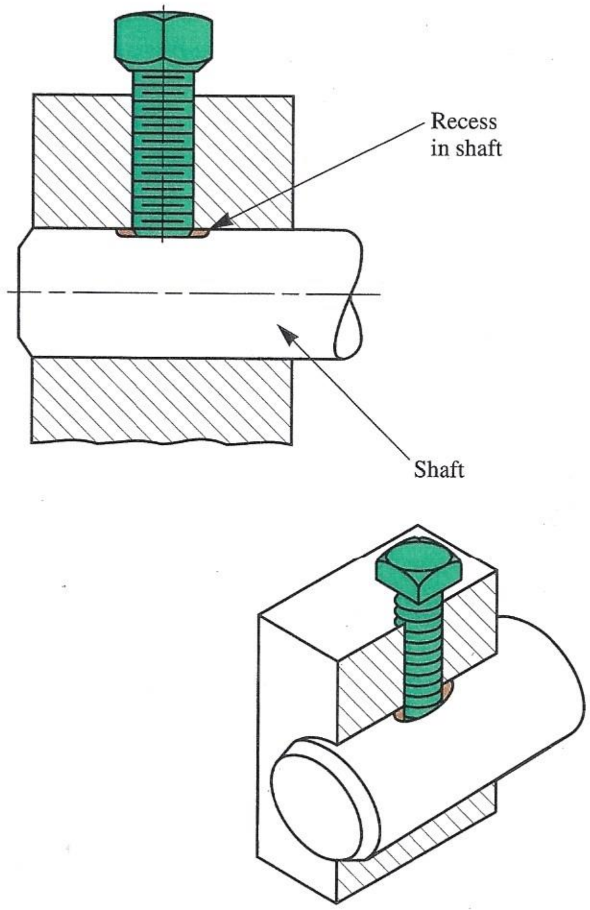


**Figure 3-6.** *Set screws lock pulleys and gears to shafts to prevent rotation of shaft in hole. Note recessed area on shaft.*

## Self-tapping screws

A variety of ***self-tapping screws*** are shown in **Figure 3-9.** Self-tapping screws are fasteners that will cut their own threads in a predrilled hole if the hole diameter is of appropriate size. ***Tapping*** is the

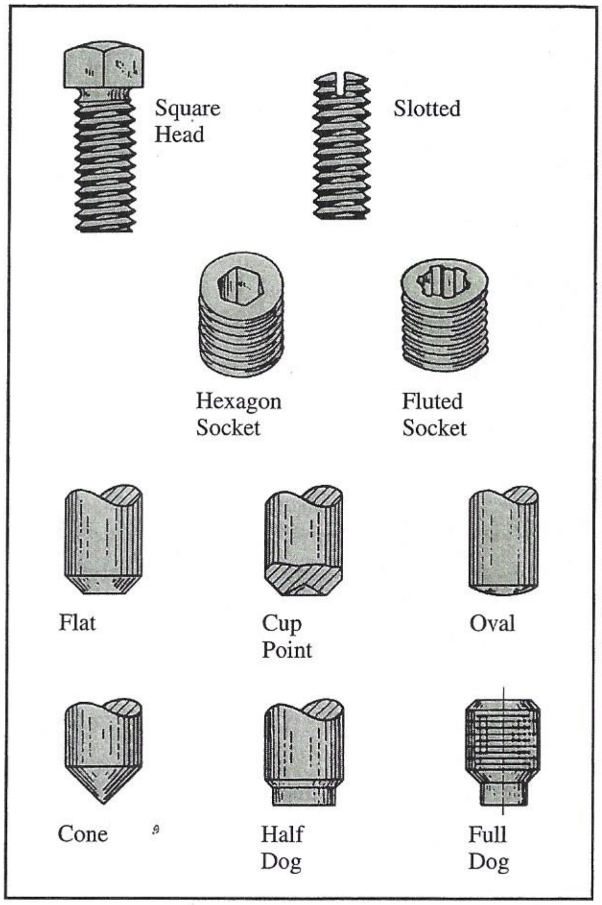


**Figure 3-7.** *Common types of set screw heads and points. Set screws are hardened steel.*

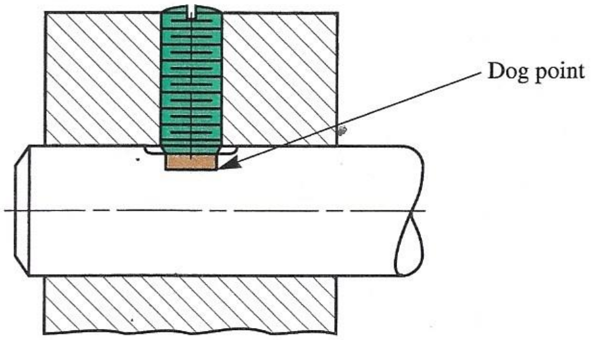


**Figure 3-8.** *Dog point of screw in hole in shaft.*

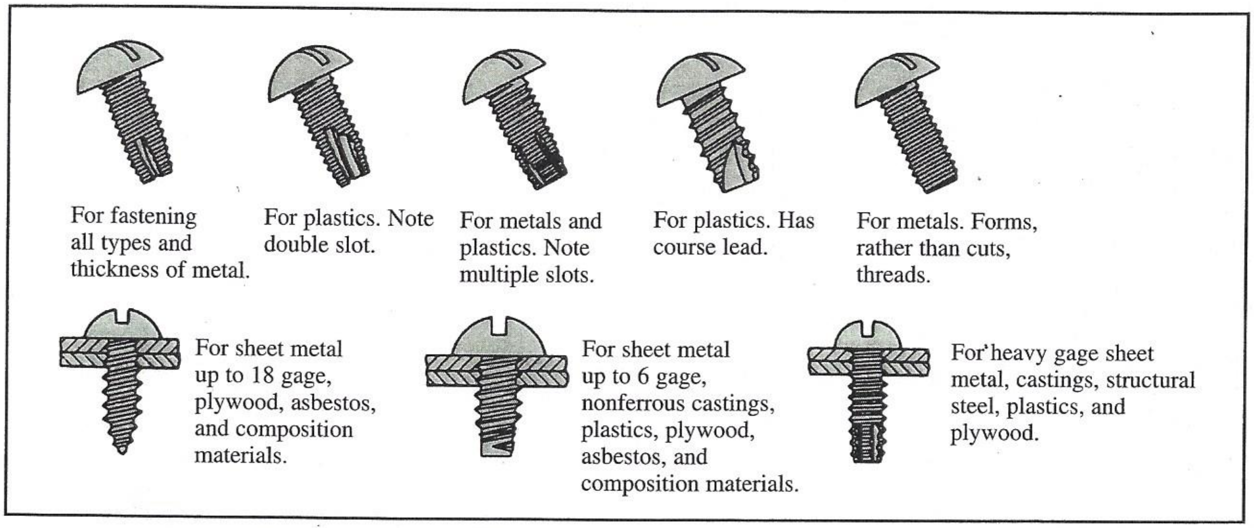


**Figure 3-9.** *Self-tapping screws cut, or form their own threads.*

process of cutting threads in a hole. ***Threading*** is the process of making external threads on an external cylindrical surface. Self-tapping screws have a grooved or tapered point that forms the threads in the hole. Self-tapping screws are hardened steel because they perform as a cutting tool as well as a fastener.

## Bolts

***Bolts*** are threaded fasteners that hold parts together by squeezing them between the head on one end and a nut on the other end. See **Figure 3-10.** Bolts are used with a nut to apply a squeezing force to one or more components. The hole the bolt passes through is not threaded. It should have a small amount of clearance so that the bolt does not have to be driven through the hole. The head of a bolt may be the same shape as the head used on a screw since their use is interchangeable. See **Figure 3-5.** As previously mentioned, screws may be threaded all the way to the head. However, if screws are to be used as bolts, they should not be threaded all the way to the head. The unthreaded portion, or shank, of a bolt should pass through all of the top part and partially through the second component. See **Figure 3-11.** The threaded portion is called the *grip-length* of the bolt.

Often, a lock washer is placed between the face of the nut and the part surface to prevent loos-

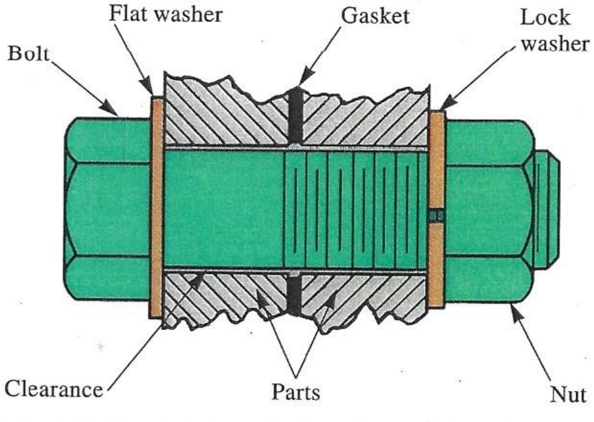


**Figure 3-10.** *A bolt and nut apply great clamping force. Washers are used with nut and bolt. Note gasket between parts.*

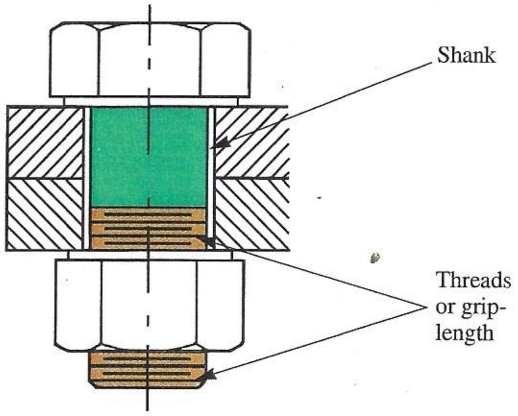


**Figure 3-11.** *The unthreaded portion, or shank, of a bolt should pass through all of the top part and partially through the second component.*

ening caused by vibration. A flat washer is often used to provide a smooth and larger clamping surface. This is often necessary when fastening soft materials such as aluminum, plastic, or wood. Washers are covered in detail later in this chapter.

## *Nuts*

Nuts vary in shape and size depending upon their intended function. Plain hexagon nuts are most common. Other types used include wing nuts, castle nuts, and various self-locking nuts. See **Figure 3-12.**

***Square nuts,*** like square headed bolts, are not commonly used, but can be found on old implements. A ***jam nut*** is used in conjunction with a plain ***hexagon nut.*** The jam nut is a thinner nut used with a plain nut to produce a locking condition of one nut tightening against the other. See **Figure 3-13.** The ***castle nut*** is used on bolts that have a drilled hole through the threaded end. A cotter pin is used to prevent the castle nut from turning. Cotter pins should always be installed properly as shown in **Figure 3-14.** Castle nuts are used on bolts or shafts when a component turns or pivots on it. They are also used when ***axial clearance*** is required, such as with axle shafts having tapered roller or ball bearings. ***Acorn nuts*** are used to tighten and also cover the sharp thread end of a bolt for safety. It is important when using acorn nuts to be certain that the bolt end does not bottom in the nut before it tightens. Acorn nuts get their name from their likeness in shape to oak tree acorns and are often used to provide a smooth, neat appearance. ***Wing nuts*** are used when something needs to be frequently adjusted and can be tightened or loosened by hand. There are many special nuts, some of which are shown in **Figure 3-15.** After being tightened, a bolt should be long enough to pass through the parts, any washers, the nut, and protrude from one and one-half to two threads beyond the nut.

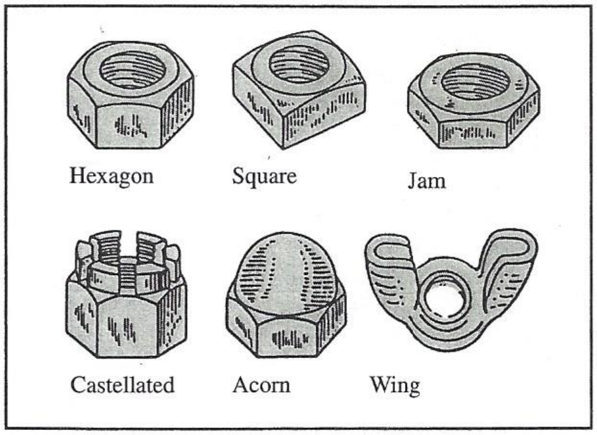


**Figure 3-12.** *Various kinds of nuts apply clamping pressure on bolts.*

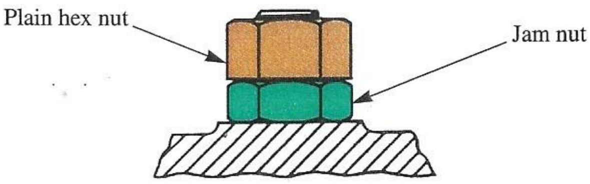


**Figure 3-13.** *Two nuts used to prevent loosening of bolt.*

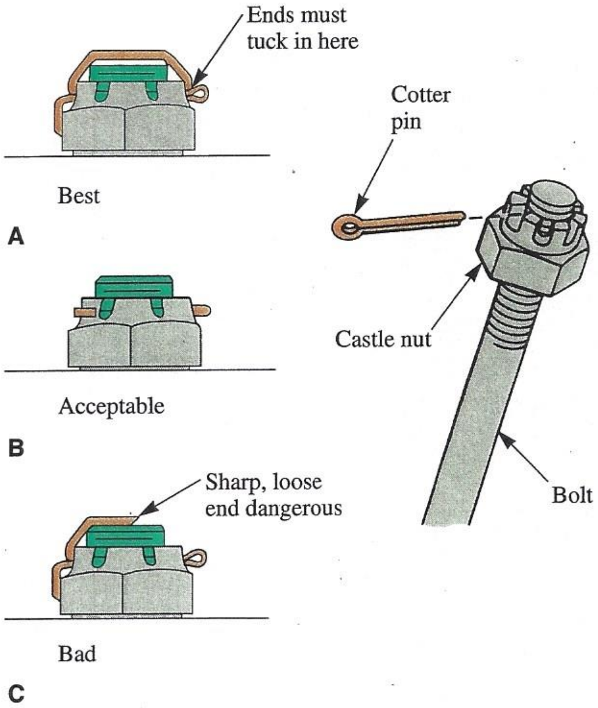
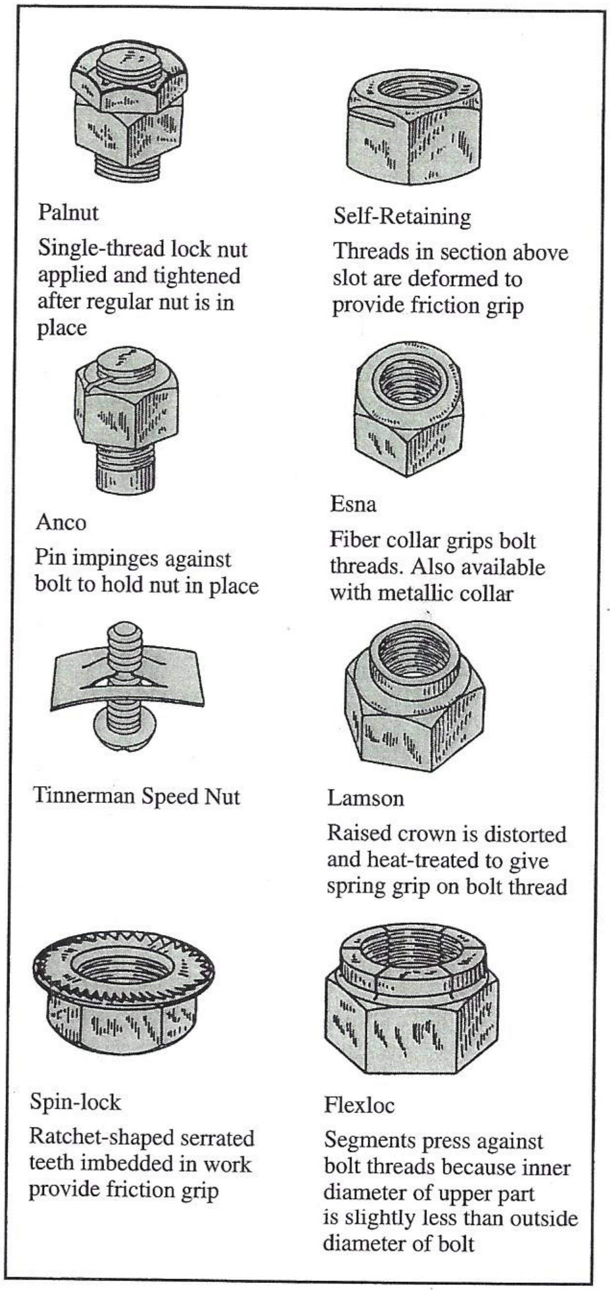


**Figure 3-14.** *Cotter pin is placed through castle nut and bolt hole to prevent nut from coming off bolt. Installation method A or B is acceptable. Method A is more difficult to produce, but eliminates sharp ends.*

### Lock nuts

Lock nuts are designed to create friction to reduce the tendency for vibration, or motion to rotate and loosen the nut. **Figures 3-12** and **3-15** illustrate some locking-type nuts.



Palnut

Single-thread lock nut applied and tightened after regular nut is in place

Self-Retaining

Threads in section above slot are deformed to provide friction grip

Anco

Pin impinges against bolt to hold nut in place

Esna

Fiber collar grips bolt threads. Also available with metallic collar

Tinnerman Speed Nut

Lamson

Raised crown is distorted and heat-treated to give spring grip on bolt thread

Spin-lock

Ratchet-shaped serrated teeth imbedded in work provide friction grip

Flexloc

Segments press against bolt threads because inner diameter of upper part is slightly less than outside diameter of bolt

**Figure 3-15.** *Some nuts are self locking.*

## *Bolt and nut terminology*

Bolts and nuts come in various sizes (lengths, diameters, and head size), grades (strengths), and thread types. Being familiar with these differences is important when the need arises to replace nuts and bolts. Important bolt dimensions are:

- ***Bolt size.*** The major (largest) diameter of the bolt threads.
- ***Bolt head size.*** The dimension across the flats of the hexagon. It is the same as the wrench size.
- ***Bolt length.*** The distance from the base of the bolt head to the threaded end of the bolt.
- ***Thread pitch.*** The number of threads per inch on U.S. customary fasteners. On metric fasteners it is the distance between each thread measured in millimeters.

### Bolt grades

***Bolt grades*** are related to the minimum tensile (pulling) strength requirements of the bolt. **Figure 3-16** shows the amounts in P.S.I. (pounds per square inch of cross section of the bolt). The bolt heads are often marked with a symbol indicating the grade of the bolt. For example, an SAE Grade 5 bolt has three marks on the head. A Grade 6 bolt has four marks on the head. In every case the number of marks on the head is 2 less than the Grade Number. A Grade 1 and 2 has no marks on the head. Metric bolt heads are marked with 5D, 8G, 10K, 12K. See **Figure 3-16** for corresponding ***tensile strengths.***

The torque specifications listed in **Figure 3-16** are approximate guidelines only and may vary depending on conditions when used, such as amount and type of lubricant, type of plating on bolt, etc.

It should be noted that the tensile strengths would only be accurate for a bolt having exactly a 1″ cross-sectional area. For example, a 1/4″ diameter, Grade 2 bolt showing a 64,000 P.S.I. strength would support a maximum 3155 lb of weight. The reason is a 1/4″ diameter bolt area is only .0493 of a 1 sq in. Therefore: .0493 × 64,000 P.S.I = 3,155.20 lb. It should not be expected that one 1/4″ bolt will withstand a 64,000 lb load. It should also be understood that the load applied to the bolt due to overtightening (primary load), plus the external (secondary) load exerted upon it could exceed the tensile limits of the bolt. An external load could be applied as a result of pulling, lifting a load, and/or heat expansion.

When a bolt reaches its load bearing limit it becomes weaker, exceeds its ***elastic limit,*** and begins to stretch plastically. When a bolt stretches plastically it does not return to its original length or shape when the load is released. The bolt may appear to be loose or show signs of leakage at a

| SAE Standard/Foot-Pounds | | | | | | |
|---|---|---|---|---|---|---|
| ***Grade of Bolt*** | ***SAE 1 & 2*** | ***SAE 5*** | ***SAE 6*** | ***SAE 8*** | | |
| Min. Ten. Strength | 64,000 P.S.I. | 105,000 P.S.I. | 133,000 P.S.I. | 150,000 P.S.I. | | |
| Markings on Head | ⬢ | ⬢ | ⬢ | ⬢ | Size of Socket or Wrench Opening | |
| U.S. Standard | Foot Pounds | | | | U.S. Regular | |
| Bolt Dia. | | | | | Bolt Head | Nut |
| 1/4 | 5 | 7 | 10 | 10.5 | 3/8 | 7/16 |
| 5/16 | 9 | 14 | 19 | 22 | 1/2 | 9/16 |
| 3/8 | 15 | 25 | 34 | 37 | 9/16 | 5/8 |
| 7/16 | 24 | 40 | 55 | 60 | 5/8 | 3/4 |
| 1/2 | 37 | 60 | 85 | 92 | 3/4 | 13/16 |
| 9/16 | 53 | 88 | 120 | 132 | 7/8 | 7/8 |
| 5/8 | 74 | 120 | 167 | 180 | 15/16 | 1 |
| 3/4 | 120 | 200 | 280 | 296 | 1-1/8 | 1-1/8 |

| Metric Standard | | | | | | |
|---|---|---|---|---|---|---|
| ***Grade of Bolt*** | | ***5D*** | ***.8G*** | ***10K*** | ***12K*** | |
| Min. Ten. Strength | | 71,160 P.S.I. | 113,800 P.S.I. | 142,200 P.S.I. | 170,679 P.S.I. | |
| Markings on Head | | 5D | .8G | 10K | 12K | Size of Socket or Wrench Opening |
| Metric | | Foot Pounds | | | | Metric |
| Bolt Dia. | U.S. Dec. Equiv. | | | | | Bolt Head |
| 6mm | .2362 | 5 | 6 | 8 | 10 | 10mm |
| 8mm | .3150 | 10 | 16 | 22 | 27 | 14mm |
| 10mm | .3937 | 19 | 31 | 40 | 49 | 17mm |
| 12mm | .4720 | 34 | 54 | 70 | 86 | 19mm |
| 14mm | .5512 | 55 | 89 | 117 | 137 | 22mm |
| 16mm | .6299 | 83 | 132 | 175 | 208 | 24mm |
| 18mm | .7090 | 111 | 182 | 236 | 283 | 27mm |
| 22mm | .8661 | 182 | 284 | 394 | 464 | 32mm |

**Figure 3-16.** *General bolt torque chart. Torque values increase as bolt size and grade increases.*

gasket. Unknowingly, one might retighten the bolt. This stretches it, weakens it more, and will result in the bolt failing in service or breaking during the tightening.

## Thread types

**Figure 3-17** illustrates some of the various parts of a thread. There are several types, or series, of threads of commercial importance. Only three are of significance for the purpose of this text. The first type are the coarse-thread series designated ***Unified National Coarse (UNC)*** and National Coarse (NC). These are for general use where they are not subjected to vibration.

The second type are the fine-thread series designated ***Unified National Fine (UNF)*** and National Fine (NF). These are for work where vibration is a considerable factor, such as automotive and aircraft applications.

Unified coarse and unified fine refers to the number of threads per inch of length on threaded fasteners. Every bolt or nut diameter will have a specific number of threads per inch of length. For example, a 1/2″ diameter Unified National Coarse bolt or nut will always have 13 threads per inch of length. A Unified National Fine thread of the same diameter will always have 20 threads per inch. The 1/2″ is always the ***major (largest) diameter*** of the thread of the bolt or nut.

The third type are the metric series designated ***Metric (M).*** The metric thread is formed with a 60° angle, which is similar to the unified threads. For the metric threads, the root may be rounded and the depth somewhat greater. The International Standards Organization (ISO) has attempted to standardize metric threads. The ISO metric thread series has 25 thread diameters ranging from 1.6 millimeters (mm) to 100mm.

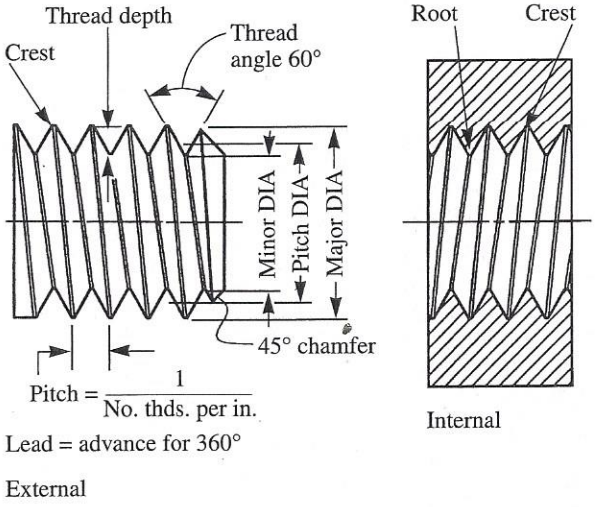


**Figure 3-17.** *Thread terminology for external and internal threads.*

Threads are either right-handed or left-handed. A fastener with right-handed threads must be turned clockwise to tighten it. A fastener with left-handed threads must be turned counterclockwise to tighten it. The letter *L* may be stamped on the fastener with left-handed threads.

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The thread of a nut or threaded hole must always be the same series, size, and type as that of the bolt or screw entering it. If they are not the same, thread stripping or damage will occur.

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## Thread fit

Some thread applications can tolerate loose fitting threads. Other applications may require closer fitting, or tight threads. For example, the head on a gasoline engine may be held to the engine block with bolts that are threaded on both ends called ***stud bolts***. See **Figure 3-18.** One end is threaded into the engine block. The other end receives a nut that tightens against the cylinder head. It is desirable to have the stud bolt remain in the engine block when the nut is removed. The block end requires a tighter fitting thread than the end with the nut. If the fit of the nut is too tight, the entire stud may be removed when the nut is turned with a wrench. In some cases, a UNF thread is used in the block and a UNC thread on the nut end.

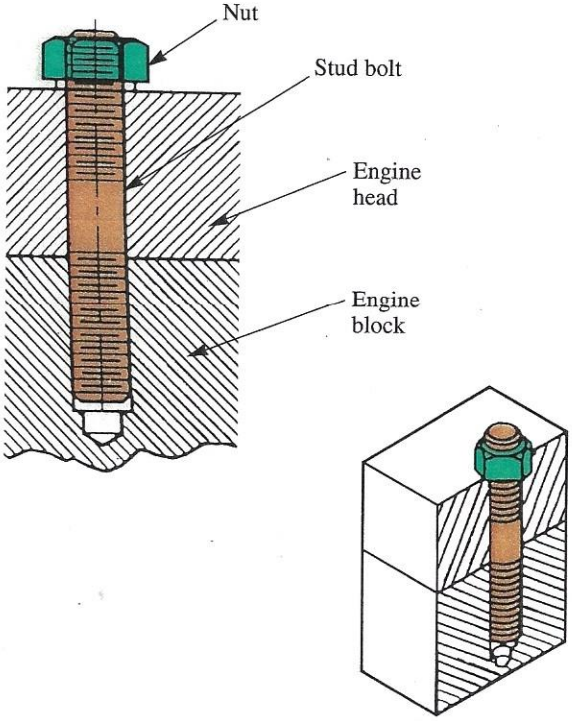


**Figure 3-18.** *Stud bolts are threaded at both ends.*

Unified threads are classified as external or internal, and according to classification of fit as follows:

- ***Class 1 Fit.*** Has the largest manufacturing tolerance. Used where ease of assembly is desired and a loose thread is not objectionable.
- ***Class 2 Fit.*** Used on the largest percentage of threaded fasteners.
- ***Class 3 Fit.*** Will be tight when assembled.

## *Thread designations*

The thread designation is a series of numbers and letters used to describe a bolt and thread. For example, the designation of 1/2-13 UNC-2A × 1 is defined as follows:

- ***1/2.*** Indicates the thread diameter. In this case, the diameter is 1/2″.
- ***13.*** Indicates the threads per inch. In this case, there are 13.
- ***UNC.*** Indicates the series of thread. In this case, it is a Unified National Coarse thread. The letters ***UNF*** is a Unified National Fine thread.
- ***2.*** Indicates the class of fit. In this case, a ***2*** indicates a class 2 fit. The number ***1*** is a class 1 fit and ***3*** is a class 3 fit.
- ***A.*** Indicates that it is an external or internal thread. In this case, an ***A*** indicates an external thread. The letter ***B*** is an internal thread, such as a nut or threaded hole.
- ***1.*** This number indicates the length of the fastener in inches. In this case, the ***1*** is 1″.

A letter *L* at the far right of thread designation indicates left-handed threads. For example, 1/4-20 UNC-2A L is a left-handed thread. If the *L* is not present, the thread is understood to be right-handed.

Metric thread designations are slightly different. For example, the metric designation of M-10 × 1.5 × 25 is defined as follows:

- ***M.*** Indicates that the thread is metric.
- ***10.*** Indicates the diameter of the thread in millimeters. In this case, the diameter is 10mm.
- ***1.5.*** Indicates the distance between threads (pitch). In this case, the pitch is 1.5mm.
- ***25.*** Indicates the length of the fastener in millimeters. In this case, the length is 25mm.

## *Tightening and loosening threaded fasteners*

As previously mentioned, if a bolt, nut, or screw has right-handed threads, the direction for tightening is always clockwise and the direction for loosening is always counterclockwise. For beginners, this may be a problem until they gain this understanding. It can be particularly difficult to understand if the bolt, nut, or screw is in the inverted (upside-down) position on an engine or implement. In fact if not careful, the head of the fastener may be twisted off by attempting to turn it the wrong direction. This may introduce the problem of getting the broken fastener out of the hole. If removing the fastener is successful, then the threads may have to be recut (chased) in the hole. A threading tap is a tool used for chasing the threads. For more details on the chasing procedure, see the *Chasing threads* section in this chapter.

### Tightening to specific torque settings

Tightening bolts, nuts, and screws on engines should be done with a torque wrench. They should be tightened to specific torque (turning effort) settings. See torque charts for fractional and metric size bolts in **Figure 3-16**. More information is provided on this subject in *Torque wrenches* section of Chapter 2 and in the *Torque specifications* section of Chapter 12.

## *Chasing threads*

When threads become damaged in a nut or threaded hole, it may be necessary to recut the thread with a tool called a ***threading tap***. See **Figure 3-19**. This procedure is called ***chasing*** the thread. If the hole goes all the way through, then it is called a ***through hole***. A nut is an example of a through hole. In the case of a nut, select a tap designated to fit the existing thread. If the existing thread is 1/2-13 UNC, then select a tap designated 1/2-13 UNC. This designation will be stamped on the tap shank of the tap.

For a through hole a taper tap should be used. A ***taper tap*** has a slender taper at the beginning of the tap that makes it start easier in the threads. Select a tap wrench to turn the tap. Install the square end of the tap in the wrench and tighten it. You will need to decide whether the part can be secured in a vise or whether it can be done in place. A small item can be clamped in a vise to hold it. See **Figure 3-20.** Add a few drops of cutting oil on the tap before beginning. This will improve the cutting action and produce better threads. Align the tap with the hole and turn it clockwise (right-handed threads) until the tap turns freely. Then, reverse the rotation until the tap can be removed.

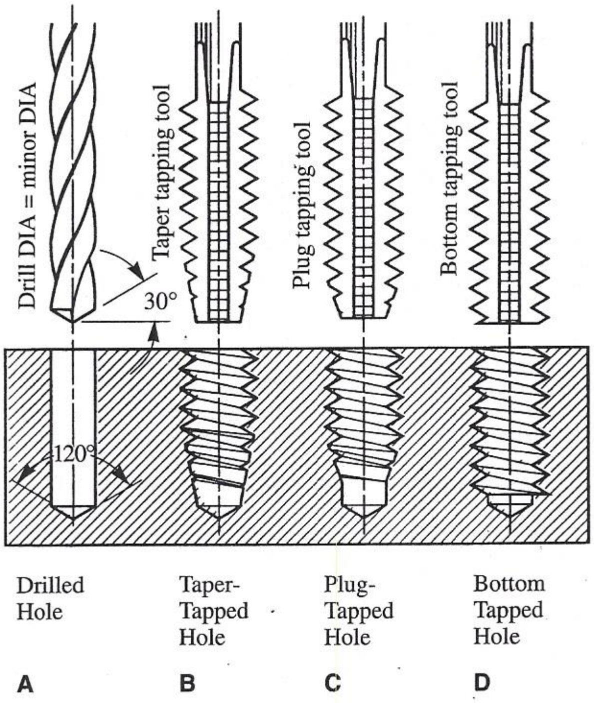


**Figure 3-19.** *Taps are tools for cutting threads in holes. For blind holes the taper tap should be used first, followed by the plug tap, and then the bottom tap.*

If bolt or screw threads are damaged, they can be chased with a threading die held in a die holder. Place the bolt head in a vise. Select the correct die according to the thread of the bolt. If the thread type is not known, determine it by measuring the major diameter of the thread, and counting the number of threads per lineal inch. If the bolt diameter is 3/8″ and there are 16 threads per inch, it is a 3/8-16 UNC thread. Select a corresponding die. Now, place the die in a die handle and secure it with the set screws. See **Figure 3-21.** There is a right side and a wrong side for starting the die. The correct side has beginning teeth tapered. This makes starting easier and the cutting edges of the teeth cut in the proper direction. Place some cutting oil on the die teeth and on the bolt threads. Place the die on the end of the bolt and begin turning it clockwise (right-handed threads) to cut and

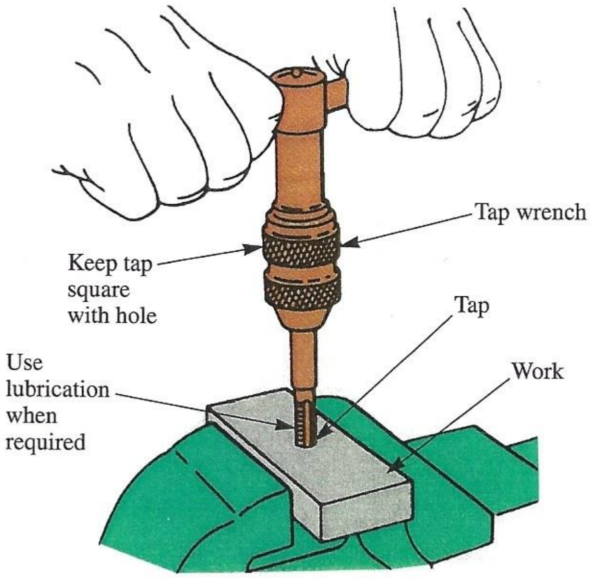


**Figure 3-20.** *Taps fit into a special tap wrench. Tap must be held straight with the hold as it is turned into the work. Turn wrench ahead 2/3 of one turn, back up 1/3 of one turn. Use a tapping fluid on the tap.*

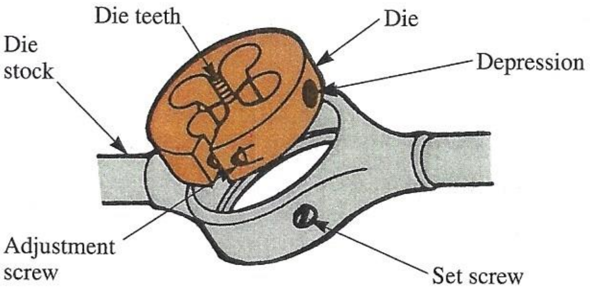


**Figure 3-21.** *Threading dies are used to cut external threads. The die is inserted in a wrench called a die-stock. The conical teeth of the die should be started on the rod or bolt.*

correct the threads. Now, reverse the die rotation until it can be removed from the bolt.

## *Tapping new threads*

The procedure of tapping new threads is similar to that of chasing threads. Prior to tapping, however, a new hole must be drilled to the proper diameter. The proper diameter is obtained for UNC and UNF threads from a tap drill chart. See **Figure 3-22.** If a tap drill chart is not available, the following formula can be used to obtain the decimal drill size to use.

For Unified thread form (UNC and UNF):

$$\text{Drill size} = \text{Basic major diameter} - \frac{(1.08253 \times \%)\text{size}}{\text{No. threads per inch}}$$

For practical purposes when hand tapping, between 65% and 75% thread depth is suitable. For example, to find the drill size for a 1/4-20 UNC threaded hole, multiply 1.08253 by .75 to get .8119. Now, divide .8119 by 20 to get .0416. Finally, subtract .0416 from .25(1/4) to get .2084. Choose the drill size that is closest to .2084, which would be a number 4 drill. Refer to the drill size chart in **Figure 3-22** to check this drill size. For tap drill sizes for metric threads refer to **Figure 3-23.**

### Rules for hand tapping

1. Use a good tapping fluid, except when tapping gray cast iron, which should be tapped dry.
2. For through holes, start and end with a taper tap.
3. For ***blind holes,*** start with a taper tap, followed with a ***plug tap,*** followed with a ***bottom tap.***
4. Be careful to start the tap straight in the hole.
5. The tap wrench should be turned clockwise two-thirds of a turn then reversed one-third of a turn to break and clear the chips. Continue this through, or to the bottom of the hole.
6. Never excessively force a tap to turn.

Taps are very hard and brittle, and can break when forced. Removing a broken tap can be difficult, or impossible. The smaller the tap, the easier it breaks.

## *Threading with a die*

Threading is cutting external threads on a rod, bolt, shaft, or pin. A cutting tool called a ***die*** is used in a die handle called a ***die-stock***. See **Figure 3-21.** The threading procedure is the same as for tapping. The diameter of the rod must be the same as the major diameter of the thread. Select the die. If the die is of the split type, it can be opened with the adjustment screw for the first cut and then adjusted down later to the desired fit in the threaded hole. Place the die in the die-stock so that the set screws align with the depressions along the edge of the die. Tighten the set screws. Start the die on the correct side and keep it as straight as possible with the rod. A good cutting fluid should be used on the die teeth.

## Decimal Equivalents and Tap Drill Sizes

| Fraction or Drill Size | | Decimal Equivalent | Tap Size | Fraction or Drill Size | | Decimal Equivalent | Tap Size |
|---|---|---|---|---|---|---|---|
| Number Size Drills | 80 | .0135 | | | 39 | .0995 | |
| | 79 | .0145 | | | 38 | .1015 | 5 — 40 |
| 1/64 | | .0156 | | | 37 | .1040 | 5 — 44 |
| | 78 | .0160 | | | 36 | .1065 | 6 — 32 |
| | 77 | .0180 | | 7/64 | | .1094 | |
| | 76 | .0200 | | | 35 | .1100 | |
| | 75 | .0210 | | | 34 | .1110 | |
| | 74 | .0225 | | | 33 | .1130 | 6 — 40 |
| | 73 | .0240 | | | 32 | .1160 | |
| | 72 | .0250 | | | 31 | .1200 | |
| | 71 | .0260 | | 1/8 | | .1250 | |
| | 70 | .0280 | | | 30 | .1285 | |
| | 69 | .0292 | | | 29 | .1360 | 8 — 32, 36 |
| | 68 | .0310 | | | 28 | .1405 | |
| 1/32 | | .0312 | | 9/64 | | .1406 | |
| | 67 | .0320 | | | 27 | .1440 | |
| | 66 | .0330 | | | 26 | .1470 | |
| | 65 | .0350 | | | 25 | .1495 | 10 — 24 |
| | 64 | .0360 | | | 24 | .1520 | |
| | 63 | .0370 | | | 23 | .1540 | |
| | 62 | .0380 | | 5/32 | | .1562 | |
| | 61 | .0390 | | | 22 | .1570 | |
| | 60 | .0400 | | | 21 | .1590 | 10 — 32 |
| | 59 | .0410 | | | 20 | .1610 | |
| | 58 | .0420 | | | 19 | .1660 | |
| | 57 | .0430 | | | 18 | .1695 | |
| | 56 | .0465 | | 11/64 | | .1719 | |
| 3/64 | | .0469 | 0 — 80 | | 17 | .1730 | |
| | 55 | .0520 | | | 16 | .1770 | 12 — 24 |
| | 54 | .0550 | | | 15 | .1800 | |
| | 53 | .0595 | 1 — 64, 72 | | 14 | .1820 | 12 — 28 |
| 1/16 | | .0625 | | | 13 | .1850 | |
| | 52 | .0635 | | 3/16 | | .1875 | |
| | 51 | .0670 | | | 12 | .1890 | |
| | 50 | .0700 | 2 — 56, 64 | | 11 | .1910 | |
| | 49 | .0730 | | | 10 | .1935 | |
| | 48 | .0760 | | | 9 | .1960 | |
| 5/64 | | .0781 | | | 8 | .1990 | |
| | 47 | .0785 | 3 — 48 | | 7 | .2010 | 1/4 — 20 |
| | 46 | .0810 | | 13/64 | | .2031 | |
| | 45 | .0820 | 3 — 56 | | 6 | .2040 | |
| | 44 | .0860 | | | 5 | .2055 | |
| | 43 | .0890 | 4 — 40 | | 4 | .2090 | |
| | 42 | .0935 | 4 — 48 | | 3 | .2130 | 1/4 — 28 |
| 3/32 | | .0938 | | 7/32 | | .2188 | |
| | 41 | .0960 | | | 2 | .2210 | |
| | 40 | .0980 | | | 1 | .2280 | |

(Continued)

**Figure 3-22.** *The correct hole size to drill for a given thread series and diameter can be obtained from a tap drill chart like this.*

## Decimal Equivalents and Tap Drill Sizes

| *Fraction or Drill Size* | *Decimal Equivalent* | *Tap Size* |
|---|---|---|
| Letter Size Drills A | .2340 | |
| 15/64 | .2344 | |
| B | .2380 | |
| C | .2430 | |
| D | .2460 | |
| 1/4 — E | .2500 | |
| F | .2570 | 5/16 — 18 |
| G | .2610 | |
| 17/64 | .2656 | |
| H | .2660 | |
| I | .2720 | 5/16 — 24 |
| J | .2770 | |
| K | .2810 | |
| 9/32 | .2812 | |
| L | .2900 | |
| M | .2950 | |
| 19/64 | .2969 | |
| N | .3020 | |
| 5/16 | .3125 | 3/8 — 16 |
| O | .3160 | |
| P | .3230 | |
| 21/64 | .3281 | |
| Q | .3320 | 3/8 — 24 |
| R | .3390 | |
| 11/32 | .3438 | |
| S | .3480 | |
| T | .3580 | |
| 23/64 | .3594 | |
| U | .3680 | 7/16 — 14 |
| 3/8 | .3750 | |
| V | .3770 | |
| W | .3860 | |
| 25/64 | .3906 | 7/16 — 20 |
| X | .3970 | |
| Y | .4040 | |
| 13/32 | .4062 | |
| Z | .4130 | |
| 27/64 | .4219 | 1/2 — 13 |
| 7/16 | .4375 | |
| 29/64 | .4531 | 1/2 — 20 |
| 15/32 | .4688 | |
| 31/64 | .4844 | 9/16 — 12 |
| 1/2 | .5000 | |
| 33/64 | .5156 | 9/16 — 18 |
| 17/32 | .5312 | 5/8 — 11 |
| 35/64 | .5469 | |
| 9/16 | .5625 | |
| 37/64 | .5781 | 5/8 — 18 |
| 19/32 | .5938 | |
| 39/64 | .6094 | |
| 5/8 | .6250 | |
| 41/64 | .6406 | |
| 21/32 | .6562 | 3/4 — 10 |
| 43/64 | .6719 | |
| 11/16 | .6875 | 3/4 — 16 |
| 45/64 | .7031 | |
| 23/32 | .7188 | |
| 47/64 | .7344 | |
| 3/4 | .7500 | |
| 49/64 | .7656 | 7/8 — 9 |
| 25/32 | .7812 | |
| 51/64 | .7969 | |
| 13/16 | .8125 | 7/8 — 14 |
| 53/64 | .8281 | |
| 27/32 | .8438 | |
| 55/64 | .8594 | |
| 7/8 | .8750 | 1 — 8 |
| 57/64 | .8906 | |
| 29/32 | .9062 | |
| 59/64 | .9129 | 1 — 12 |
| 15/16 | .9375 | |
| 61/64 | .9531 | |
| 31/32 | .9688 | |
| 63/64 | .9844 | 1 1/8 — 7 |
| 1 | 1.0000 | |
| 1 3/64 | 1.0469 | 1 1/8 — 12 |
| 1 7/64 | 1.1094 | 1 1/4 — 7 |
| 1 1/8 | 1.1250 | |
| 1 11/64 | 1.1719 | 1 1/4 — 12 |
| 1 7/32 | 1.2188 | 1 3/8 — 6 |
| 1 1/4 | 1.2500 | |
| 1 19/64 | 1.2969 | 1 3/8 — 12 |
| 1 11/32 | 1.3438 | 1 1/2 — 6 |
| 1 3/8 | 1.3750 | |
| 1 27/64 | 1.4219 | 1 1/2 — 12 |
| 1 1/2 | 1.5000 | |

### Pipe Thread Sizes (NPSC)

| Thread | Drill | Thread | Drill |
|---|---|---|---|
| 1/8 — 27 | 11/32 | 1 1/2 — 11 1/2 | 1 3/4 |
| 1/4 — 18 | 7/16 | 2 — 11 1/2 | 2 7/32 |
| 3/8 — 18 | 37/64 | 2 1/2 — 8 | 2 21/32 |
| 1/2 — 14 | 23/32 | 3 — 8 | 3 1/4 |
| 3/4 — 14 | 59/64 | 3 1/2 — 8 | 3 3/4 |
| 1 — 11 1/2 | 1 5/32 | 4 — 8 | 4 1/4 |
| 1 1/4 — 11 1/2 | 1 1/2 | | |

**Figure 3-22.** *Continued*

**Metric Tap Drill Size**

| | *Recommended Metric Drill* | | | | *Closest Recommended Inch Drill* | | | |
|---|---|---|---|---|---|---|---|---|
| *Metric Tap Size* | *Drill Size (mm)* | *Inch Equivalent* | *Probable Hole Size (in.)* | *Probable Percent of Thread* | *Drill Size* | *Inch Equivalent* | *Probable Hole Size (in.)* | *Probable Percent of Thread* |
| M1.6 × .35 | 1.25 | .0492 | .0507 | 69 | — | — | — | — |
| M1.8 × .35 | 1.45 | .0571 | .0586 | 69 | — | — | — | — |
| M2 × .4 | 1.60 | .0630 | .0647 | 69 | #52 | .0635 | .0652 | 66 |
| M2.2 × .45 | 1.75 | .0689 | .0706 | 70 | — | — | — | — |
| M2.5 × .45 | 2.05 | .0807 | .0826 | 69 | #46 | .0810 | .0829 | 67 |
| *M3 × .5 | 2.50 | .0984 | .1007 | 68 | #40 | .0980 | .1003 | 70 |
| M3.5 × .6 | 2.90 | .1142 | .1168 | 68 | #33 | .1130 | .1156 | 72 |
| *M4 × .7 | 3.30 | .1299 | .1328 | 69 | #30 | .1285 | .1314 | 73 |
| M4.5 × .75 | 3.70 | .1457 | .1489 | 74 | #26 | .1470 | .1502 | 70 |
| *M5 × .8 | 4.20 | .1654 | .1686 | 69 | #19 | .1660 | .1692 | 68 |
| *M6 × 1 | 5.00 | .1968 | .2006 | 70 | #9 | .1960 | .1998 | 71 |
| M7 × 1 | 6.00 | .2362 | .2400 | 70 | $\frac{15}{64}$ | .2344 | .2382 | 73 |
| *M8 × 1.25 | 6.70 | .2638 | .2679 | 74 | $\frac{17}{64}$ | .2656 | .2697 | 71 |
| M8 × 1 | 7.00 | .2756 | .2797 | 69 | J | .2770 | .2811 | 66 |
| *M10 × 1.5 | 8.50 | .3346 | .3390 | 71 | Q | .3320 | .3364 | 75 |
| M10 × 1.25 | 8.70 | .3425 | .3471 | 73 | $\frac{11}{32}$ | .3438 | .3483 | 71 |
| *M12 × 1.75 | 10.20 | .4016 | .4063 | 74 | Y | .4040 | .4087 | 71 |
| M12 × 1.25 | 10.80 | .4252 | .4299 | 67 | $\frac{27}{64}$ | .4219 | .4266 | 72 |
| M14 × 2 | 12.00 | .4724 | .4772 | 72 | $\frac{15}{32}$ | .4688 | .4736 | 76 |
| M14 × 1.5 | 12.50 | .4921 | .4969 | 71 | — | — | — | — |
| *M16 × 2 | 14.00 | .5512 | .5561 | 72 | $\frac{35}{64}$ | .5469 | .5518 | 76 |
| M16 × 1.5 | 14.50 | .5709 | .5758 | 71 | — | — | — | — |
| M18 × 2.5 | 15.50 | .6102 | .6152 | 73 | $\frac{39}{64}$ | .6094 | .6144 | 74 |
| M18 × 1.5 | 16.50 | .6496 | .6546 | 70 | — | — | — | — |
| *M20 × 2.5 | 17.50 | .6890 | .6942 | 73 | $\frac{11}{16}$ | .6875 | .6925 | 74 |
| M20 × 1.5 | 18.50 | .7283 | .7335 | 70 | — | — | — | — |
| M22 × 2.5 | 19.50 | .7677 | .7729 | 73 | $\frac{49}{64}$ | .7656 | .7708 | 75 |
| M22 × 1.5 | 20.50 | .8071 | .8123 | 70 | — | — | — | — |
| *M24 × 3 | 21.00 | .8268 | .8327 | 73 | $\frac{53}{64}$ | .8281 | .8340 | 72 |
| M24 × 2 | 22.00 | .8661 | .8720 | 71 | — | — | — | — |
| M27 × 3 | 24.00 | .9449 | .9511 | 73 | $\frac{15}{16}$ | .9375 | .9435 | 78 |
| M27 × 2 | 25.00 | .9843 | .9913 | 70 | $\frac{63}{64}$ | .9844 | .9914 | 70 |
| *M30 × 3.5 | 26.50 | 1.0433 | | | | | | |
| M30 × 2 | 28.00 | 1.1024 | | | | | | |
| M33 × 3.5 | 29.50 | 1.1614 | | | | | | |
| M33 × 2 | 31.00 | 1.2205 | | | | | | |
| M36 × 4 | 32.00 | 1.2598 | | | | | | |
| M36 × 3 | 33.00 | 1.2992 | | | | | | |
| M39 × 4 | 35.00 | 1.3780 | | | | | | |

Reaming Recommended to the Drill Size Shown

**Figure 3-23.** *Metric Tap Drill Chart.*

## Washers

Flat washers are used to provide a wider bearing surface for a bolt or screw head and/or nut. When tightening a bolt or screw against a softer material such as wood, plastic, and soft metals (like aluminum, copper, or brass), the head may gradually become imbedded in the surface. This may cause the fastener to become loose during use. A ***flat washer*** tends to prevent imbedding and provides a harder surface for the bolt or screw head to pull against. See **Figure 3-24.**

***Lock washers*** prevent loosening of bolts and screws. There are many kinds to choose from. The most common for locking nuts is the ***kantlink*** washer. It is made of spring steel and has beveled ends. Due to the slight helix of the washer, it tends to cut into the mating surfaces of the nut and

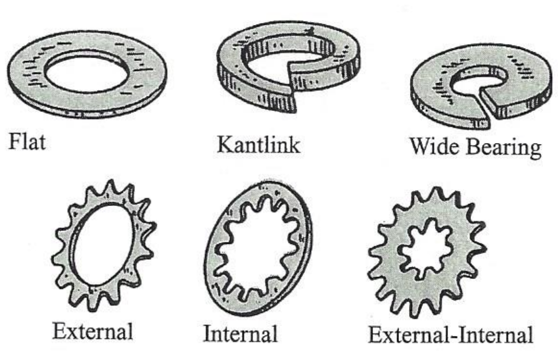


**Figure 3-24.** *Common washers common of several sizes and shapes.*

component. When the nut is tightened the washer is compressed flat. The tendency of the nut to reverse rotation causes the toothed ends of the washer to dig into the surfaces. This prevents further loosening of the fastener.

The ***wide bearing*** lock washer combines the characteristics of a flat washer and a kantlink lock washer. It provides the hard surface for the bolt or screw head to pull against that is characteristic of a flat washer. It also provides toothed ends that are characteristic of the kantlink washer.

Multiple ***toothed washers*** are stamped from sheet metal and are either *internal*, *external*, or *external-internal* toothed. This type of washer is used under the heads of screws to prevent their backing out. The teeth are twisted to resist rotation in the direction that would cause loosening of the screw.

## Pins

***Pins*** are used to either retain parts in a fixed position or to preserve alignment of parts. **Figure 3-25** illustrates several types of pins that may be found on some gasoline engines or their parts.

### Cotter pins

***Cotter pins*** are sized by a nominal dimension, such as 3/32″. The hole size for a cotter pin should be slightly larger than the nominal size of the pin. Cotter pins are used to lock castle nuts and secure clevis pins. Cotter pins should be installed properly as shown in **Figure 3-14.** Cotter pins may be made of copper, brass, aluminum, or stainless steel. They can be cut to length with side cutting pliers. They can be bent with combination slip joint, or needle nose pliers. They can be tapped lightly with a soft hammer to form them.

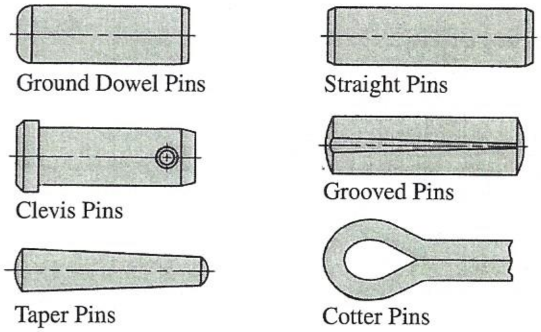


**Figure 3-25.** *Pins are used to hold parts together in assembly.*

> As with old fasteners, tools, part, or equipment, old cotter pins should be replaced with new ones.

### Clevis pins

***Clevis pins*** function as an axle so a part can swivel on it. It requires a flat washer and cotter pin to prevent the part from sliding off the pin.

### Dowel pins

***Dowel pins*** are used for alignment and usually fit very snugly. They are heat treated and hardened. The dowel pin is pressed into a hole with an interference fit. This means the mating part has a matching hole that fits closely to the pin, but allows the part to be assembled or disassembled easily.

### Straight pins

***Straight pins*** are also used for alignment. They fit closely, but are not usually an interference fit.

### Grooved pins

***Grooved pins*** are driven into an interference hole. The groove cuts into the wall of the hole and secures the pin. There are seven types of grooved pins. Each type is shaped differently, and each has a different size and shape of groove. See **Figure 3-26.**

### Taper pins

***Taper pins*** have a uniform taper of .250 per foot over the length of the pin. Each end is rounded slightly. Taper pins are generally used to fasten pulleys and gears to shafts to prevent rotation on the shaft. Taper pins fit into tapered holes that match the two mating parts. The taper pin is held in the hole by tapping it into the tapered holes, thus wedging it tightly in place. A taper pin should be of such size and length, that when tapped tightly into the mating parts it does not extend beyond the holes. The tapered pin can be removed from the small end by driving it out with a pin pinch and hammer. Pins are designated by pin size number and standard lengths.

## Retaining Rings

***Retaining rings*** are circular spring steel that fit externally or internally into a groove of a part. For example, they may be placed in a groove that is machined into the surface of a shaft, or internally in a groove in a cylindrical hole. There are several types of retaining rings. See **Figure 3-27.**

The purpose of an external retaining ring is to prevent movement of a shaft beyond a point through a hole such as in a bearing. At the same time the retaining ring does not prevent the shaft from rotating. See **Figure 3-28.** Internal retaining rings prevent a shaft from traveling beyond the retaining ring located in its groove in the cylindrical part. Most retaining rings must be installed and removed with a retaining ring tool. The tool has nibs that fit into the small holes at the ends of the rings. When the handles of the plier-like tool are squeezed, internal rings are compressed inward and smaller so they can be installed in the cylinder and groove. External rings are forced open so they can be slid over the shaft and into the groove. The reverse action is used for removal. The springs are very strong and require extreme care when installing and removing.

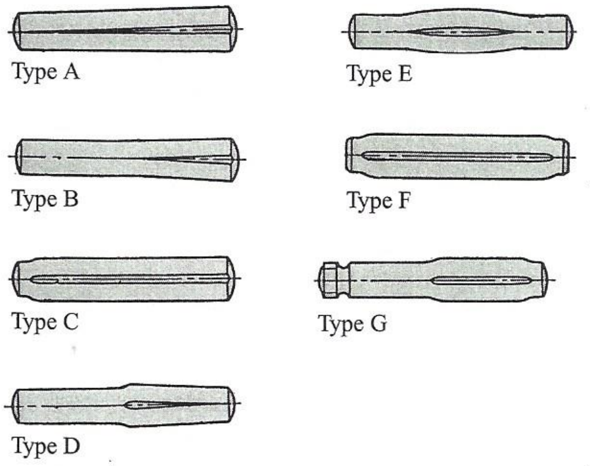


**Figure 3-26.** *Groove pins come in several types.*

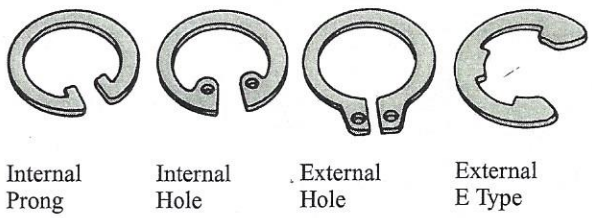


**Figure 3-27.** *Retaining rings may be internal or external.*

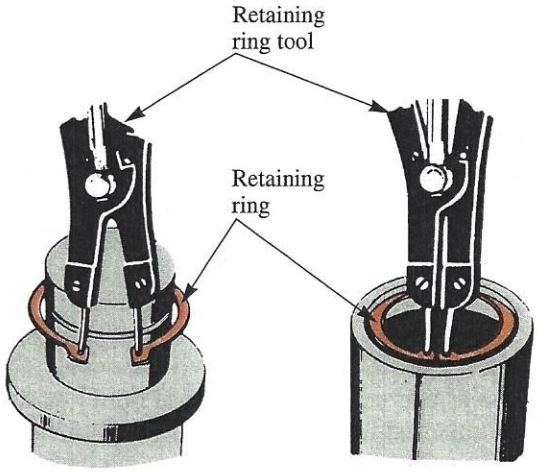


**Figure 3-28.** *A special plier-like tool is required to install some retaining rings. Nibs are inserted in holes in ring to expand or close ring.*

⚠ Safety glasses with side shields must always be worn when installing or removing retaining rings. They can easily slip off the nibs of the tool, and because they are made of strong spring steel they can fly with considerable velocity.

## Keys

***Keys*** are used almost exclusively on shafts that have a component which fits and rotates with the shaft. The recess in which the key rests in the shaft is called the ***keyseat***. The groove in the pulley, gear, or collar is the ***keyway***. See **Figure 13-29.**

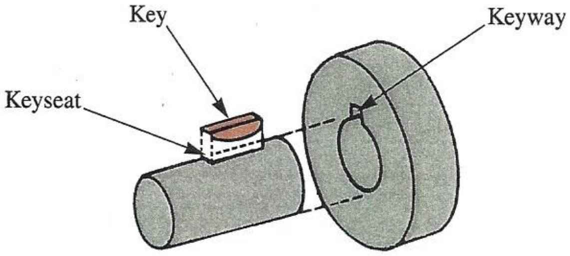


**Figure 3-29.** *Key rests in keyseat of shaft. Keyway is located in surrounding part.*

An example is the flywheel on the crankshaft of a small gas engine. The key must fit the keyseat and keyway closely to prevent motion between them. Engine flywheel keys keep the engine timing correct. Several key types are used as shown in **Figure 3-30.**

## Adhesives and Sealants

Many types of adhesives and sealants can be encountered when working with engines. Both adhesives and sealants are either a liquid or semiliquid material. They can be sprayed, brushed, or spread on. There are various types that have varying properties. Some of these adhesives and sealants setup hard and others remain pliable. The sections to follow details some of these adhesives and sealants.

### Thread adhesives

***Thread adhesives*** can be applied to the threads of nuts, bolts, or screws to prevent them from loosening during service. Adhesive strengths vary from light (removable) to high strength (that might require applied heat to remove). Only a drop of adhesive on the thread prior to fastening is needed. See **Figure 3-31.**

The adhesive cures once the threads are mated. This locks the mating threads together. Complete cure time may vary from 30 minutes to 24 hours. There are other uses for these adhesives such as fastening bearings, bushings, gears, and sleeves on shafts.

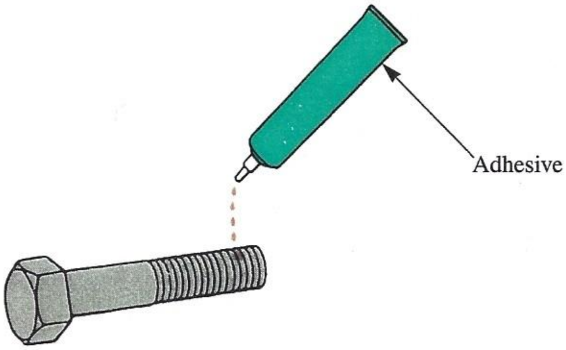


**Figure 3-31.** *A drop of thread adhesive can be placed on the thread to lock a screw or nut.*

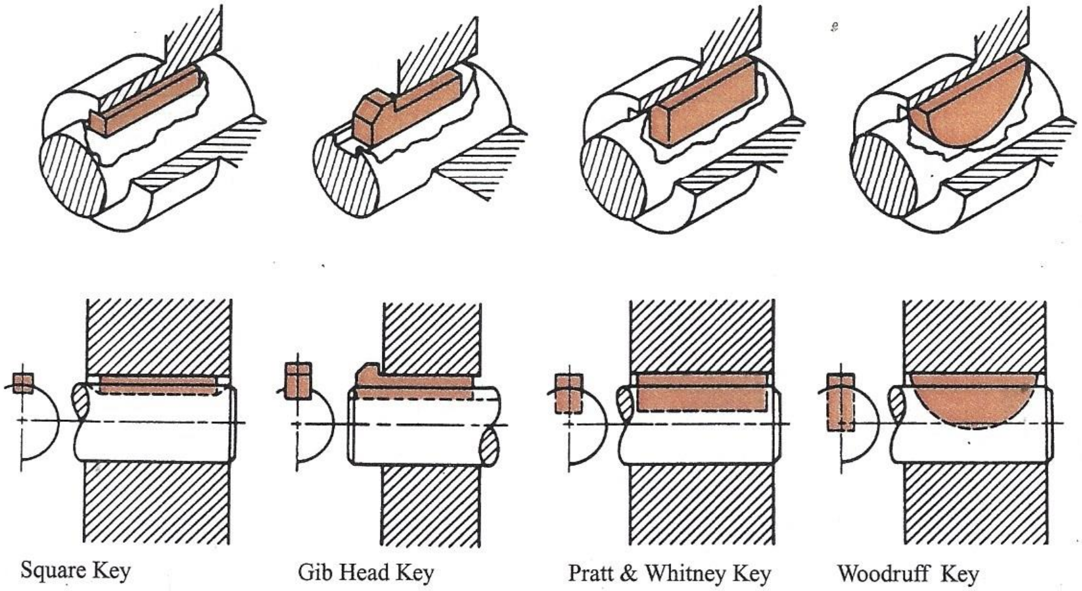


**Figure 3-30.** *Keys used to connect shaft to pulley, gear, or wheel.*

Always read health warning labels on adhesive containers. Adhesives may contain chemicals that can cause injury to eyes, lungs, and other parts of the body. Always follow the manufacturer's recommended procedures.

## Sealants

Most sealants are resistant to oil, water, gas, grease, and salt solutions. Resistance to hot and cold conditions vary. Most sealants can be used for all applications, except for use on the exhaust system. Special high-temperature sealants are used for exhaust systems.

***Form-in-place sealants*** can be used in place of conventional gaskets (gaskets are covered later in this chapter). This type of sealant can be used when the exact replacement gasket is not available. ***Room temperature vulcanizing sealant (RTV)*** is a form-in-place sealant that is also referred to as silicon sealant.

***Anaerobic sealants*** are similar to RTV, but they can cure in the absence of air. This type of sealant can be used as a thread locking material or between two machined surfaces.

Become familiar with the sealants you use. Know the properties of those sealants and their recommended uses.

## Antiseize compounds

***Antiseize compounds*** are applied to threaded fasteners and metal components that are exposed to constant heat. The compound is a lubricant that prevents the metal material from being *cold welded* together. If a threaded fastener and its connecting metal component are cold welded, then removal of the fastener will be impossible. The antiseize compounds should be applied to the threads or the connecting metal. These compounds can be used for the connection of the exhaust system.

Remember, antiseize compounds are lubricants and not sealants.

## Gaskets

***Gaskets*** are used between engine parts to seal and prevent leakage of engine oil, coolant, compression, and vacuum. Gaskets are soft, pliable materials such as fiber, rubber, neoprene (synthetic rubber), cork, treated paper, thin steel, or laminated materials. Gaskets are manufactured to the shape of the surfaces between the mating parts with appropriate shapes and locations of holes. See **Figure 3-32.** The particular gasket material used depends upon the functions and conditions of the parts to be joined. This is specified by the engine manufacturer. Some replacement gaskets can be made by hand.

If gaskets are made by hand, make sure they are made of the same material and same thickness as the originals. Incorrect substitution will result in failure of the gasket. This may cause damage to the part and/or engine.

When a gasket is placed between parts and the bolts or screws are tightened, the gasket material is compressed and deformed. Any small dents, gaps, scratches, or other imperfections in the part surfaces are filled by the gasket. This produces a leakproof seal between the parts.

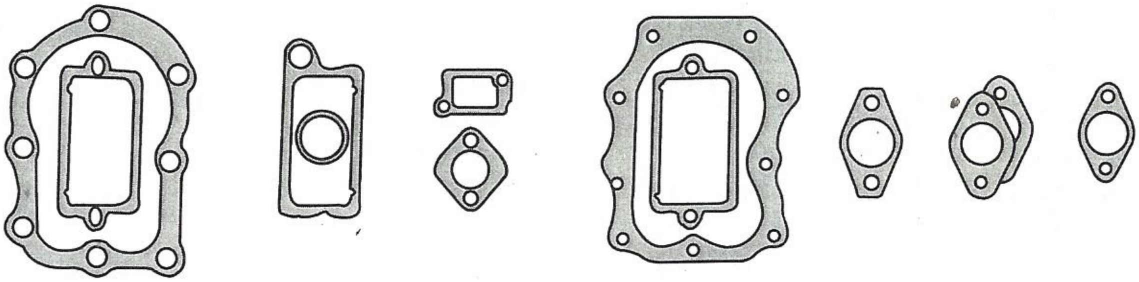


**Figure 3-32.** *Engine gaskets vary in size, shape, and material. Some gaskets are delicate and should be handled carefully.*

## Gasket rules

The following are specific gaskets rules. These rules should always be followed when working with gaskets.

1. ***Inspect for leaks before disassembling engine.*** Determine if *only* the gasket is leaking or whether the part is cracked or seriously deformed.
2. ***Avoid damaging the parts during disassembly.*** Care must be taken while removing parts. Do not score, dent, or deform the mating surfaces.
3. ***Remove old gasket carefully.*** Remove all of the old gasket material from the part surfaces by scraping or wire brushing. Soft metals such as aluminum and brass are damaged easily and require extra care. Use a dull scraper and wire brush lightly.
4. ***Wash and dry the parts thoroughly.*** Wash the parts in solvent after the gasket has been removed. Blow-dry with compressed air and wipe dry with a clean cloth.
5. ***Check new gasket fit.*** Compare the new gasket shape to the part surface shape. Lay the new gasket in place and inspect its fit. All holes and sealing surfaces must match precisely. Read any manufacturer's notices about the gasket. It may look symmetrical in shape, but really is not. It is common to install the gasket upside down or in reverse direction. This may cover or partly obscure a small hole in the part.
6. ***Use gasket sealant as directed only.*** Some gaskets may need a ***gasket sealant,*** and others may not. Check the service manual for details about the recommended type(s) to use. Use sealant sparingly. Using large amounts of sealant may cause clogging of passages in the parts.
7. ***Start all fasteners by hand before tightening.*** After the gasket and parts are in place, start the bolts by hand. This assures proper alignment and threading of the bolts. Check for proper bolt lengths at this time.
8. ***Tighten the bolts in small steps.*** Tighten each bolt a little at a time. Tighten the first one to about half its specified torque. Then tighten the others the same amount. Repeat to about three-fourths torque specification.
9. ***Use a crisscross tightening pattern.*** Final torquing should follow either a basic crisscross pattern or the factory recommended pattern. This procedure produces even gasket compression and sealing, and prevents possible warping of parts. See **Figure 3-33.**

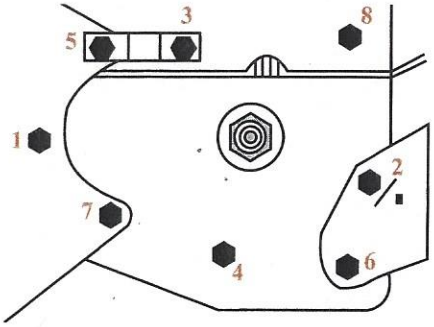


**Figure 3-33.** *Bolts on an engine head should be tightened in a crisscross manner.*

10. ***Do not overtighten fasteners.*** Apply only the specified torque. It is easy to distort sheet metal or thin parts by overtightening. Instead of sealing, overtightening can create leakage between the fasteners.

## Summary

Many varied fasteners are used in the assembly of small gasoline engines and the implements they drive. Most, but not all, are threaded fasteners. Fasteners are exposed to conditions such as heating and cooling, cyclic loading, tensile and shear loads, corrosion, and vibration. Helical portions of screws and bolts are called threads. When disassembling an engine all parts, fasteners, and washers should be noted so they can be replaced in proper locations. Damaged fasteners should be replaced with new ones. Lightly rusted fasteners may be cleaned and examined for reuse. All threaded fasteners should be lubricated before installing.

Screws hold parts together by passing through one part and threading into another. Set screws are heat treated, hardened-alloy steel used to secure pulleys, gears, and shafts. They have a variety of heads and points. Self-tapping screws are hardened steel and cut their own threads in a predrilled hole of proper size for the screw. The process of cutting threads is called tapping.

Bolts are threaded fasteners that hold parts together by squeezing them between the bolt head on one end and a nut on the other. A lock washer is often placed between the face of the nut and the part surface to prevent loosening caused by vibration. Nuts vary in shape and size depending upon their intended function. Most common are plain hexagon nuts. Other types are wing nuts, castle nuts, acorn nuts, jam nuts, and various self-locking nuts.

Bolt terminology includes major diameter, head size, length, and thread pitch. Bolt grades are related to the minimum tensile strength required of the bolt. Bolt heads are marked with symbols to identify grade. Thread types of significance for small gas engines are Unified National Coarse (UNC), Unified National Fine (UNF), and metric (M). Threads of a bolt or screw must be the same as the mating thread in the hole or nut. Threads are identified by a thread designation such as 1/2–13 UNC–2A for American threads and M10 × 1.5 × 25 for metric threads. Tightening bolts, nuts, and screws on engines should be done with a torque wrench to a specified tightness obtained from a torque chart. Threads can be repaired by chasing them with a threading tap for holes, or a threading die for bolts and screws. When tapping new threads, the proper size hole must first be drilled, as determined from a tap drill chart or by formula. Proper tapping and threading procedures must be applied to avoid breaking a tap in the hole or tearing threads.

Flat washers are used to provide a bearing surface for bolt and screw heads and nuts. Various types of lock washers prevent loosening of bolts and screws.

Cotter pins are used to secure castle nuts and clevis pins. Dowel pins and straight pins are used for alignment of parts and should fit quite snugly. Grooved pins are driven into interference fit holes. The grooves are cut into the walls of the hole to secure the pin. Taper pins have a taper of .250 inch per lineal foot. They are used to fasten pulleys and gears to shafts to prevent slipping around the shaft. Retaining rings are circular spring steel that fit into a groove around a shaft or in a hole. They require a special plier-like tool to install and remove.

Keys are used on shafts that have a gear, pulley, or sleeve that fits and rotates with the shaft. The key rests in a keyseat and keyway.

Many kinds of adhesives and sealants are used on engines and implements. Thread adhesives are used to prevent threaded fasteners from loosening caused by vibration. Some liquid sealants are used to prevent leakage between the parts. It is important to use the correct sealant as specified by the manufacturer. Antiseize compounds are lubricants that prevent parts from locking together.

Gaskets seal between engine parts to prevent leakage of engine oil, coolant, compression, and vacuum. Gaskets are made of soft, pliable materials die cut to fit the shapes of surfaces they seal. The correct material, shape, and thickness is important when replacing a gasket. Following the rules for good procedures when installing gaskets will avoid gasket failure.

## Know These Terms

helix
thread
screws
countersunk
set screws
hexagon socket
self-tapping screws
tapping
threading
bolts
square nuts
jam nuts
hexagon nut
castle nut
axial clearance
acorn nuts
wing nuts
bolt grades
tensile strength
elastic limit
Unified National Coarse (UNC)
Unified National Fine (UNF)
major diameter
Metric (M)
thread fit
stud bolts
threading tap
chasing
through hole
taper tap
blind holes
plug tap
bottom tap
die
die stock
lock washers
kantlink
toothed washer
pins
cotter pins
clevis pins
dowel pins
straight pins
grooved pins
interference hole
taper pins
retaining rings
keys
keyseat
keyway
thread adhesives
form-in-place sealants
room temperature vulcanizing sealant (RTV)
anaerobic sealant
antiseize compounds
gaskets
neoprene
gasket sealant

## Chapter 3 Review Questions

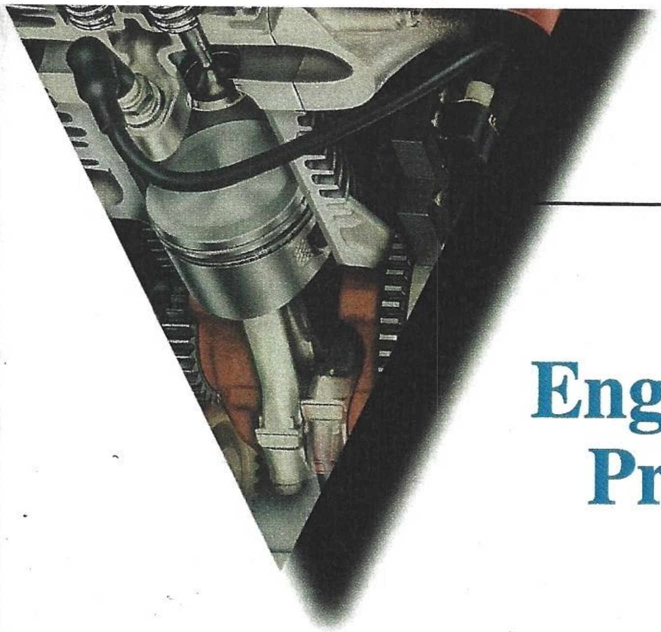
***Answer the following questions on a separate sheet of paper.***

1. The helical portion of a screw or bolt, or the helix in a hole that it fastens into, is called a(n) __________.

2. A type of hardened screw that makes its own threads, usually found in sheet metal, is a(n) __________ screw.
3. The heads found on screws are very different than those found on bolts. True or False?
4. Flat head screws must be set into __________ holes.
5. The most common angle for flat head screws is __________°.
6. Name the four common head types for set screws.
7. Name the six set screw points.
8. The unthreaded part of a bolt or screw is called the __________.
9. The threaded area of a bolt or screw is called the __________.
10. The term bolt implies the use of a(n) __________.
11. What does a palnut do?
12. Jam nuts are usually used with __________ __________ nuts.
13. Answer the following about the thread notation given below:
    **3/8-16 UNC 1A**
    a. The major diameter of the thread is __________″.
    b. How many threads per lineal inch are there?
    c. Is the thread coarse or fine?
    d. Is the thread internal or external?
    e. Is the thread a loose, average, or close fit?
14. The proper thread notation for a 14 millimeter thread with a 1.5 millimeter pitch on a screw that is 40 millimeters long is __________.
15. A(n) __________ drill is the proper tap drill for a 1/4-28 UNF screw.
16. For cutting threads in a *through-hole* the proper tap to use would be a(n) _________ tap.
17. The cutting tool used to cut external threads is called a threading __________.
18. To provide a wider bearing surface for a bolt head or nut, a(n) __________ or __________ washer should be used.
19. Toothed washers are either internal or external. True or False?
20. What fasteners are used to lock castle nuts?
21. Retaining rings are made of __________ steel.
22. The four styles of keys shown in this chapter are the _________, _________, _________, and __________.
23. __________ __________ are liquids or semi-liquids that can be applied to the threads of nuts, bolts, or screws to prevent them from loosening during service.
24. __________ are used between engine parts to seal and prevent leakage of engine oil, coolant, compression, and vacuum.
25. When tightening bolts on an engine head use a(n) __________ pattern unless a different pattern is specified by the manufacturer.

## Suggested Activities

1. Make a collection of fasteners for a display board. Categorize and label each.
2. Explore the shop and identify as many different kinds of screws, bolts, nuts, and washers as you can. List them and the function of each kind.
3. Identify UNC and UNF taps and dies.
4. Identify the correct side to start a threading die.
5. Identify taper, plug, and bottom taps.
6. Chase threads on a damaged bolt. Chase threads on a nut.
7. Select the proper tap drill for a screw and drill a blind hole about 3/4″ deep in a piece of mild steel. Tap threads to the bottom of the hole using the proper procedure and sequence of taps. If you have never tapped threads before, to avoid breakage, select a screw size 3/8″ or more in diameter.
8. Make a display of keys and pins.
9. Display proper and improper installations of cotter pins.
10. Demonstrate proper installation of a gasket.
11. Demonstrate the proper technique for tightening engine head bolts. Demonstrate the proper way to torque engine head bolts.



## CHAPTER 4

# Engine Construction and Principles of Operation

After studying this chapter, you will be able to:

- Explain simple engine operation.
- List the qualities of gasoline that make it an efficient fuel for small engines.
- Explain why gasoline is atomized in the small engine.
- Identify the basic components of a small engine and describe the function of each part.

## Gasoline Engines

A gasoline-fueled engine is a mechanism designed to transform the chemical energy of burning fuel into mechanical energy. In operation, it controls and applies this energy to mow lawns, cut trees, propel tractors, and perform many other laborsaving jobs.

A gasoline engine is an internal combustion engine. Gasoline is combined with air and burned inside the engine. In its simplest form, an engine consists of a ported cylinder, piston, connecting rod, and crankshaft. See **Figure 4-1.**

The piston is a *close fit* inside the cylinder, yet it is free to slide on the lubricated walls. One end of the connecting rod is attached to the piston; the other end is fastened to an offset crankpin, or journal, of the crankshaft. As the piston moves up and down, the connecting rod forces the journal to follow a circular path, rotating the crankshaft.

## Simple Engine in Operation

When the engine is cranked, gasoline is atomized (reduced to minute particles) and mixed with air. This mixture is forced through an intake port and into the cylinder, where it is compressed by the piston on the upstroke and ignited by an electrical spark.

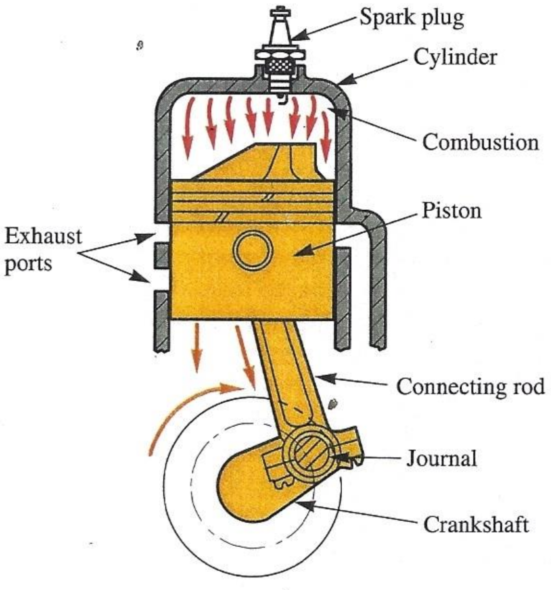


**Figure 4-1.** *Combustion forces the piston down to rotate crankshaft.*

Burning rapidly, the heated gases trapped within the cylinder (combustion chamber) expand and apply pressure to the walls of the cylinder and to the top of the piston. This pressure drives the piston downward on the power stroke, causing the crankshaft to turn. See **Figure 4-1.**

As the piston and connecting rod push the crankshaft journal to the bottom of the stroke, the pressure of the burned gases is released through an exhaust port. Meanwhile, a fresh air-fuel charge enters the cylinder and the momentum of the power stroke turns the crankshaft journal through bottom dead center (BDC) and into the upstroke on another power cycle.

## Gasoline

***Gasoline*** is a hydrocarbon fuel (mixture of hydrogen and carbon), refined from petroleum. ***Petroleum*** is a dark, thick liquid that is extracted from the earth by oil wells. Luckily, petroleum is the second most plentiful liquid in the world; only water is available in greater quantity. Gasoline, however, cannot be recycled as water can. Therefore, it is imperative that we conserve gasoline and use it wisely.

Gasoline contains a great amount of energy. For engine use, it should:

- 1 Ignite readily, burn cleanly, and resist detonation (violent explosion).
- 2 Vaporize easily, without being subject to vapor lock (vaporizing in fuel lines, impeding flow of liquid fuel to carburetor).
- 3 Be free of dirt, water, and abrasives.

Gasoline is assigned an ***octane number*** that corresponds to its ability to resist detonation. Premium grade gasoline burns slower than regular gasoline. It has a high octane number and is used in engines with high compression. Regular grade gasoline has a lower octane number and burns relatively fast. Generally, regular gasoline is used in small, low compression, one-cylinder and two-cylinder, gasoline engines.

Gasoline was once available in both leaded and unleaded varieties. The use of lead compounds was the most economical way to increase gasoline's octane number. For many years, most gasolines contained *tetraethyl lead.*

Since the mid 1970s unleaded gasoline has replaced leaded gasoline. Instead of lead compounds, *oxygenates (alcohols and ethers)* are commonly added to these fuels to increase octane levels. The main reason that unleaded gas was introduced was to provide fuel for automobiles equipped with catalytic converters. These vehicles will not operate properly on leaded fuel.

Modern unleaded gasoline is a complex substance. Ongoing research is necessary to seek ways to produce fuels that offer efficient engine performance and meet air pollution standards.

In the 1970s, a 10% ethanol blend of gasoline, known as gasohol, was introduced. Today, this product is often sold as *super unleaded* or *premium unleaded* gasoline, depending on the octane level.

The main drawback to these gasoline blends is their ability to absorb moisture, which can pass through the fuel filter and into the combustion chamber. These fuels should never be stored in high humidity areas or used in engines that set idle for long periods of time. Gasoline containing alcohol can also corrode fuel tank linings, shrink carburetor floats and seals, increase carbon deposits, and pit metal parts. For maximum performance and engine life, only use the type of gasoline recommended by the engine manufacturer. See *Appendix* for gasoline recommendations.

### Gasoline must burn quickly

Gasoline placed in a container and ignited will produce a hot flame, yet it will not burn fast enough to produce the rapid release of heat necessary to run an engine. Even though a considerable quantity of fuel may be involved, a large flame will not necessarily result. See **Figure 4-2.**

Under no circumstances should experiments illustrated in this chapter be performed. Gasoline can be a very dangerous fuel and must be handled with caution. Illustrations and examples discussed here are meant to demonstrate how gasoline is prepared and used in an engine.

In **Figure 4-2,** the surface area of the wick in the lighter is small. Vapor from the surface of the liquid, combined with oxygen, is what burns readily. If the surface of the liquid is small, relatively little vapor will be given off to provide combustion. Since the liquid must change to vapor before it is burned, it would take considerable time to use up the fuel at this rate.

By placing the same amount of fuel in a shallow, wide container, more surface area will contact air and the fuel will burn rapidly. See **Figure 4-3.**

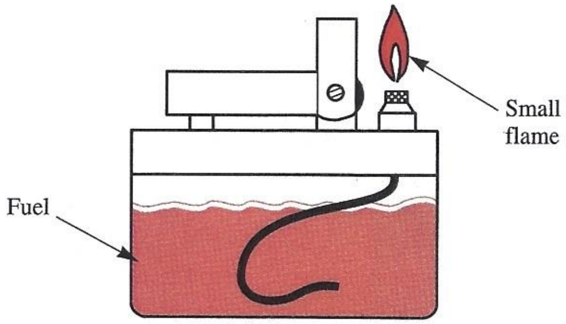


**Figure 4-2.** *A small flame is produced, due to small area of exposed fuel.*

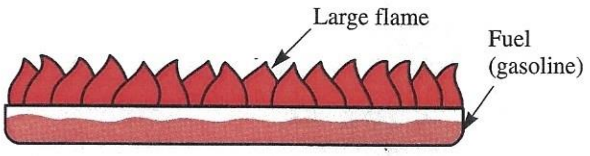


**Figure 4-3.** *A large flame is produced by a large area of exposed fuel.*

### *Fuel is atomized*

The more surface area of gasoline exposed to the air, the faster a given amount will burn. To produce the rapid burning required in an engine, gasoline must be broken up into tiny droplets and mixed with air. This is called ***atomizing.***

Once the entire surface of each droplet of the air-fuel mixture is exposed to the surrounding air, a huge burning area becomes available. Given a spark, the entire amount of gasoline will flash into flame almost instantly. In effect, atomization causes a sudden, explosive release of heat energy. See **Figure 4-4.**

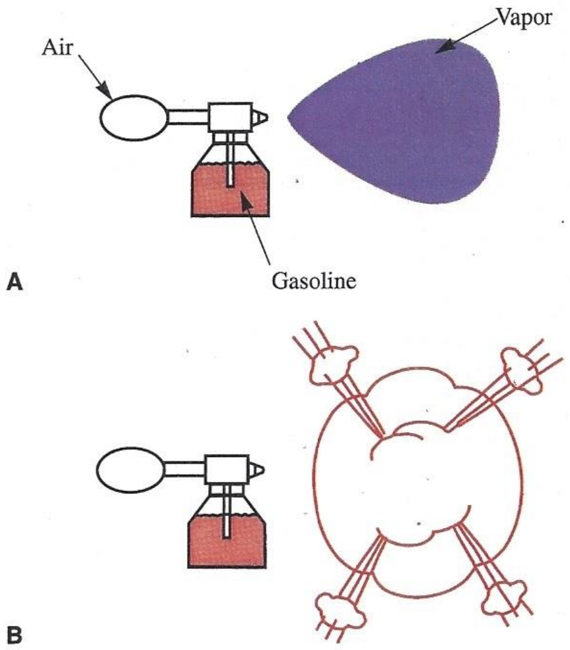


**Figure 4-4.** *Atomized fuel exposes a large area of fuel, which, when ignited, releases heat energy with an explosive force.*

### *Explosion must be contained*

To perform useful work, the explosive force caused by the burning gas must be contained and controlled. To illustrate this point, imagine that a metal lid is suspended on a string and held several inches from the ground. If a mixture of gasoline and air (atomized) were sprayed under it and ignited, the lid would be raised a short distance by the force of the explosion. See **Figure 4-5.**

The reason the lid hardly moved is because the explosion was not confined and directed

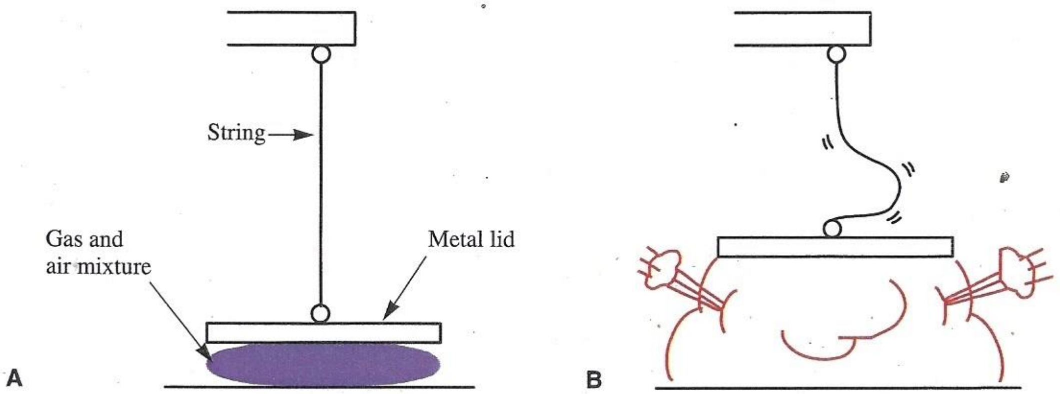


**Figure 4-5.** *A mixture of air and fuel ignited under a lid, lifts lid a short distance.*

toward the lid. Instead, the explosion exerted force in all directions, and much of the force was lost. If the gasoline and air mixture is sprayed inside a metal container with a lid, the full force of the explosion will be directed against the lid when the mixture is ignited. This will blow the lid high into the air. See **Figure 4-6.**

### *Further improvement*

Even though the burning air-fuel mixture is confined by the container, once the lid starts to lift, a large amount of the force escapes to the sides. To eliminate this loss, a long, cylindrical container may be used with the lid having a close, sliding fit. See **Figure 4-7.** With the fuel mixture slightly compressed in the bottom of the container by the weight of the lid, the fuel will burn and direct most of the pressure against the lid as it travels up through the container. When the lid reaches the top, it will be traveling at a high rate of speed. The expansion of the gas will be nearly complete and little force will be lost, even after the lid clears the container.

## Basis for an Engine

An elementary engine can be formed by attaching a crankshaft and a connecting rod to the setup illustrated in **Figure 4-7.** The lid will serve as a piston and the container will act as a cylinder. See **Figure 4-8.** When the air-fuel mixture in the cylinder is ignited, it will drive the piston upward, causing the crankshaft to turn.

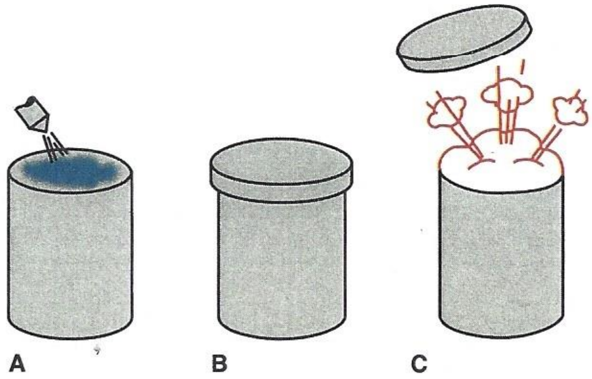


**Figure 4-6.** *A—Mixture of fuel and air is sprayed into a container. B—Lid is placed on top. C—Full force of explosion is directed toward base of lid when mixture is ignited, and lid is driven high into air.*

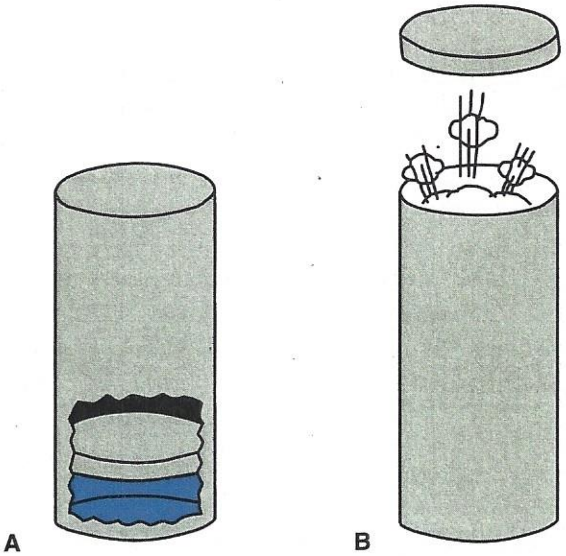


**Figure 4-7.** *A—Lid is placed in a long container. B—Most of energy of burning fuel is absorbed by lid, imparting greater speed to lid when explosion occurs.*

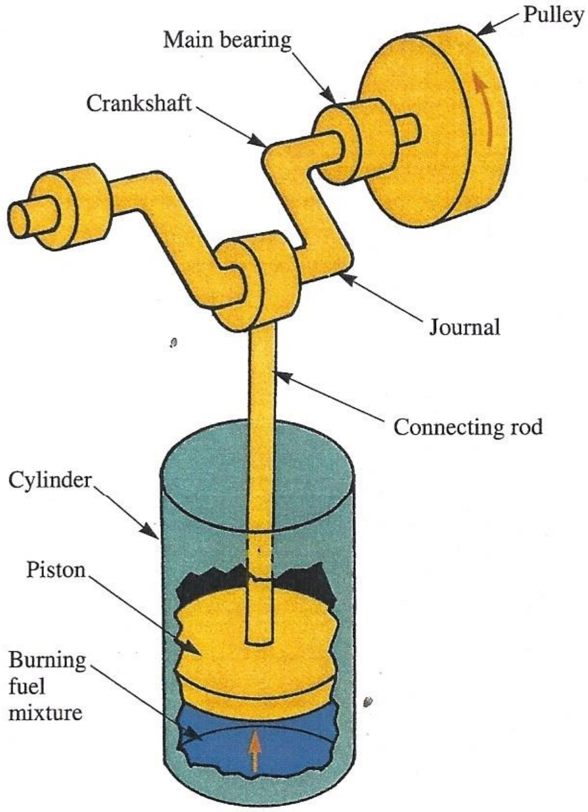


**Figure 4-8.** *Principles of operation illustrated here are the same as used in a modern gasoline engine. Note how burning fuel mixture forces lid (piston) upward to turn crankshaft and pulley.*

Although it is crude, this elementary engine illustrates the operating principles of a modern gasoline engine. Study the names of the various parts shown in **Figure 4-8.** Become acquainted with the parts and their application to engine design.

There are many faults with the engine pictured in **Figure 4-8.** These faults are explored with the following questions:

- How will a fresh air-fuel charge be admitted to the cylinder?
- How will the charge be ignited?
- What holds the various parts in alignment?
- How will the engine be cooled and lubricated?
- What will *time* the firing of the air-fuel mixture so that the piston will push on the crankshaft when the journal is in the correct position?
- How will the burned charge be removed (exhausted) from the cylinder?
- What will keep the crankshaft rotating after the charge is fired, and until another charge can be admitted and fired?

The previous questions can be categorized into five basic areas:

1. **Mechanical** (engine design and construction)
2. **Carburetion** (mixing gasoline and air, and admitting it to the cylinder)
3. **Ignition** (firing the fuel charge)
4. **Cooling** (heat dissipation)
5. **Lubrication** (oiling of moving parts)

In this chapter, emphasis will be placed on the mechanical aspects of engine design and construction. It will provide you with an opportunity to develop a workable engine. We will assume that the gasoline and air are being mixed correctly, the fuel charge is being fired at the right time, and the engine is properly cooled and lubricated.

## Cylinder block

The *cylinder block* keeps all engine parts in alignment. See **Figure 4-9.** This critical engine component is usually a casting of iron or an aluminum alloy. The cylinder formed in the block can be produced accurately by modern methods. It may be bored directly into the casting, or a steel sleeve may be inserted into an oversize hole bored in the block.

Aluminum cylinder blocks are cast around a steel sleeve. Aluminum, being a soft metal, would wear out quickly due to the friction of the piston. Advantages of aluminum are its light weight and ability to dissipate heat rapidly.

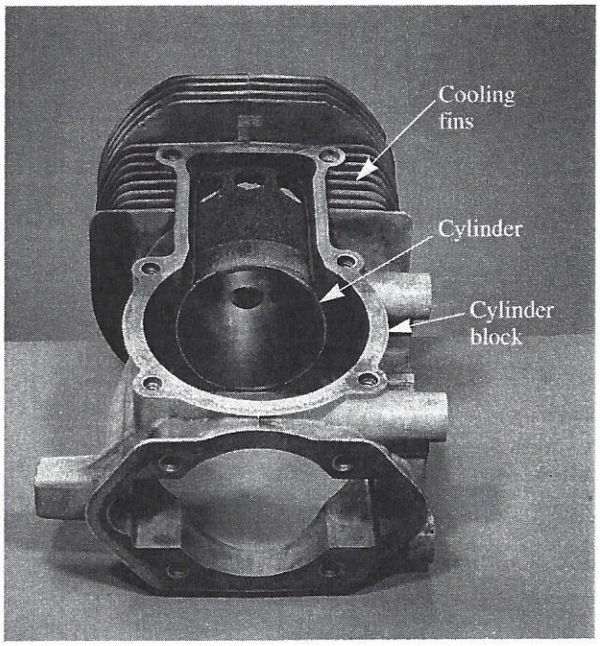


**Figure 4-9.** *Cylinder block is important because it keeps all moving parts in alignment.*

1 All air-cooled engines have ***cooling fins*** on the outside of the cylinder and cylinder head. The size, thickness, spacing, and direction of the cooling fins is carefully engineered for efficient air circulation and heat control.

The cylinder block must be rigid and strong enough to contain the power developed by the expanding gases. In some cases, the cylinder is a separate unit; in others, it is cast as part of the crankcase. Similarly, the cylinder head may be bolted to the block or it may be cast as one complete unit. The method employed depends on the intended application of the engine and the manufacturer's preference.

**Figure 4-10** shows a combined cylinder block and crankcase with a separate, bolted cylinder head. Note the gasket that seals the unit. A sleeved, aluminum, die-cast cylinder is shown in **Figure 4-11.**

## Crankshaft and crankcase

The *crankshaft* is the major rotating part of the engine. See **Figure 4-12.** Generally, it is forged or cast steel, with all bearing surfaces carefully machined and precision ground. Counterweights are used to balance the weight of the connecting rod, which is fastened to the journal. Since

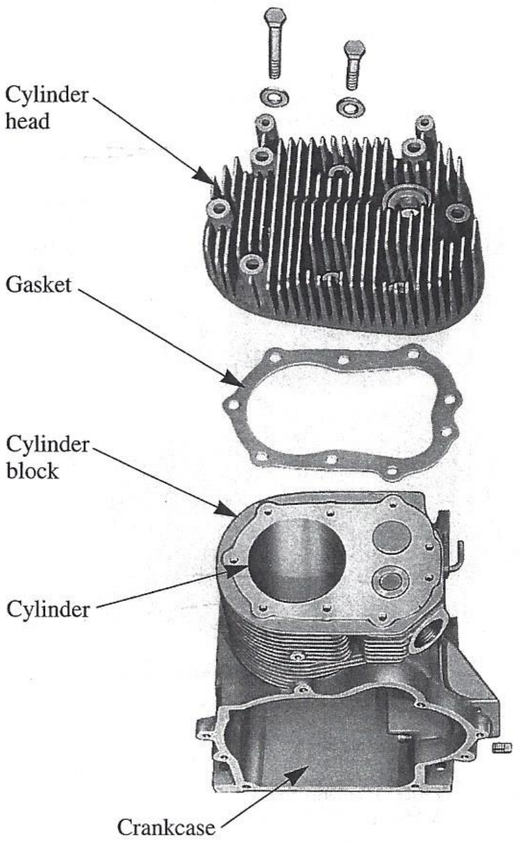


**Figure 4-10.** *A combined cylinder block and crankcase. Cylinder head and sealing gasket are bolted to cylinder block. (Wisconsin Motor Corp.)*

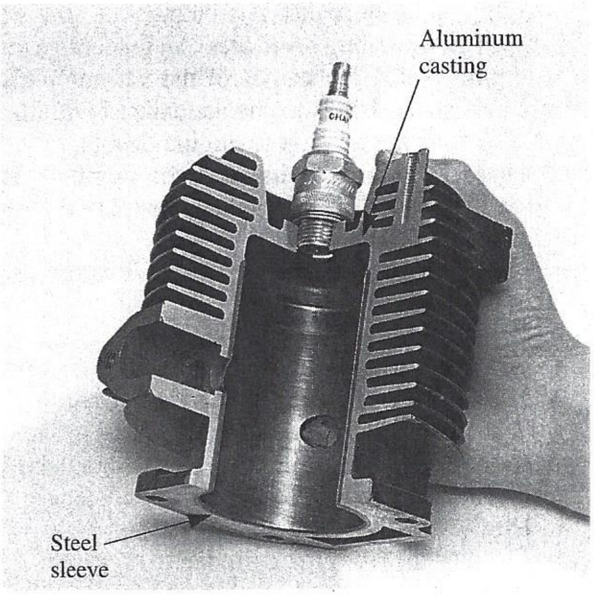


**Figure 4-11.** *An aluminum cylinder block die cast around a steel sleeve. Note fins for air cooling.*

connecting rods are cast or forged from different weight materials, holes are often drilled in counterweights to balance the crankshaft and prevent vibration.

**Figure 4-13** shows a crankshaft being installed in a crankcase. Note the tapered roller bearings. The flywheel is keyed to the end of the shaft with

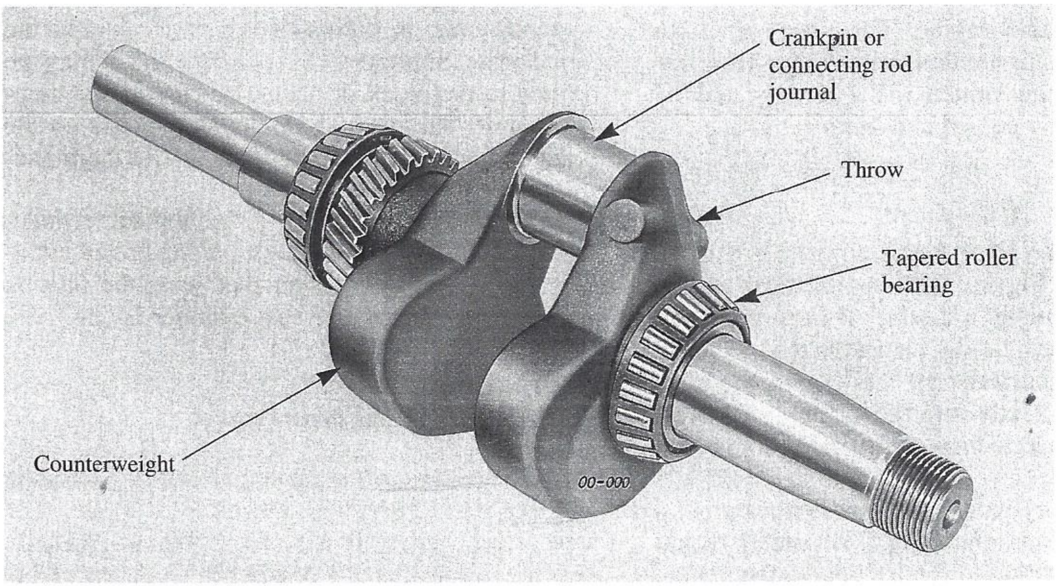


**Figure 4-12.** *Crankshaft for a single cylinder engine. Large counterweights opposite the crank journal balance rotational forces.*

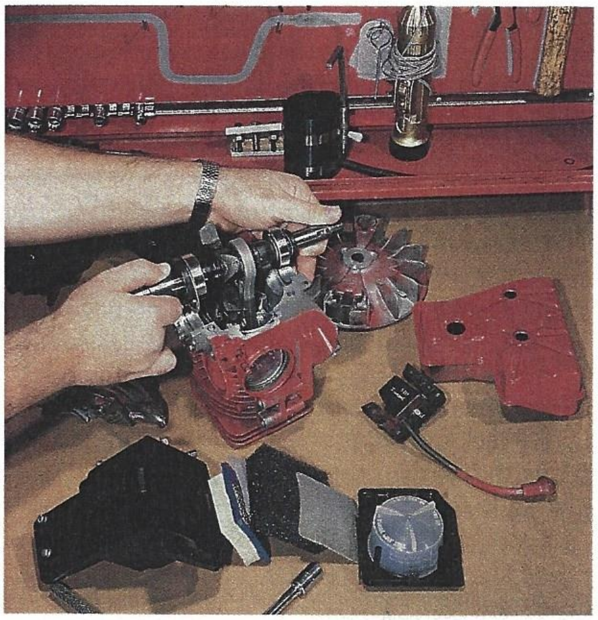


**Figure 4-13.** *Crankshaft must be clean and carefully installed in crankcase. Tapered end fits into flywheel, which is secured with a key, lock washer, and nut. (Tecumseh)*

a Woodruff key. This type of key cannot slip out during operation. A lock washer and nut hold the flywheel in place.

The end of the crankshaft and the hole through the flywheel have matched tapers that provide good holding power. When roller bearings are used to support the crankshaft, highly polished, hardened alloy steel bearing races are pressed into the crankcase to reduce friction and provide good wearability.

The ***crankcase*** must be rigid and strong enough to withstand the rotational forces of the crankshaft, while keeping all parts in proper alignment. Oil for lubrication is contained in the crankcase on some engines. On others, a valve system is used that allows a fuel, air, and oil mixture to enter. The crankcase must be designed to protect the internal parts. Gaskets and oil seals are used to keep out dirt and keep in the clean oil.

The crankcase and the cylinder block may be cast as a unit or fastened together by bolts. ***Casting*** metal is pouring molten metal into a form of a desired shape. **Figure 4-14** shows a two cylinder engine with the cylinder block being placed on the crankcase with the crankshaft already installed. Note the tapered end on the crankshaft, which receives the flywheel.

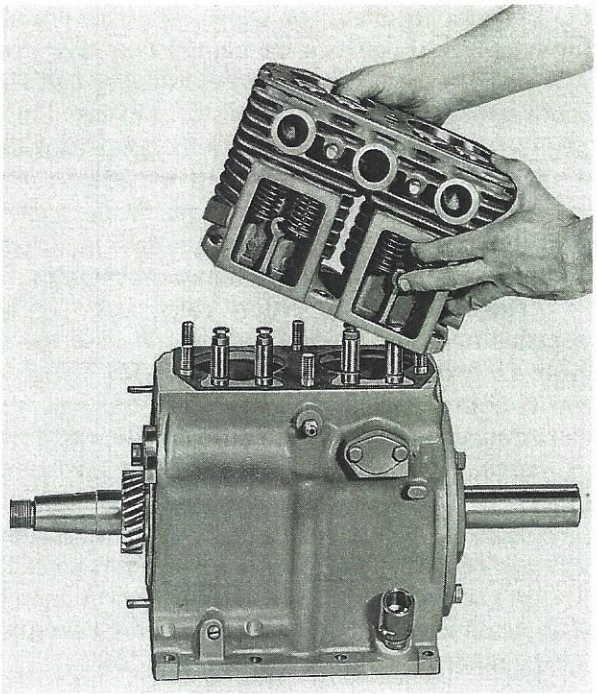


**Figure 4-14.** *Two cylinder crankcase and cylinder block being assembled. Stud bolts in crankcase will hold cylinder block in place when nuts are tightened.*

In certain engine applications, the crankcase is not only an important part of the engine but also an integral part of the apparatus being driven. See **Figure 4-15.** A chain saw is a good example of this.

## Pistons

The ***piston*** is the straight line driving member of the engine. It is subjected to the direct heat of combustion and must have adequate clearance in

**Figure 4-15.** *The assembled engine components, become the driving members of this lightweight chain saw.*

the cylinder to allow for expansion. The piston provides a seal between the combustion chamber and the crankcase. This is accomplished by cutting grooves near the top of the piston and installing ~~***piston rings.***~~ The piston rings fit the grooves with a slight side clearance and exert tension on the cylinder wall. Properly installed, piston rings prevent blowby of exhaust gases into the crankcase and leakage of oil into the combustion chamber.

The number of piston rings per piston depends upon the type of engine and its design. Note the two piston rings in **Figure 4-16.** The piston is hollow to reduce weight. The top may be flat, domed, or contoured to provide efficient flow of gases entering and leaving the combustion chamber.

There is a hole in each side of the piston through which a ***piston pin***, or ***wrist pin***, is placed. This pin acts as a hinge between the connecting rod and piston and holds the two together. Generally, spring retainers hold the piston pin in place.

### Connecting piston to crankshaft

The sliding piston is connected to the rotating crankshaft with a metal link called a ***connecting rod.*** The big end of the connecting rod encircles the crankshaft journal and contains a bearing to permit free movement. The upper, or small end, of the connecting rod also must be movable. Note how the metal piston pin is passed through the connecting rod and piston. See **Figure 4-17.**

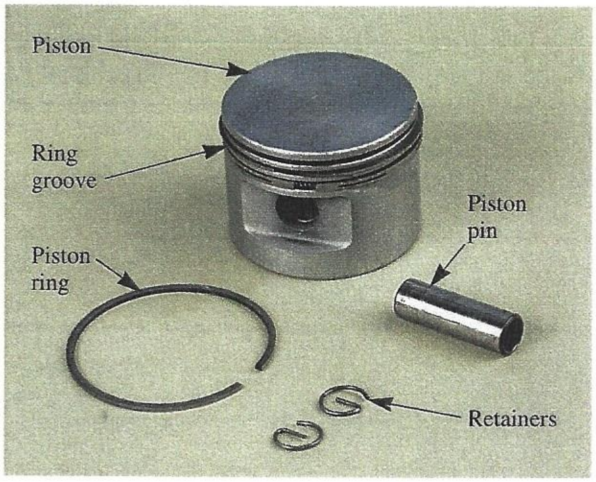


**Figure 4-16.** *The piston is the largest sliding-reciprocating part in engine. Piston rings seal combustion chamber from crankcase and must fit properly.*

Also note the needle-type roller bearings, bearing race shells, and retainers, which must be installed in the large end of the connecting rod when it is placed on the crank journal. The bearing cap holds the assembly together with connecting rod bolts or screws. **Figure 4-18** shows the relative position of the connecting rod and cap.

Expanding gases push the piston toward the crankshaft, causing the connecting rod to turn the shaft. **Figure 4-19** shows how the reciprocating (up and down) movement of the piston is changed to rotary (revolving) motion by the crankshaft. Notice that the upper connecting rod bearing allows the connecting rod to swing back and forth while the lower bearing permits the crankshaft journal to rotate within the rod.

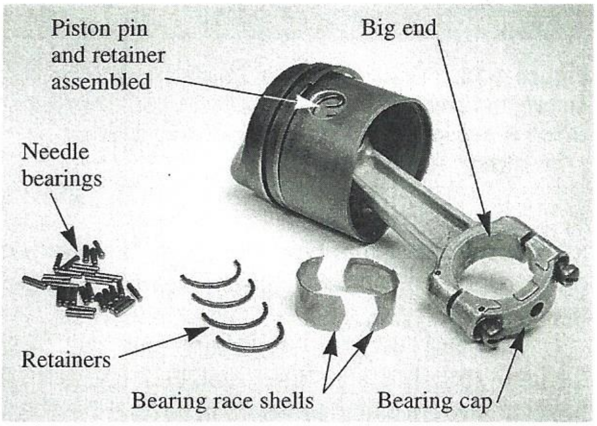


**Figure 4-17.** *Big end of connecting rod is capped to fit around crankshaft journal. Needle bearings are inserted to help reduce friction. Piston pin and retainers are shown assembled. (Jacobsen Mfg. Co.)*

**Figure 4-18.** *Shown is the relative positions of connecting rod parts.*

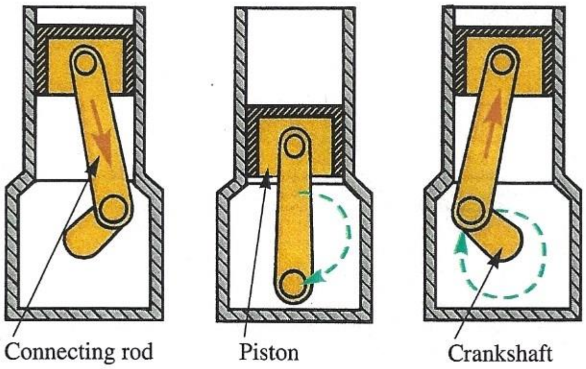


**Figure 4-19.** *Connecting rod must be free to pivot on piston pin, while crank journal follows a rotary path. Connecting rod must withstand severe stress in operation.*

## Intake and exhaust ports

In developing an engine, we need to provide a way in which a fresh air-fuel mixture can be admitted to the engine and, once burned, the waste products exhausted. This can be done by using ***ports*** (openings) that are alternately covered and exposed by the piston (two-stroke cycle design) or by using ***poppet valves*** to open and close the port openings (four-stroke cycle design). Both two-stroke and four-stroke designs are commonly used. Each has definite advantages and disadvantages. The four-stroke cycle engine will be discussed here.

## Poppet valves

For a four-stroke cycle engine (see Chapter 5 for additional information on fundamentals), passages leading to and from the cylinder area must be constructed. **Figure 4-20** shows two ports cast into the cylinder block, one intake and one exhaust. The cylinder head is recessed to provide a passage from the ports to the cylinder.

By installing a valve in each port, it is possible to control the flow of fresh fuel mixture into the cylinder and provide a means of exhausting the burned gases. During the period of expansion of the burning gases that drive the piston downward, both valves are tightly closed. See **Figure 4-21.**

The angled face of each valve will close tightly against a smooth seat cut around each port opening. To align the valve and assure accurate raising and lowering in relation to the seat, the valve stem passes through a machined hole in block. This hole is called a ***valve guide***.

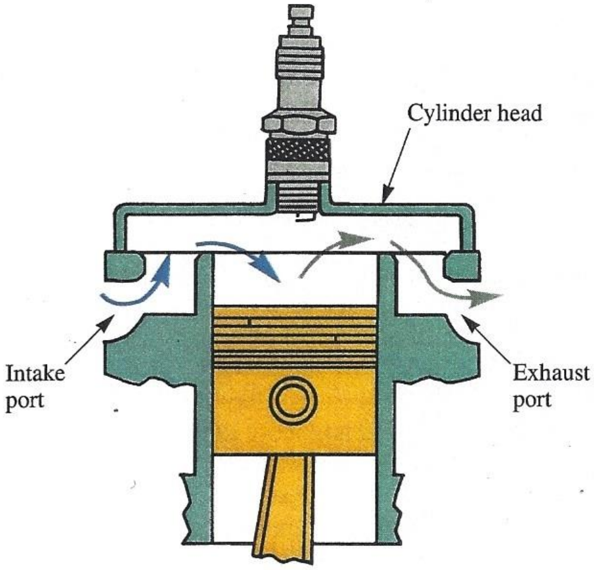


**Figure 4-20.** *Intake port permits air-fuel mixture to enter. Exhaust port allows burned gases to escape.*

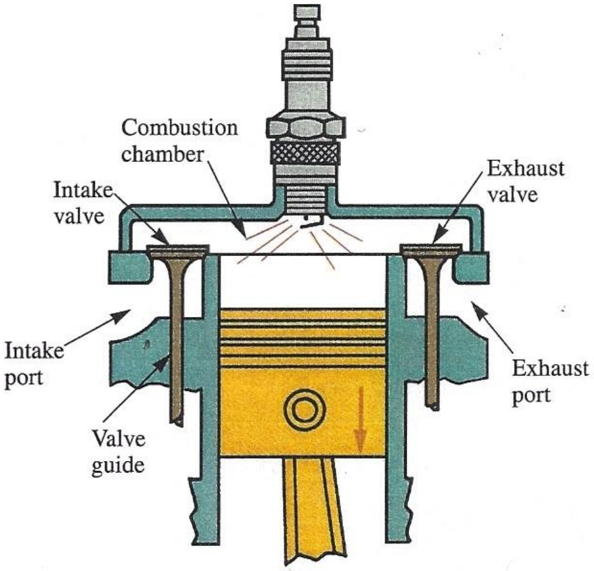


**Figure 4-21.** *Poppet valves seal intake and exhaust ports during power stroke. Valve guides keep valves aligned with valve seats.*

## Valve spring assembly

A ***valve spring*** must be used on each valve to hold it firmly against the seat. Placed over the valve stem, the spring is compressed to provide tension. It is connected to the valve stem by means of a washer and keeper (lock).

The spring allows the valve to be opened when necessary and will close it when pressure is removed from the valve stem. **Figure 4-22** shows the location of the spring and keeper assembled on the valve. An enlarged view of the *horseshoe* valve lock system is shown in **Figure 4-23.**

A valve in the open position is illustrated in **Figure 4-24.** When pressure is removed from the end of the valve stem, the spring will draw the valve down against the seat and seal off the port from the combustion chamber. For the engine to function properly, the valves must be opened the right amount at the right time. They must remain open for a specific period and close at the correct instant.

By using a shaft with two thick sections spaced to align with the valve stems, a basic device for opening and closing the valves is provided. By grinding the thick sections into a cam shape, the *camshaft* is formed. When the shaft is revolved, the cam lobe will cause the valve to rise and fall, opening and closing the ports. This procedure is shown in **Figure 4-25.**

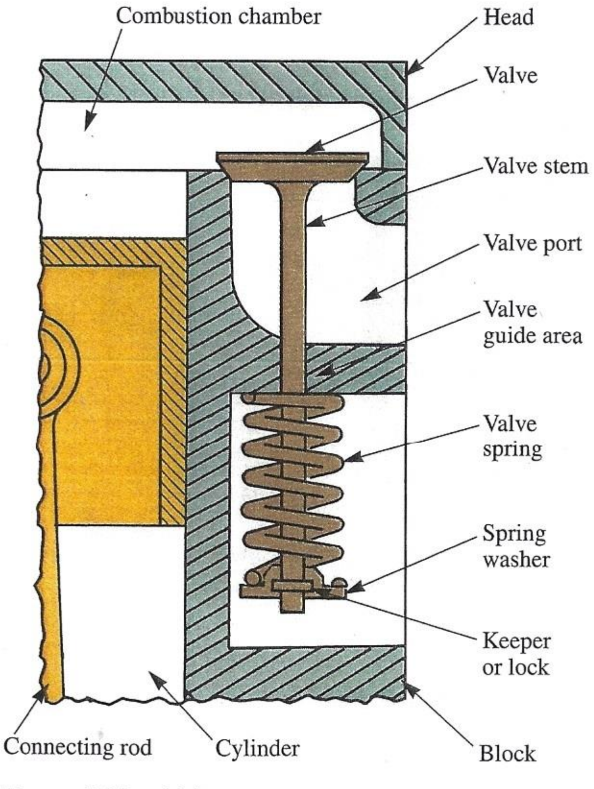


**Figure 4-22.** *Valve spring keeps tension on valve to ensure proper seating. Valve spring keeper and washer hold spring in place and permit removal when necessary.*

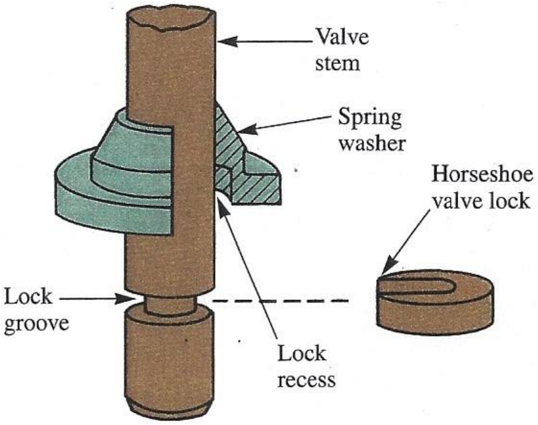


**Figure 4-23.** *Typical method of retaining valve spring on valve stem. Special tool generally is used to compress spring prior to removing horseshoe valve lock.*

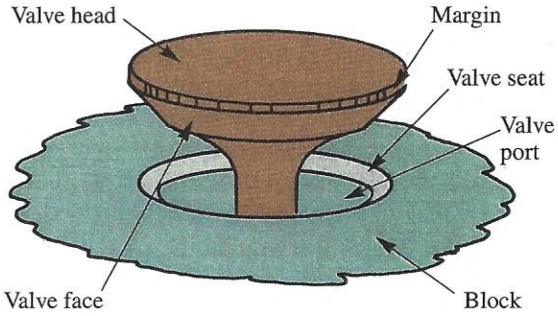


**Figure 4-24.** *Valve face and valve seat must be ground to correct angles, and concentric to centerline of guide, to seal properly.*

## *Valve lifter or tappet*

In actual practice, the cam lobe does not contact the valve stem directly. By locating the camshaft some distance below the valve stem end, it is possible to insert a ***valve lifter*** between the lobe and stem. The valve lifter may have an adjustment screw in the upper end to provide a means of adjusting valve stem-to-lifter clearance. Without this adjustment, proper clearance must be obtained by grinding the end of the lifter or valve stem. The base of the lifter may be made wider than the body to provide a larger cam lobe-to-lifter contact area. See **Figure 4-26.**

By drilling a hole in the block above the camshaft, a guide is formed in which the lifter can operate. See **Figure 4-27.** The base of the lifter rides on the cam and the adjusting screw almost

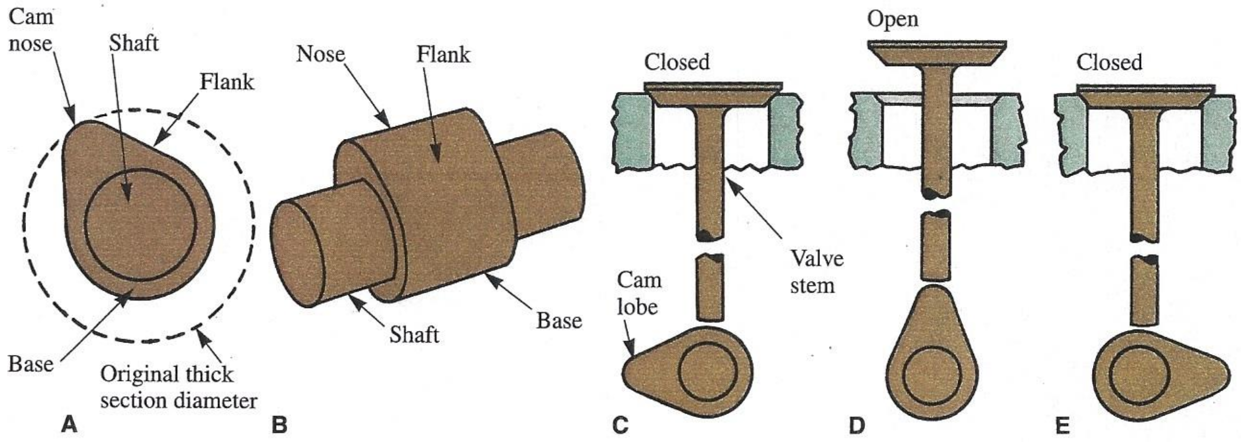


**Figure 4-25.** *A, B—By grinding a round shaft into a cam shape, a camshaft is formed. C, D, E—When camshaft is revolved, cam lobe will open valve.*

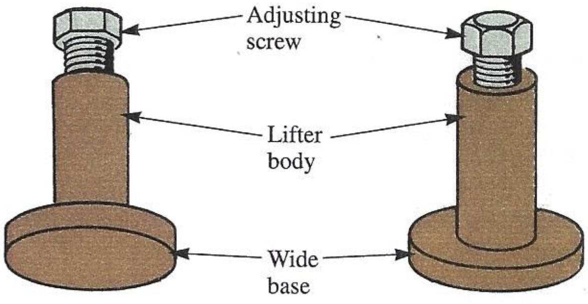


**Figure 4-26.** *Valve lifter may be called a tappet or cam follower. Adjustment screw allows setting of proper valve clearance. Wide base provides a larger contact area.*

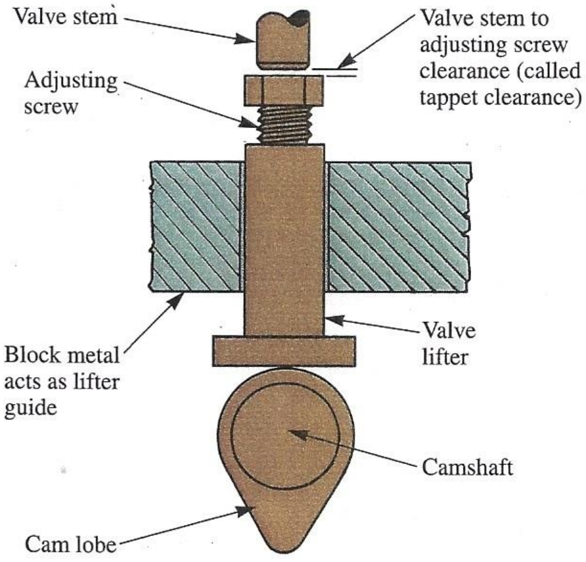


**Figure 4-27.** *As camshaft turns, cam lobe will operate valve lifter to open valve, then allow it to close.*

touches the end of the valve stem. As the camshaft revolves, the lifter will rise and fall, opening and closing the valve.

## *Camshaft*

Generally, the camshaft is located in the crankcase, directly below the valve stems and valve lifters. The ends of the camshaft are supported in bearings in the block. See **Figure 4-28.** One type of

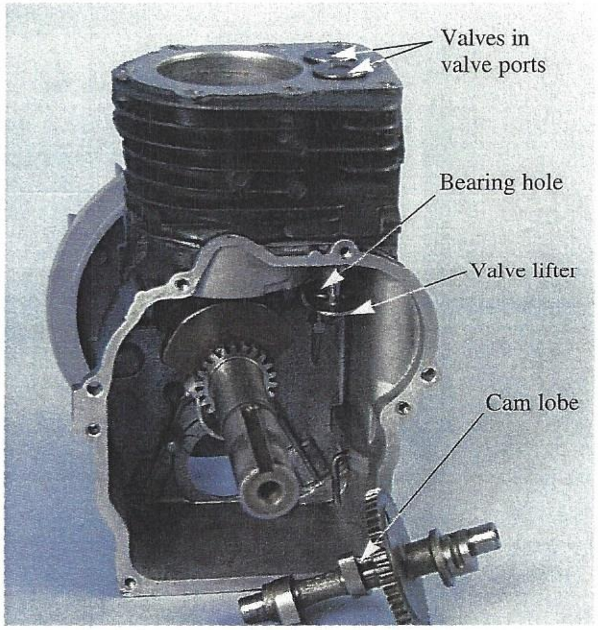


**Figure 4-28.** *Cam lobes are located directly under valve lifters. Camshaft turns in lubricated bearing holes.*

valve assembly is illustrated in **Figure 4-29.** Study the relationship of the parts. **Figure 4-30** shows the location of each valve part in relation to the rest of the engine block.

The camshaft is driven by the crankshaft through gears. **Figure 4-31** shows the large camshaft gear meshed with the smaller crankshaft gear. The camshaft gear is always twice as large as the crankshaft gear. This gear ratio will be explained in Chapter 5 under four-stroke cycle engine.

## *Flywheel*

Even though the crankshaft moves fast during the power stroke, it is relatively light and tends to slow down or stop before the next power stroke. This periodic application of power, followed by coasting, would cause the engine to speed up, slow down, and/or run roughly.

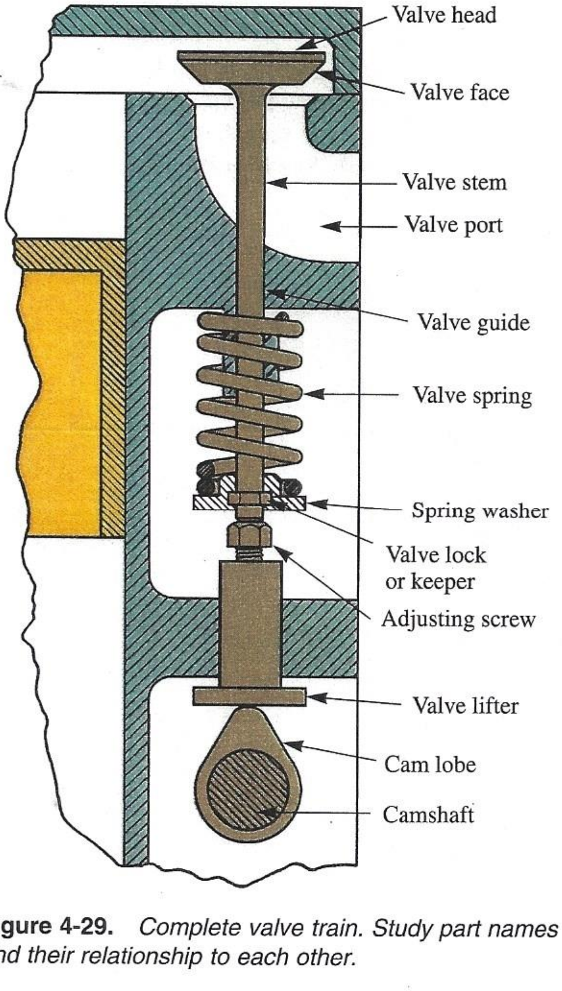


**Figure 4-29.** *Complete valve train. Study part names and their relationship to each other.*

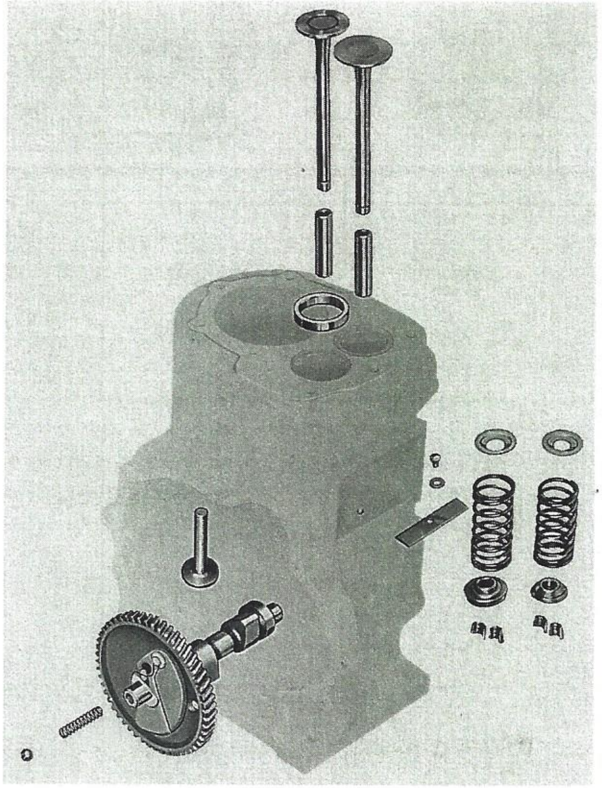


**Figure 4-30.** *Valve parts and their positions relative to cylinder block and crankcase.*

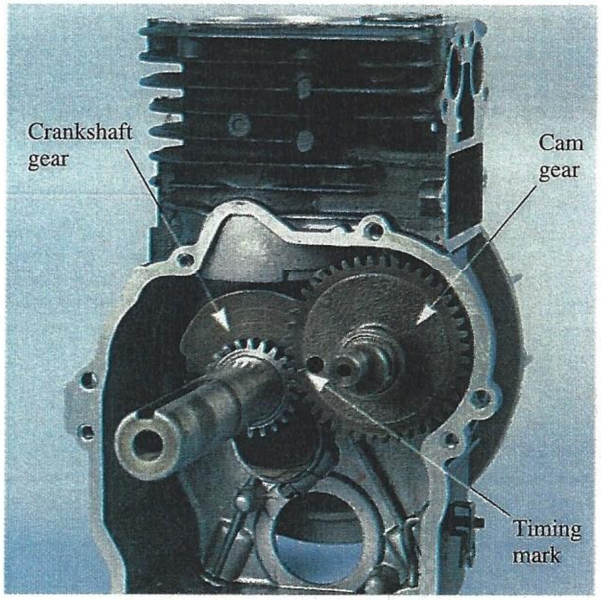


**Figure 4-31.** *Camshaft is gear driven from crankshaft. Camshaft gear is always twice as large as crankshaft gear for proper timing. During assembly, timing marks must be matched.*

To improve the running quality of the engine, an additional weight in the form of a round ***flywheel*** is fastened to one end of the crankshaft. See **Figure 4-32.** During the nonpower strokes, the inertia of the heavy flywheel keeps the crankshaft spinning and smoothes engine operation. Metal fins on the flywheel act as a fan that forces air over the cylinder to cool the engine. Magnets cast into the flywheel produce electrical current for the ignition system.

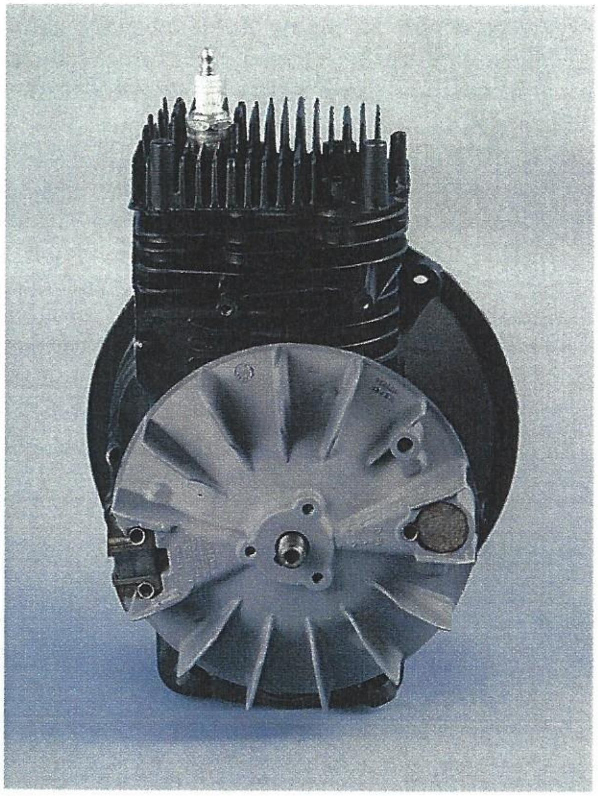


**Figure 4-32.** *Flywheel is fastened to crankshaft. When rotating, its weight smoothes engine operation.*

## Summary

A gasoline engine is designed to transform the chemical energy of burning fuel into mechanical energy. For engine use, gasoline should ignite readily, burn cleanly, and vaporize easily. It should also be free from dirt and oil and resist detonation.

For efficient small engine use, gasoline must be broken into small particles and mixed with air. This process is called atomizing.

To perform useful work, the explosive force caused by burning gasoline must be contained and controlled by a piston and a cylinder.

The cylinder block keeps all engine parts in alignment. Air-cooled engines have cooling fins on the outside of the cylinder block. The crankshaft is the major rotating part in the engine. The crankcase is designed to protect internal engine parts and must be rigid enough to withstand the rotational forces of the crankshaft.

The piston is the straight line driving member of the engine. It provides a seal between the combustion chamber and the crankcase. The piston is connected to the crankshaft by the connecting rod.

Air-fuel mixture is admitted and burned gases are exhausted through ports in the engine. In some engines, valves are installed in the ports to help control intake and exhaust. A camshaft and lifters are used to open and close the valves.

## Know These Terms

gasoline
petroleum
octane number
atomizing
cylinder block
cooling fins
crankshaft
crankcase
casting
piston
piston rings
piston pin
wrist pin
connecting rod
ports
poppet valves
valve guide
valve spring
camshaft
valve lifter
flywheel

## Chapter 4 Review Questions

***Answer the following questions on a separate sheet of paper.***

1. Fuel must be atomized in the engine for the purpose of __________.
2. Force on the piston is transmitted to the crankshaft by the __________.
3. Name five desirable characteristics of gasoline for use in small engines.

4. Small gasoline engines generally use __________.
   a. high octane fuel
   b. low octane fuel
5. What effect did lead (tetraethyl lead) have when introduced into gasoline?
6. What was the main reason that unleaded gasoline was introduced?
7. What adverse effects can result from using gasoline with alcohol blends?
8. The bearings that support the crankshaft are called __________ bearings.
9. The cylinder block is generally made of __________ or __________.
10. When are sleeved cylinders used?
11. Why are sleeved cylinders used?
12. Why are metal fins made as a part of the cylinder?
13. __________ are designed into the crankshaft to provide for engine balancing.
14. Why do some pistons have a contoured face?
15. The __________ will cause the valve to rise and fall, opening and closing the ports.
16. The angled face of each valve will close tightly against a smooth __________ cut around each port opening.
17. Which is larger, the camshaft gear or the crankshaft gear? How much larger?
18. What are three tasks which are performed by the flywheel?

## Suggested Activities

1. Visit a local gasoline station and find out the following:
   a. Various fuel prices.
   b. Octane ratings of the fuels sold.
   c. Kind of containers fuel may be sold in.
   d. Quantities that legally may be stored at home.
2. Disassemble an engine and identify the parts discussed in this chapter. Carefully analyze the function of each part as it relates to the others.
3. If the engine used for disassembly is a used one, look for possible defects such as worn bearings, burned valves, broken or worn piston rings, a scored cylinder, or a loose piston pin.
4. Write to manufacturers of small gasoline engines requesting specifications for the models they produce. Write a report on the types of pistons, connecting rods, and crankshafts they use.
5. Prepare a display of the major components of a small gasoline engine. Use actual parts, photos, drawings, and cutaways to show the principal use of each part.