

# **MEASURING SYSTEMS AND TOOLS**

## **OBJECTIVES**

After studying Chapter 7, the reader will be able to:

1. Describe how to read a ruler.
  2. Explain how to use a micrometer and vernier dial caliper.
  3. Describe how to use a telescopic gauge and a micrometer to measure cylinder and lifter bores.
  4. Discuss how to measure valve guides using a small-hole gauge.
  5. Calculate engine displacement and compression ratios.
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## **KEY TERMS**

**Barrel** (p. 88)

**Feeler Gauge** (p. 91)

**Small-Hole Gauge** (p. 91)

**Spindle** (p. 88)

**Split-Ball Gauge** (p. 91)

**Straightedge** (p. 91)

**Thickness Gauge** (p. 91)

**Thimble** (p. 88)

## ENGLISH CUSTOMARY MEASURING SYSTEM

The English customary measuring system was established about A.D. 1100 in England during the reign of Henry I. The foot was determined to be 12 inches and was taken from the length of a typical foot. The yard (36 inches) was determined to be the length from King Henry's nose to the end of his outstretched hand. The mile came from Roman days and was originally defined as the distance traveled by a soldier in 1,000 paces or steps. Other English units, such as the pound (weight) and gallon (volume), evolved over the years from Roman and English measurements.

The Fahrenheit temperature scale was created by Gabriel Fahrenheit (1686–1736) and he used 100°F as the temperature of the human body, which he missed by 1.4 degrees (98.6°F is considered now to be normal temperature). On the Fahrenheit scale, water freezes at 32°F and water boils at 212°F.

## METRIC SYSTEM OF MEASURE

Most of the world uses the metric system of measure. The metric system was created in the late 1700s in France and used the physical world for the basis of the measurements. For example, the meter was defined as being 1/40,000,000 of the circumference of the earth (the distance around the earth at the poles). The Celsius temperature scale developed by Anders Celsius (1701–1744) used the freezing point of water as 0°C (32°F) and the boiling point of water as 100°C (212°F). Other units include a liter of water, which was then used as a standard of weight where 1 liter of water (about 1 quart) weighs 1 kilogram (1,000 grams). Units of measure are then divided or multiplied by 10, 100, and 1,000 to arrive at usable measurements. For example, a kilometer is 1,000 meters and is the most commonly used metric measurement for distance for travel. Other prefixes include:

m = milli = 1/1,000

k = kilo = 1,000

M = mega = 1,000,000

### Linear Metric Measurements

1 kilometer = 0.62 miles

1 meter = 39.37 inches

1 centimeter (1/100 meter) = 0.39 inch

1 millimeter (1/1,000 meter) = 0.039 inch

### Volume Measurement

1 cc (cubic centimeter) = 0.06 cubic inches

1 liter = 0.26 U.S. gallons (about 1 quart)

## FREQUENTLY ASKED QUESTION

### WHAT WEIGHS A GRAM?

To better understand the metric system measurements, it is often helpful to visualize a certain object and relate it to a metric unit of measure. For example, the following objects weigh about one gram:

- A dollar bill
- A small paper clip

### Weight Measurement

1 gram = 0.035 ounces

1 kilogram (1,000 grams) = 2.2 pounds

### Pressure Measurements

1 kilopascal (kPa) = 0.14 pounds per square inch  
(6.9 kPa = 1 PSI)

1 bar = 14.5 pounds per square inch

### Derived Units

All units of measure, except for the base units, are a combination of units that are referred to as derived units of measure. Some examples of derived units include:

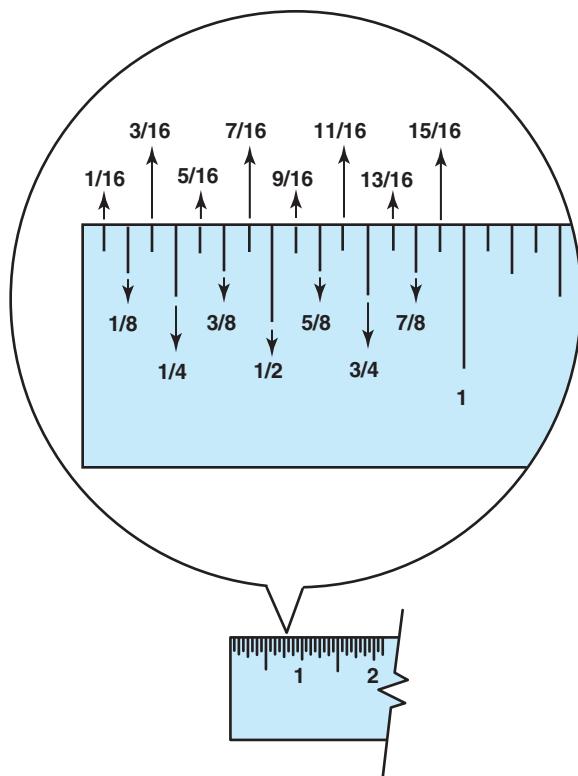
Torque  
Velocity  
Density  
Energy  
Power

### LINEAR MEASUREMENTS (TAPE MEASURE/RULE)

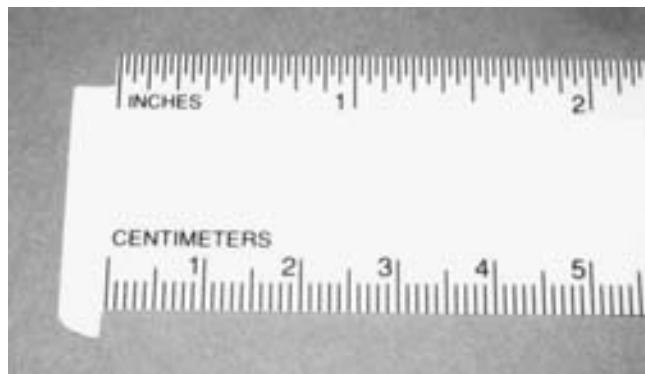
A tape measure or machinist rule divides inches into smaller units. Each smaller unit is drawn with a line shorter than the longer unit. The units of measure starting with the largest include:

1 inch  
1/2 inch  
1/4 inch  
1/8 inch  
1/16 inch

See Figure 7-1.



**FIGURE 7-1** A rule showing that the larger the division, the longer the line .

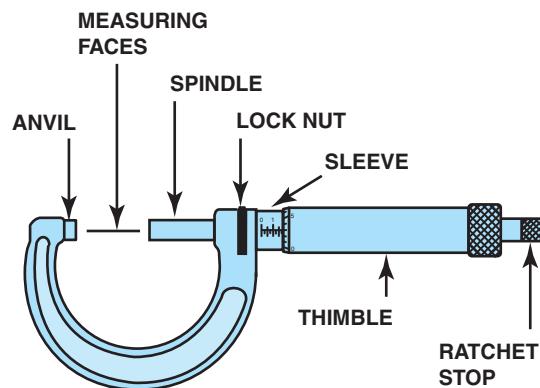


**FIGURE 7-2** A plastic rule that has both inches and centimeters. Each line between the numbers on the centimeters represents one millimeter because there are 10 millimeters in 1 centimeter.

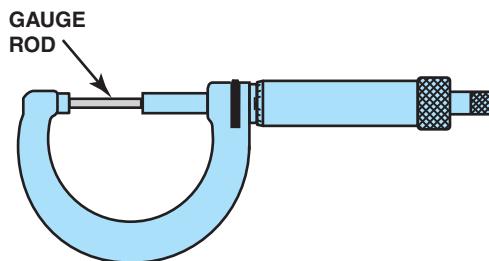
A metric scale is also included on many tape measures and machinists rules. See Figure 7-2.

## MICROMETER

A micrometer is the most used measuring instrument in engine service and repair. See Figure 7-3.



**FIGURE 7-3** A typical micrometer showing the names of the parts .



**FIGURE 7-4** All micrometers should be checked and calibrated as needed using a gauge rod.

The **thimble** rotates over the **barrel** on a screw that has 40 threads per inch. Every revolution of the thimble moves the **spindle** 0.025 inch. The thimble is graduated into 25 equally spaced lines; therefore, each line represents 0.001 inch. Every micrometer should be checked for calibration on a regular basis. See Figures 7-4 through 7-6.

## Crankshaft Measurement

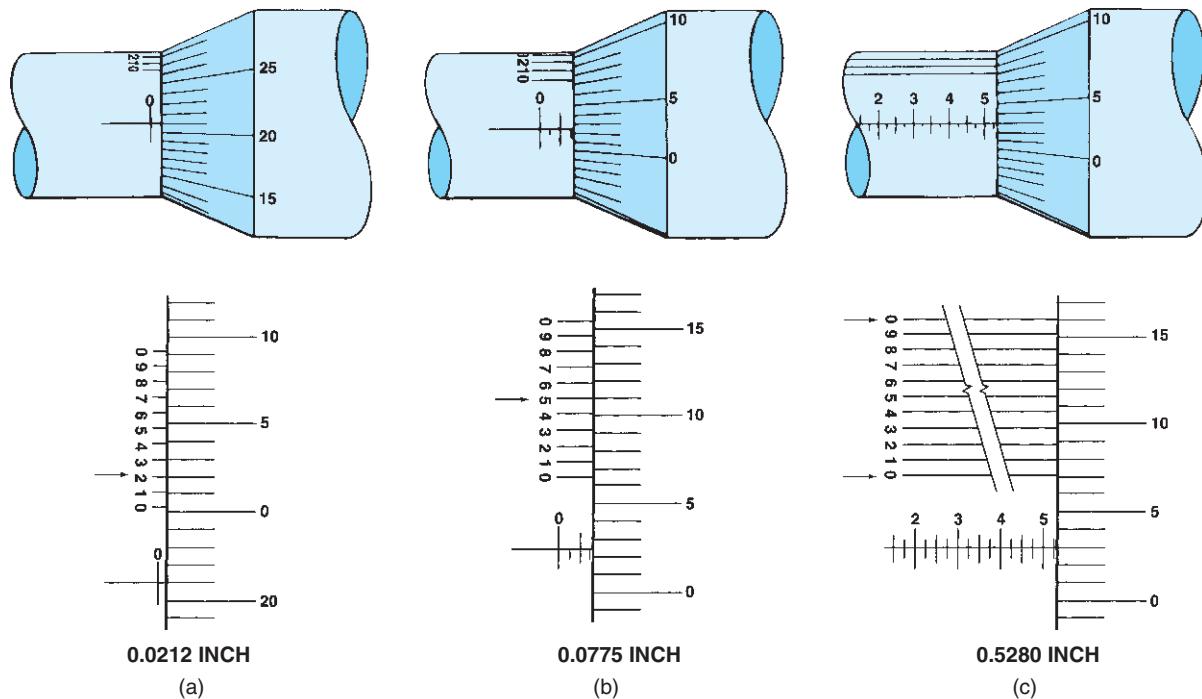
Even though the connecting rod journals and the main bearing journals are usually different sizes, they both can and should be measured for out-of-round and taper. See Figure 7-7 on page 90.

**Out-of-Round.** A journal should be measured in at least two positions across the diameter and every 120 degrees around the journal, as shown in Figure 7-8, for an example of the six readings. Calculate the out-of-round measurement by subtracting the lowest reading from the highest reading for both A and B positions.

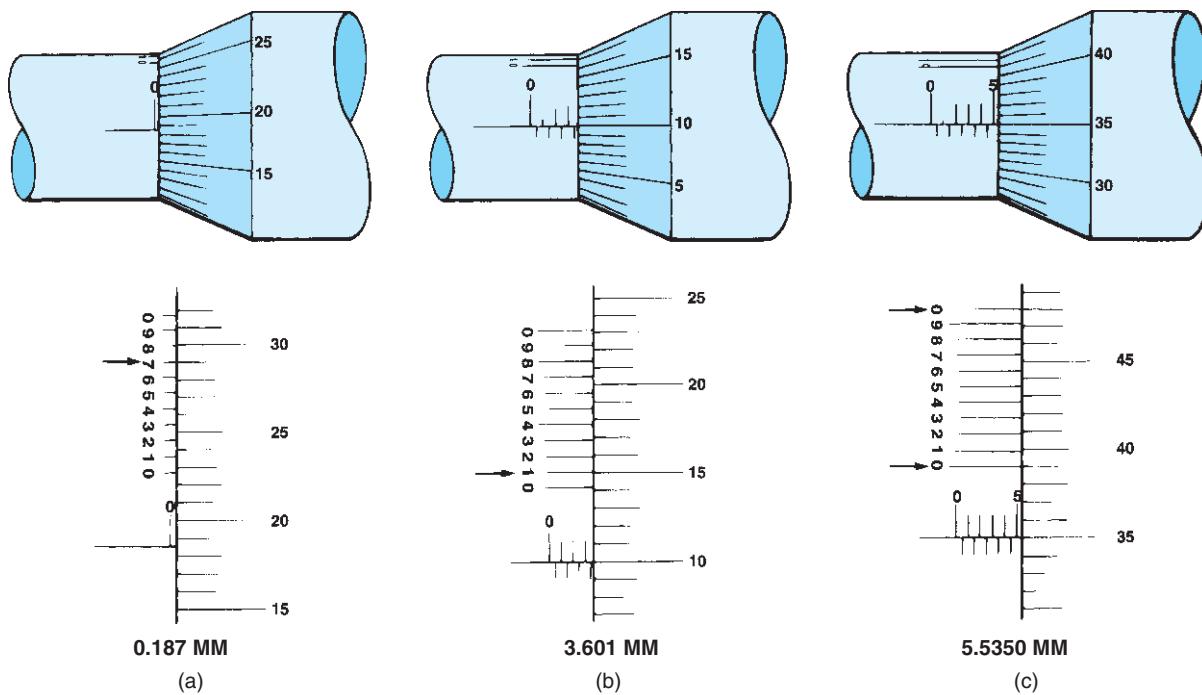
$$\text{Position A: } 2.000 - 1.9995 = 0.0005 \text{ inch}$$

$$\text{Position B: } 2.000 - 1.9989 = 0.0011 \text{ inch}$$

The maximum out-of-round measurement occurs in position B (0.0011 inch), which is the measurement that should



**FIGURE 7-5** The three micrometer readings are (a) 0.0212 inch; (b) 0.0775 inch; (c) 0.5280 inch. These measurements used the vernier scale on the sleeve to arrive at the ten-thousandth measurement. The number that is aligned represents the digit in the ten-thousandth place.



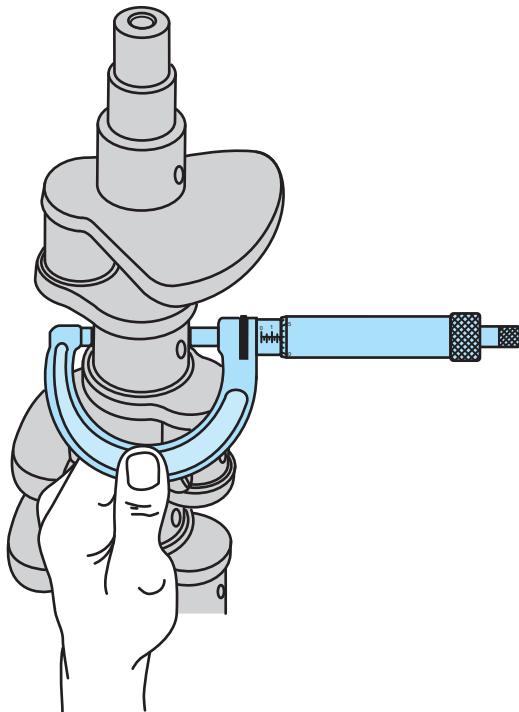
be used to compare against factory specifications to determine if any machining will be necessary.

**Taper.** To determine the taper of the journal, compare the readings in the same place between A and B positions and subtract the lower reading from the higher reading.

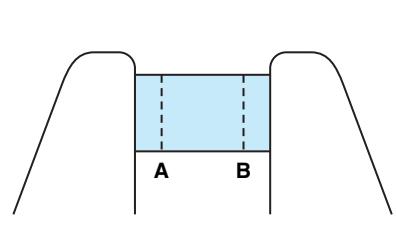
For example:

Position A		Position B	
2.0000	–	2.0000	= 0.0000
1.9999	–	1.9999	= 0.0000
1.9995	–	1.9989	= 0.0006

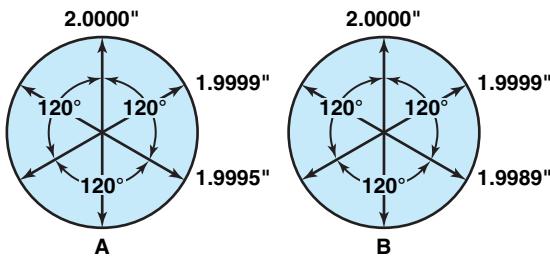
Use 0.0006 inch as the taper for the journal and compare with factory specifications.



**FIGURE 7-7** Using a micrometer to measure the connecting rod journal for out-of-round and taper.



**FIGURE 7-8** Crankshaft journal measurements. Each journal should be measured in at least six locations, but also in position A and position B and at 120-degree intervals around the journal.



## Camshaft Measurement

The journal of the camshaft(s) can also be measured using a micrometer and compared with factory specifications for taper and out-of-round. See Figure 7-9.

**NOTE:** On overhead valve (pushrod) engines, the camshaft journal diameter often decreases slightly toward the rear of the engine. Overhead camshaft engines usually have the same journal diameter.

The lift can also be measured with a micrometer and compared with factory specifications, as shown in Figure 7-10.

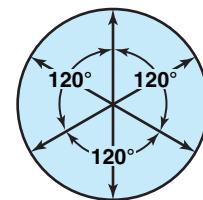
## TELESCOPIC GAUGE

A telescopic gauge is used with a micrometer to measure the inside diameter of a hole or bore.

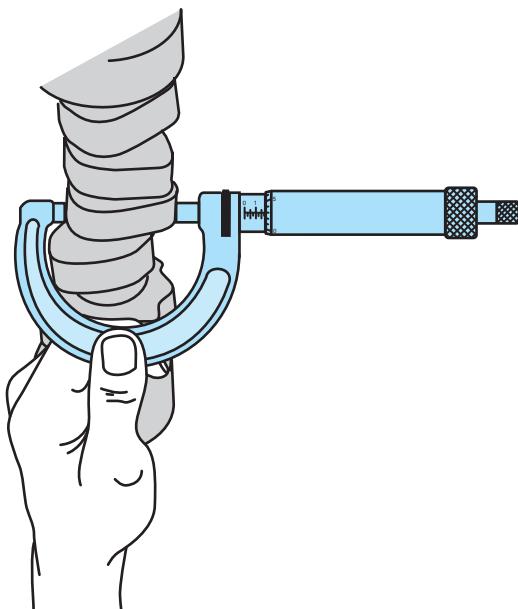
The cylinder bore can be measured by inserting a telescopic gauge into the bore and rotating the handle lock to allow the arms of the gauge to contact the inside bore of the cylinder. Tighten the handle lock and remove the gauge from the cylinder. Use a micrometer to measure the telescopic gauge. See Figure 7-11.

A telescopic gauge can also be used to measure the following:

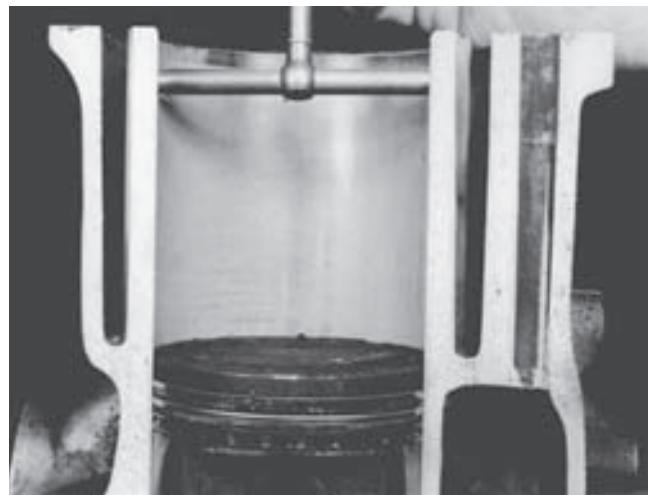
- Camshaft bearing (see Figure 7-12 on page 92)
- Main bearing bore (housing bore) measurement
- Connecting rod bore measurement



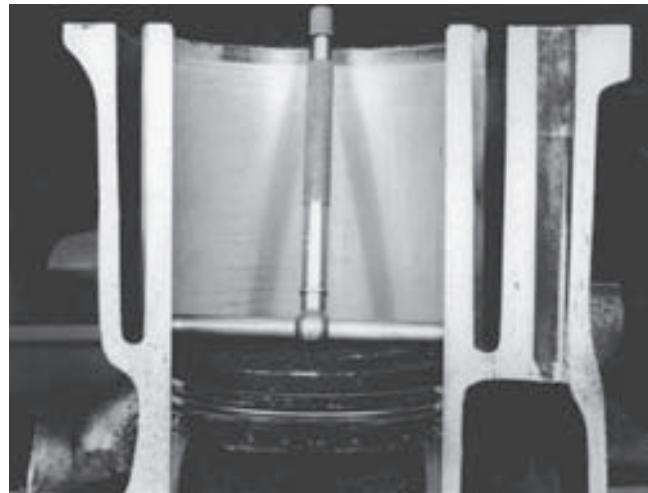
**FIGURE 7-9** Camshaft journals should be measured in three locations, 120 degrees apart, to check for out-of-round.



**FIGURE 7-10** Checking a camshaft for wear by measuring the lobe height with a micrometer.



(a)



(b)

## SMALL-HOLE GAUGE

A **small-hole gauge** (also called a **split-ball gauge**) is used with a micrometer to measure the inside diameter of small holes such as a valve guide in a cylinder head. See Figures 7-13 and 7-14.

## VERNIER DIAL CALIPER

A vernier dial caliper is normally used to measure the outside diameter or length of a component such as a piston diameter or crankshaft and camshaft bearing journal diameter. See Figure 7-15 on page 93.

## FEELER GAUGE

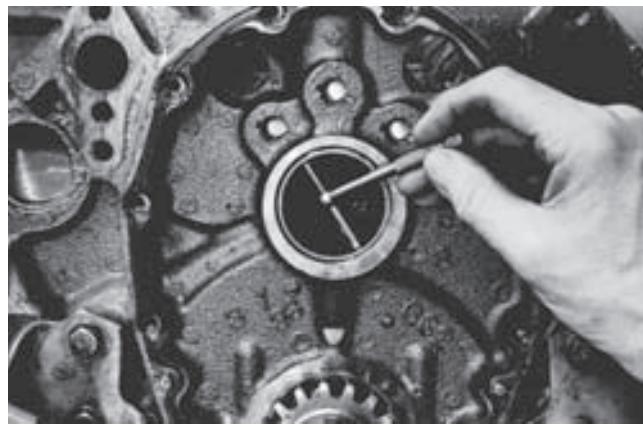
A **feeler gauge** (also known as a **thickness gauge**) is an accurately manufactured strip of metal that is used to determine the gap or clearance between two components. See Figure 7-16 on page 93.

A feeler gauge can be used to check the following:

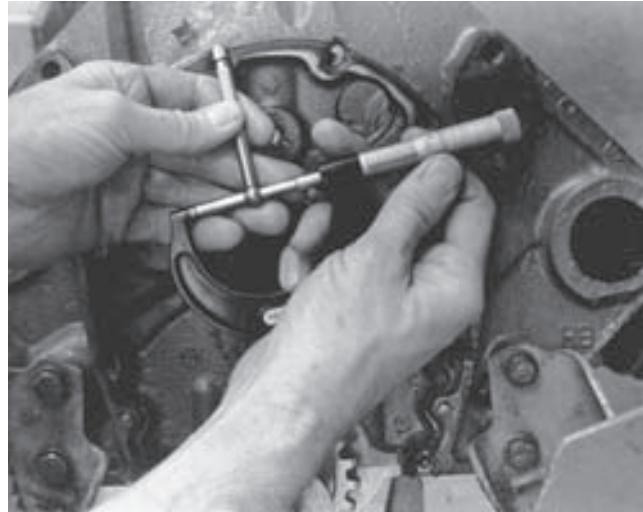
- Piston ring gap (see Figure 7-17 on page 93)
- Piston ring side clearance
- Connecting rod side clearance
- Cylinder heads (see Figure 7-18 on page 94)
- Cylinder block deck
- Straightness of the main bearing bores (saddles)

## STRAIGHTEDGE

A **straightedge** is a precision ground metal measuring gauge that is used to check the flatness of engine components when used with a feeler gauge. A straightedge is used to check the flatness of the following:

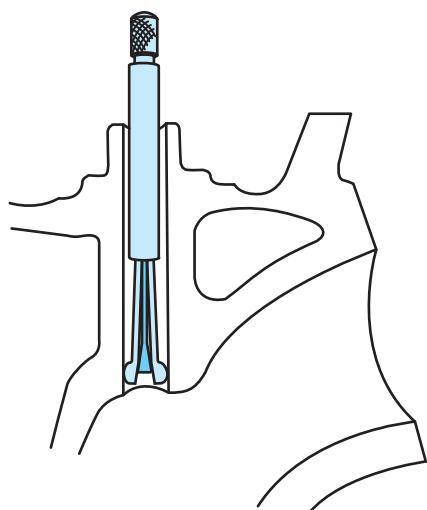


(a)

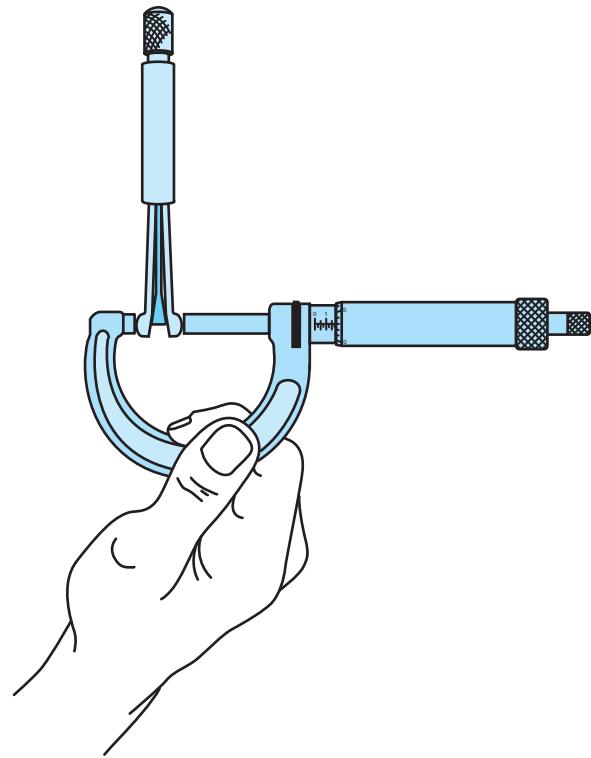


(b)

**FIGURE 7-12** (a) A telescopic gauge being used to measure the inside diameter (ID) of a camshaft bearing. (b) An outside micrometer used to measure the telescopic gauge.



**FIGURE 7-13** Cutaway of a valve guide with a hole gauge adjusted to the hole diameter.



**FIGURE 7-14** The outside of a hole gauge being measured with a micrometer.

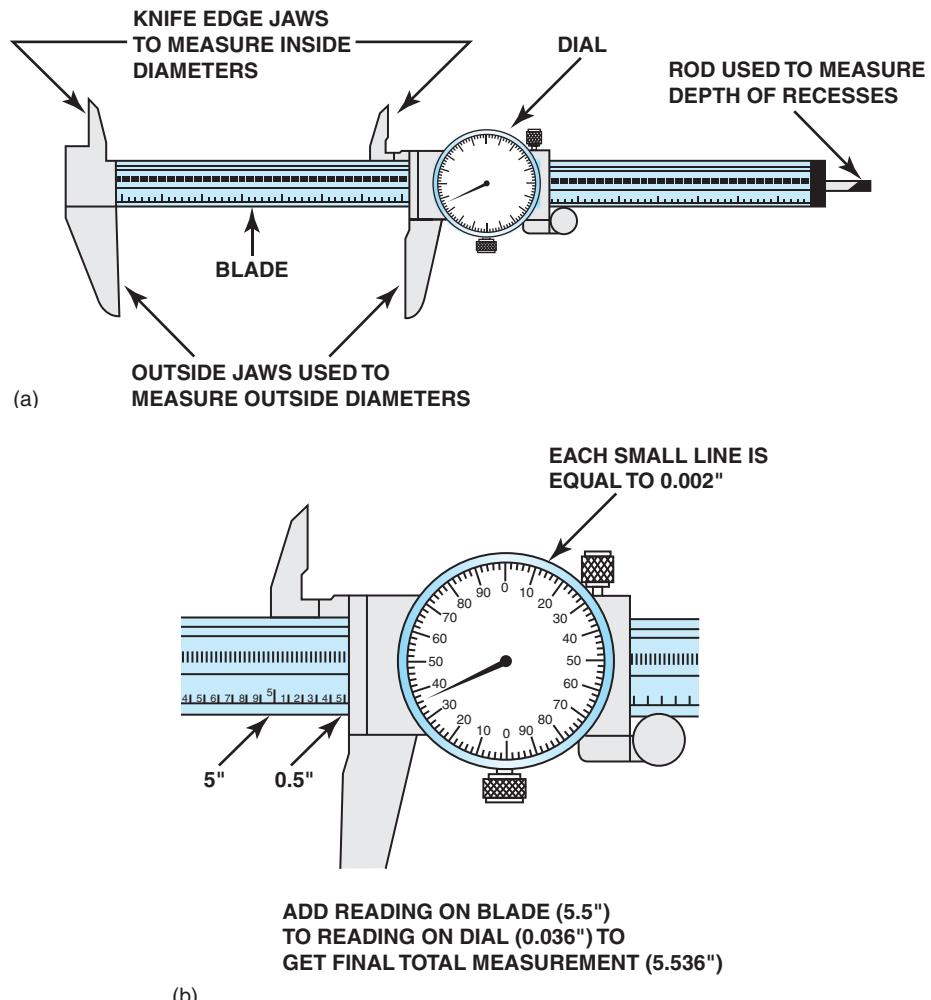


## FREQUENTLY ASKED QUESTION

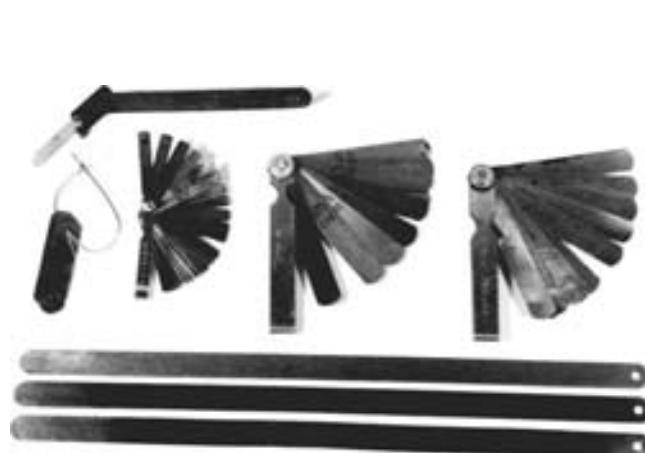
### WHAT IS THE DIFFERENCE BETWEEN THE WORD GAGE AND GAUGE?

The word *gauge* means “measurement or dimension to a standard of reference.” The word *gauge* can also be spelled *gage*. Therefore, in most cases, the words mean the same.

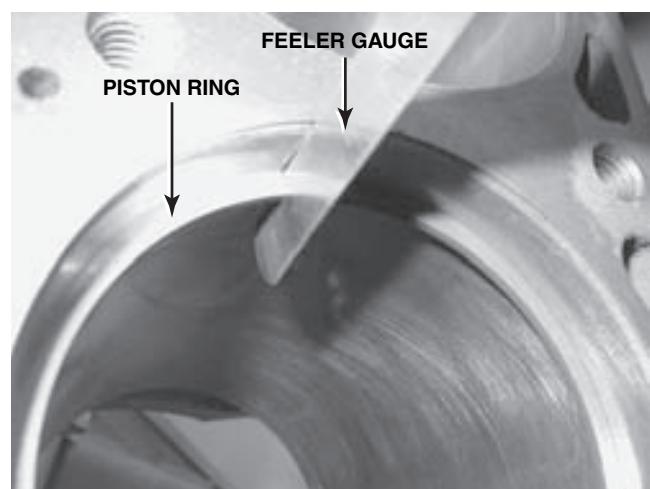
**NOTE:** One vehicle manufacturing representative told me that *gage* was used rather than *gauge* because even though it is the second acceptable spelling of the word, it is correct and it saved the company a lot of money in printing costs because the word *gauge* has one less letter! One letter multiplied by millions of vehicles with gauges on the dash and the word *gauge* used in service manuals adds up to a big savings to the manufacturer.



**FIGURE 7-15** (a) A typical vernier dial caliper. This is a very useful measuring tool for automotive engine work because it is capable of measuring inside and outside measurements. (b) To read a vernier dial caliper, simply add the reading on the blade to the reading on the dial.



**FIGURE 7-16** A group of feeler gauges (also known as thickness gauges), used to measure between two parts. The long gauges on the bottom are used to measure the piston-to-cylinder wall clearance.



**FIGURE 7-17** A feeler gauge, also called a thickness gauge, is used to measure the small clearances such as the end gap of a piston ring.

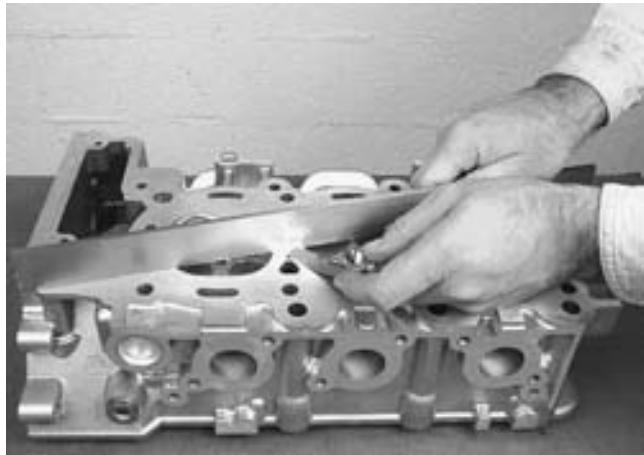
## DIAL INDICATOR

A dial indicator is a precision measuring instrument used to measure crankshaft end play, crankshaft runout, and valve guide wear. A dial indicator can be mounted three ways, including:

- **Magnetic mount.** This is a very useful method because a dial indicator can be attached to any steel or cast iron part.
- **Clamp mount.** A clamp-mounted dial indicator is used in many places where a mount could be clamped.
- **Threaded rod.** Using a threaded rod allows the dial indicator to be securely mounted, such as shown in Figure 7-19.

## DIAL BORE GAUGE

A dial bore gauge is an expensive, but important, gauge used to measure cylinder taper and out-of-round as well as main



**FIGURE 7-18** A straightedge is used with a feeler gauge to determine if a cylinder head is warped or twisted.

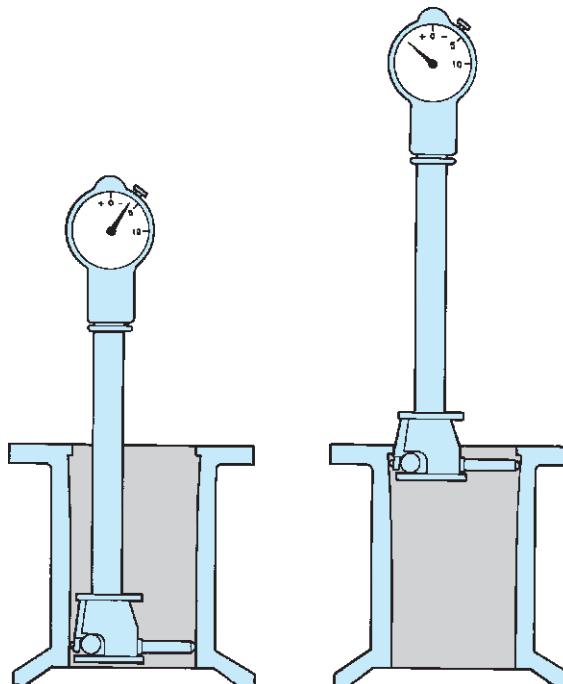


**FIGURE 7-19** A dial indicator is used to measure valve lift during flow testing of a high performance cylinder head.

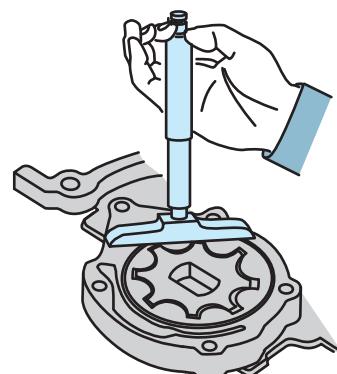
bearing (block housing) bore for taper and out-of-round. See Figure 7-20. A dial bore gauge has to be adjusted to a dimension, such as the factory specifications. The reading on the dial bore gauge then indicates plus (+) or minus (-) readings from the predetermined dimension. This is why a dial bore is best used to measure taper and out-of-round because it shows the difference in cylinder or bore rather than an actual measurement.

## DEPTH MICROMETER

A depth micrometer is similar to a conventional micrometer except that it is designed to measure the depth from a flat surface. See Figure 7-21.



**FIGURE 7-20** A dial bore gauge is used to measure cylinders and other engine parts for out-of-round and taper conditions.



**FIGURE 7-21** A depth micrometer being used to measure the height of the rotor of an oil pump from the surface of the housing.

## SUMMARY

1. A tape measure or machinist rule can be used to measure linear distances.
2. A micrometer can measure 0.001 inch by using a thimble that has 40 threads per inch. Each rotation of the thimble moves the thimble 0.025 inch. The circumference of the thimble is graduated into 25 marks, each representing 0.001 inch.
3. A micrometer is used to check the diameter of a crankshaft journal as well as the taper and out-of-round.
4. A camshaft bearing and lobe can be measured using a micrometer.
5. A telescopic gauge is used with a micrometer to measure the inside of a hole or bore, such as the big end of a connecting rod or a cylinder bore.
6. A small-hole gauge (also called a split-ball gauge) is used with a micrometer to measure small holes such as the inside diameter of a valve guide in a cylinder head.
7. A vernier dial caliper is used to measure the outside diameter of components such as pistons or crankshaft bearing journals.
8. A feeler gauge (also called a thickness gauge) is used to measure the gap or clearance between two components such as piston ring gap, piston ring side clearance, and connecting rod side clearance. A feeler gauge is also used with a precision straightedge to measure the flatness of blocks and cylinder heads.
9. A dial indicator and dial bore gauge are used to measure differences in a component such as crankshaft end play (dial indicator) or cylinder taper (dial bore gauge).

## REVIEW QUESTIONS

1. Explain how a micrometer is read.
2. Describe how to check a crankshaft journal for out-of-round and taper.
3. List engine components that can be measured with the help of a telescopic gauge.
4. List the gaps or clearances that can be measured using a feeler (thickness) gauge.
5. Explain why a dial bore gauge has to be set to a dimension before using.

## CHAPTER QUIZ

1. The threaded movable part that rotates on a micrometer is called the \_\_\_\_\_.  
  - a. Barrel
  - b. Thimble
  - c. Spindle
  - d. Anvil
2. To check a crankshaft journal for taper, the journal should be measured in at least how many locations?  
  - a. One
  - b. Two
  - c. Four
  - d. Six
3. To check a crankshaft journal for out-of-round, the journal should be measured in at least how many locations?  
  - a. Two
  - b. Four
  - c. Six
  - d. Eight
4. A telescopic gauge can be used to measure a cylinder bore if what other measuring device is used to measure the telescopic gauge?  
  - a. Micrometer
  - b. Feeler gauge
  - c. Straightedge
  - d. Dial indicator

5. To directly measure the diameter of a valve guide in a cylinder head, use a micrometer and a \_\_\_\_\_.
  - a. Telescopic gauge
  - b. Feeler gauge
  - c. Small-hole gauge
  - d. Dial indicator
6. Which of the following *cannot* be measured using a feeler gauge?
  - a. Valve guide clearance
  - b. Piston ring gap
  - c. Piston ring side clearance
  - d. Connecting rod side clearance
7. Which of the following *cannot* be measured using a straight-edge and a feeler gauge?
  - a. Cylinder head flatness
  - b. Block deck flatness
  - c. Straightness of the main bearing bores
  - d. Straightness of the cylinder bore
8. Which measuring gauge needs to be set up (adjusted) to a fixed dimension before use?
  - a. Dial indicator
  - b. Dial bore gauge
  - c. Vernier dial gauge
  - d. Micrometer
9. The freezing point of water is \_\_\_\_\_.
  - a. 0°C
  - b. 32°F
  - c. 0°F
  - d. Both a and b
10. Which metric unit of measure is used for volume measurement?
  - a. Meter
  - b. cc
  - c. Centimeter
  - d. Millimeter