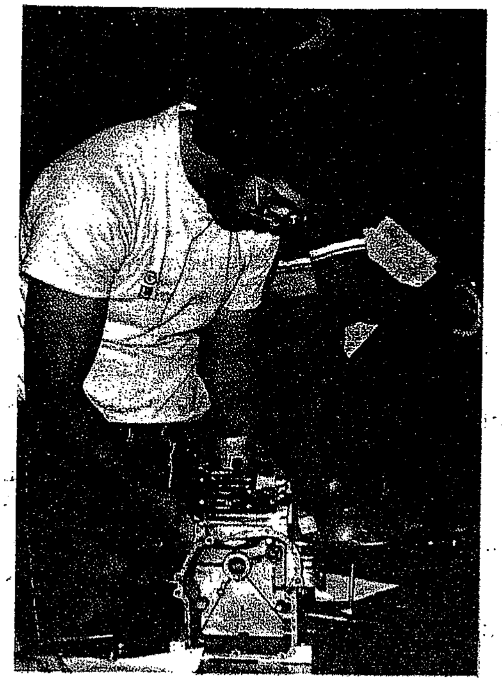

unit 4

using measuring systems and tools

The small engine and each of its parts is mac with a great deal of precision. The need for prec sion does not stop at the end of the assembly lin Precision is an important part of service. Th mechanic is furnished with specifications, tole ances and clearances which must be correct or th engine will not work properly. To use these spec fications, a mechanic must be able to measu precisely. The purpose of this unit is to explain th two measuring systems the mechanic must us and to present the precision measuring tools use in small-engine service. In later units we will se how these tools are used to measure engine parts

LET'S FIND OUT: **When you finish reading and studying this unit, you should be able to:**

1. **Explain the customary measuring system and use the customary units.**
2. **Explain the metric system of measurement and use the metric units.**
3. **Convert between the customary and metric system units.**
4. **Identify and describe the purpose of the common measuring tools.**
5. **Read the measuring scales on precision measuring tools**

THE CUSTOMARY SYSTEM OF MEASUREMENT

The customary system of measurement is one of two main measuring systems used in the world today. Originally it was the most important system. It is still the most common system used in the United States.

The customary system may be divided int units of length-measurement and units of weig or mass measurement. These units are shown Figure 4-1. For our purposes, units of weight o mass are not very important to engine servic Units of length measurement are very importa because most specifications the small-engi mechanic uses are measurements of length.

ENGLISH SYSTEM MEASUREMENT UNITS

UNITS OF LENGTH MEASUREMENT			
12	INCHES	=	1 FOOT
3	FEET	=	1 YARD
51/2	YARDS	=	1 ROD
UNITS OF WEIGHT MEASUREMENT			
16	DRAMS	=	1 OUNCE
16	OUNCES	=	1 POUND

Figure 4-1. Customary system units.

One foot may be divided into 12 inches. Small-engine specifications often are written in terms of a part of an inch. Two systems are used in subdividing an inch: fractions and decimals.

Fractions

1 in. (one inch)
1/2 in. (one half inch)
1/4 in. (one quarter inch)
1/8 in. (one eighth inch)
1/16 in. (one sixteenth inch)
1/32 in. (one thirty-second inch)
1/64 in. (one sixty-fourth inch)

A typical ruler is divided into these units. The smallest division of a rule is 1/64 of an inch, about equal to the thickness of a fingernail. Often it is necessary to make measurements much smaller than 1/64 of an inch. This is made possible by the decimal system of dividing an inch. With this system, the inch is divided by ten, this in turn by ten, and so on as shown below:

Decimals

1.0 in. (one inch)
0.1 in. (one-tenth inch)
0.01 in. (one-hundredth inch)
0.001 in. (one-thousandth inch)
0.0001 in. (one-ten-thousandth inch)

Many small-engine components must be measured to within one thousandth of an inch (0.001). Some specifications require a mechanic to measure as closely as one-ten-thousandth of an inch (0.0001). By comparison, a human hair is about three thousandths of an inch (0.003) thick.

THE METRIC SYSTEM OF MEASUREMENT

Up to 1790, each country and area used a different type of measuring system, making trade very difficult. The French government realized that a single, simple measuring system would benefit all countries. Today this metric system is used by most of the countries in the world. The United States is one of the last countries to adopt it. Since the changeover from the customary to the metric system will take a long time, a small-engine mechanic must be familiar with both systems.

The French also realized that it would not be practical to measure very small and very large things with the same units. For example, the measurement of a human hair and a soccer field require different units. The problem was solved very well. In the metric system, larger and smaller units are defined from the basic meter in decimal steps. Their names are formed by adding one of the prefixes shown in Figure 4-2 to the word "meter" (in French, "metre").

Using these prefixes, it is easy to describe lengths of any size. For example, a human hair may be measured in millimeters, the length of a soccer field in meters and the distance from the earth to the sun in gigameters.

Another convenient part of the metric system is that each prefix can be abbreviated with a symbol, as shown in Figure 4-2. The symbol for the meter is m. To this symbol can be added the prefix symbol. For example, 1,000 meters may be written 1,000 m, or, since a kilometer is equal to 1,000 meters, it may be written 1 kilometer or simply 1 km. Similarly, one thousandth of a meter may be written 1 millimeter or simply 1 mm.

NUMBER OF METERS	PREFIX	SYMBOL
1 000 000 000	gigameter	Gm
1 000 000	megameter	Mm
1 000	kilometer	km
100	hectometer	hm
10	decameter	dam
1	meter	m
0.1	decimeter	dm
0.01	centimeter	cm
0.001	millimeter	mm

Figure 4-2. Units, prefixes and symbols used in the metric system.

CONVERTING BETWEEN CUSTOMARY AND METRIC SYSTEM UNITS

Since both the customary and the metric systems are used in this country, frequently it is necessary to convert units from one system to another. A mechanic may find a specification written in millimeters but have measuring tools that measure in thousandths of an inch. Conversion charts provide a means of switching from one system to another. A conversion chart lists units of one system in one column and their equivalents from the other system beside them in a second column. A conversion chart is located in the appendix of this book.

It also is possible to make the changes yourself, by multiplying by a number called a conversion factor. The conversion factors are shown in Figure 4-3. If a specification is written as 10 mm (ten millimeters) and you want to know what this is in inches, you use the conversion factor as follows:

Multiply 10 mm by the conversion factor in Figure 4-3, .03937:

TO FIND		MULTIPLY	×	CONVERSION FACTORS
MILLIMETERS	=	INCHES	×	25.40
CENTIMETERS	=	INCHES	×	2 540
CENTIMETERS	=	FEET	×	32.81
METERS	=	FEET	×	.3281
KILOMETER	=	FEET	×	.0003281
KILOMETER	=	MILES	×	1.609
INCHES	=	MILLIMETERS	×	.03937
INCHES	=	CENTIMETERS	×	.3937
FEET	=	CENTIMETERS	×	30.48
FEET	=	METERS	×	.3048
FEET	=	KILOMETERS	×	3048.
YARDS	=	METERS	×	1.094
MILES	=	KILOMETERS	×	.6214

Figure 4-3. Converting from customary to metric units.

10 mm × .03937 = .3937 inches
10 mm is equal to .3937 inch

In order to change 5 miles into kilomet multiply 5 miles by the conversion factor in l ure 4-3, 1.609:

5 miles × 1.609 = 8.045 kilometers
5 miles is equal to 8.045 kilometers

USING MEASURING TOOLS

In this section we will examine the measur tools or instruments commonly used by the sm engine mechanic. In each case, both the custc ary and the metric measuring tool will presented.

Rule

The rule or ruler is the simplest of all measuri tools. A rule is a flat length of wood, paper, plas or metal divided, or graduated, into a number spaces. Rules using the customary system of me sure are usually six or twelve inches long, Figu 4-4. Each inch is divided into several parts. Soı rules divide the inch into 8, 16 or 32 parts. Pre sion machinist rules go to 1/64 inch. This is t smallest division of an inch that can be read wi the unaided eye.

The rule shown in Figure 4-5 is divided in metric units. Metric rules commonly are subc vided into centimeters and millimeters. Soı metric rules are further divided into .5 millimet spaces. Reading the metric rule is easier tha reading the customary rule because there is n need to add fractions.

Another metric rule is shown in Figure 4- This rule is 100 centimeters long. Every sma mark is one millimeter. Every 10th mark is larg and is equal to one centimeter. Alongside t

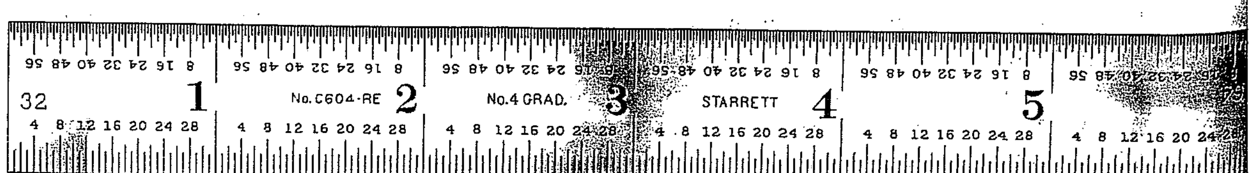

Figure 4-4. Customary system rule. (L. S. Starrett Co.)

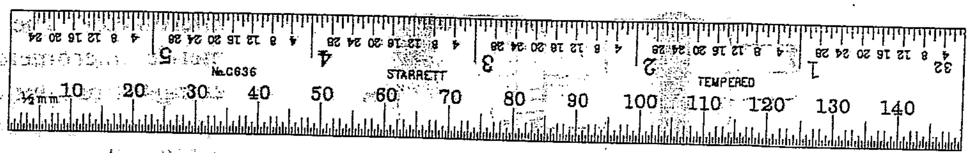

Figure 4-5. Metric system rule. (L. S. Starrett Co.)

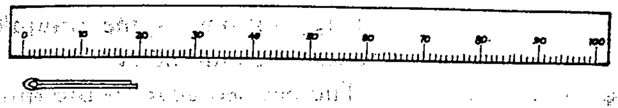

Figure 4-6. Measuring with a metric rule.

metric rule in Figure 4-6 is a cotter pin. The length of the cotter pin may be measured as 20 millimeters or two centimeters. Remember that the relationship between a centimeter and a millimeter is the same as between a dime and a penny. (Ten millimeters equals one centimeter).

Outside Micrometer

Outside micrometers, commonly called "mikes," provide the most precise measurements required for general engine service. Micrometers are made in different sizes and shapes and for a number of special purposes. For most measuring jobs, however, the standard outside micrometer shown in Figure 4-7 is used. These micrometers are marked with either customary or metric measuring units.

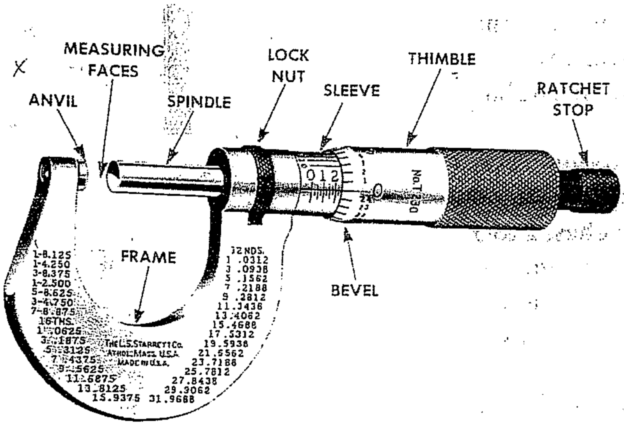

Figure 4-7. Parts of a micrometer. (L. S. Starrett Co.)

The basic parts of the micrometer, shown in Figure 4-7, are a frame, anvil, spindle, sleeve and thimble. The measuring surfaces are at the ends of the stationary anvil and the movable spindle. The spindle is actually an extension of a precision-ground screw which threads into the sleeve. The other end of the screw is attached to the thimble. So, turning the thimble moves the spindle toward or away from the anvil.

The item to be measured is placed between the anvil and spindle faces. The spindle is rotated by means of the thimble until the anvil and spindle both contact the item to be measured. The dimension is then found from the micrometer reading shown by the gradations on the sleeve and thimble.

Reading a Customary System Micrometer. The spindle is attached to a screw that is ground to extremely accurate specifications. One revolution of the spindle moves it .025 inch toward or away from the anvil. So, 40 turns of the thimble will move the spindle exactly one inch (40 × .025″ = 1.000″).

A scale on the sleeve is divided into 40 gradations, each equal to .025 inch. So, starting with the spindle against the anvil, and turning the screw out, every revolution of the thimble will uncover one of the divisions on the sleeve. Every fourth division is numbered, starting with the zero mark, when the spindle is against the anvil. The next numbered division is at .100 inch from the closed position. (This is the same as 1/10 of an inch.) The three unnumbered divisions between zero and one are .025, .050 and .075 inch.

The bevel on the front of the thimble also is divided into equal parts. And, since the thimble and spindle travel .025 inch per revolution, there are 25 divisions on the bevel. These divisions make it possible to read the amount of spindle travel for partial revolutions. For instance, a partial revolution from one thimble mark to the next is 1/25 of a revolution and moves the spindle .001

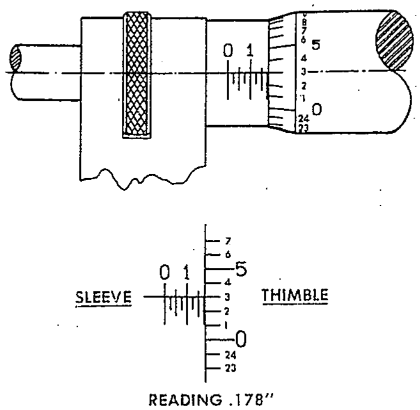

Figure 4-8. A micrometer reading of .178". (L. S. Starrett Co.)

inch. Reading a measurement taken with micrometers is a simple matter of addition. In other words, add together the last visible numbered division on the sleeve, the unnumbered sleeve divisions and the divisions on the bevel of the thimble.

To help explain, look at the illustration shown in Figure 4-8. The 1 line on the sleeve is visible, representing .100". There are three additional lines visible, each representing .025" (3 × .025" = .075"). Line three on the thimble coincides with the longitudinal line on the sleeve, each line representing .001" (3 × .001 = .003"). The micrometer reading is .178" (.100 + .075 + .003). An easy way to remember is to think of the various units as if you were making change from a $10 bill. Count the figures on the sleeve as dollars, the vertical lines on the sleeve as quarters, and the divisions on the thimble as cents. Add up your change and put a decimal point instead of a dollar sign in front of the figures.

The micrometer we have been studying up to this point has a range from 0 to 1 inch. Micrometers are made in many sizes — 1 to 2 inches, 2 to 3 inches and on up to measure large components. Adapters are available for the larger micrometers to give them multiple ranges. These are used exactly as the 0 to 1 inch micrometer.

Reading a Metric System Micrometer. A metric micrometer has the same parts and works in exactly the same way as an customary system micrometer. The pitch of the spindle scre metric micrometers is 0.500 millimeters. complete revolution of the thimble advance spindle toward or away from the anvil ex 0.500 millimeters. Two complete revolution the thimble move the spindle exactly millimeter.

The longitudinal line on the sleeve is gradu in millimeters from 0 to 25 and each millimet subdivided into 0.5 mm. Therefore, it req two revolutions of the thimble to advance spindle one millimeter.

The beveled edge of the thimble is gradu into 50 divisions, from 0 to 50, with every fifth being numbered. Since a complete revolutio the thimble advances the spindle 0.5 mm, gradation on the thimble is equal to 1/50 of mm or 0.01 mm. Two gradations equal 0.02 etc.

To read a metric micrometer, add the t reading in millimeters visible on the sleeve to reading in hundredths of a millimeter on thimble.

For example, refer to Figure 4-9:

The 5 mm mark is visible on the sleeve, rep enting 5.00 mm.

There is one additional 0.5 mm line visi representing 0.50 mm.

Line 28 on the thimble coincides with the lo tudinal line on the sleeve, each line represen 0.1 mm (28 × .01 mm = 0.28 mm).

The micrometer reading is 5.78 mm.

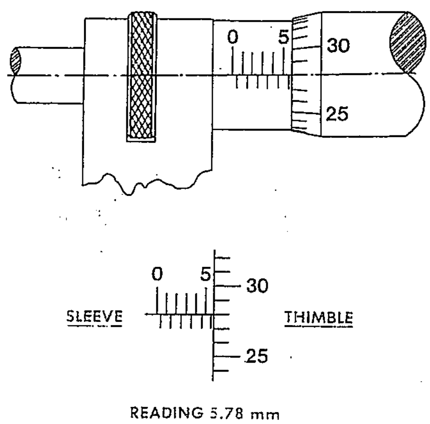

Figure 4-9. A micrometer reading of 5.78 mm. (L Starrett Co.)

Use and Care of the Micrometer. There really is no trick to reading a micrometer, but there are some things to keep in mind when you are taking the measurement. For instance, there is a right way to hold the micrometer when measuring an object. The most convenient way is with one hand. Insert one finger through the frame and use the thumb and forefinger to turn the spindle, as shown in Figure 4-10. With a little practice, you will find that this will give you the best control over the position of the anvil and spindle.

It is impossible to get a correct measurement with a micrometer unless the anvil and spindle are at right angles to the piece being measured. If they are cocked to one side, you will get an oversize reading. And, if you are measuring a diameter, make sure the spindle and anvil are centered exactly across the diameter; otherwise, the reading will be undersize. To avoid cocking and to assure being on the true diameter, hold the micrometer loosely, and gently turn the spindle down against the workpiece. Rocking the micrometer ever so slightly as you turn the spindle down the last few thousandths will enable you to tell by "feel" alone when the micrometer is square with the part and centered on the diameter.

Probably the most important thing to observe when you are measuring with a micrometer is the amount of force you use to tighten the spindle down onto the part. The spindle and anvil should just contact the part lightly, so there is a slight drag when the micrometer is moved back and forth. Just keep in mind that a micrometer is a precision tool, not a C-clamp.

If you crank the spindle down too hard, not only will you get an incorrect reading, but you might also distort the frame. Once the frame is distorted, the micrometer is useless. Some micrometers have a ratchet on the end of the thimble. Unless you have a good "feel" for the correct tightness, turn the ratchet instead of the thimble to avoid overtightening.

Sometimes you want to run the spindle in or out in a hurry to measure another workpiece. If you do, hold the frame in one hand and roll the thimble along the other arm or along the palm of the hand.

When the micrometer is not in use, it should be stored in a box in a safe place where tools will not be dropped on it accidentally. Make sure the spindle is backed off slightly, away from the anvil.

As with any other precision tool, a micrometer occasionally should be checked for accuracy. Use a master gage to check the maximum and minimum limits of measurement. For instance, to check a one-inch micrometer, use the master, which is exactly one inch in diameter. Then, run the spindle down gently against the anvil and check for a zero reading. Always make sure the spindle and anvil are clean before checking.

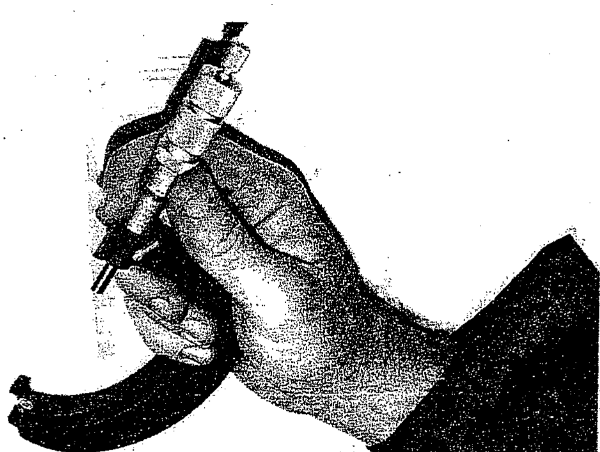

Figure 4-10. This is how to hold a micrometer.

Inside Micrometer

Another very useful measuring tool, an inside micrometer, is shown in Figure 4-11. This tool is especially valuable when boring and honing cylinders. An inside micrometer is used to measure holes. The same micrometer is used to measure many different diameters. As shown in Figure 4-12, measuring rods and spacing collars of different lengths are supplied with the microme-

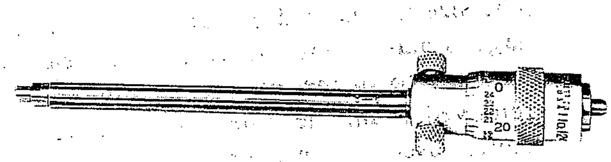

Figure 4-11. An inside micrometer is used to measure the inside of cylinders. (L. S. Starrett Co.)

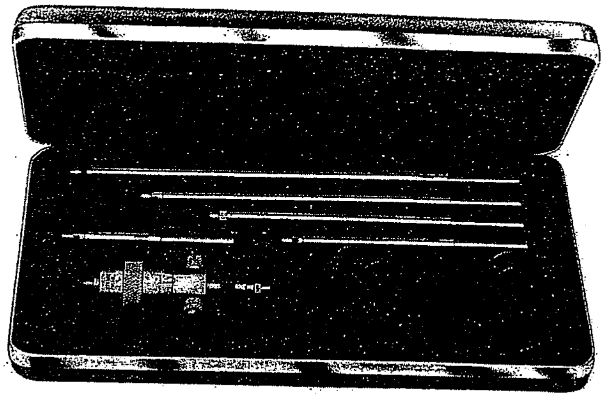

Figure 4-12. An inside micrometer is used with a selection of rods of different lengths. (L. S. Starrett Co.)

ter. Different ranges of measurement are possible by assembling different rods in the micrometer head.

The scale on the inside micrometer works and is read exactly like that for the outside micrometer. Inside micrometers are made in both customary and metric system scales. While the scales are the same, it will take a little more practice to get an accurate measurement with an inside micrometer. It is easy to get it cocked in the bore and get an incorrect reading. To get an accurate measurement, make sure the micrometer is at right angles to the centerline of the bore. Then, move one end back and forth slightly to get the maximum reading on the scales. It is always a good idea to take two or three additional readings just to check yourself.

Small-Hole Gage

When it is necessary to measure the inside of a hole that is too small for an inside micrometer, a small-hole gage, Figure 4-13, is used. This tool consists of a split sphere, the diameter of which can be changed by means of an internal wedge. The size is changed by turning the handle. The gage is placed into the hole to be measured and adjusted to fit the internal dimension. It is then removed from the hole and an outside micrometer used to measure the diameter of the expanded ball. Small-hole gages are available in

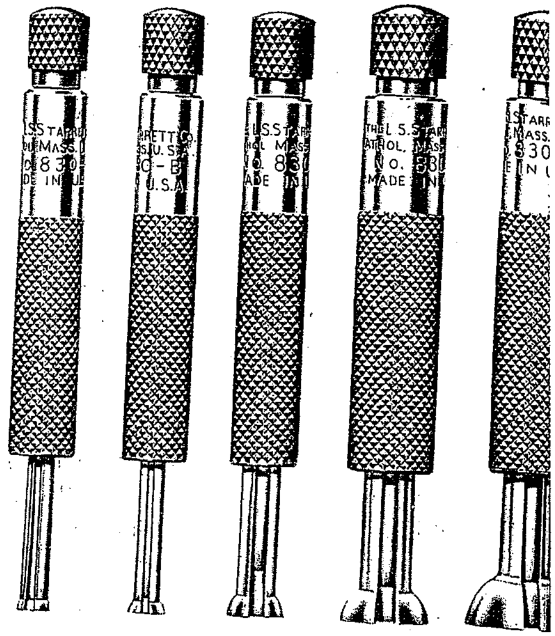

Figure 4-13. Set of small hole gages. (L. S. Sta
Co.)

sets that cover a range from 3 mm to 12 mm (.
to .500 inch).

Telescoping Gage

The telescoping gage, Figure 4-14, gets
name from the fact that it consists of a spri
loaded piston which telescopes within a cylind

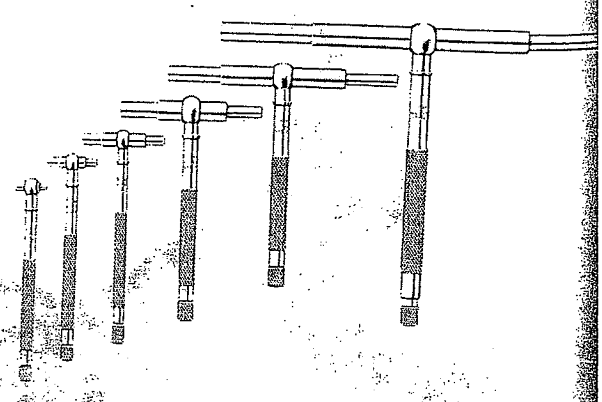

Figure 4-14. Set of telescoping gages. (L. S. Starre
Co.)

It is used with an outside micrometer to measure the inside dimension of a hole. Telescope gages are made in sets, such as that shown in Figure 4-14, to cover a range from very small to very large holes.

The gage is placed into the hole, permitting the spring-loaded piston to expand to the size of the hole. After the proper "feel" is obtained, the handle is turned to lock the piston in position. The exact size of the hole is then found by removing the gage and measuring across the two contacts with an outside micrometer.

Feeler Gage

A feeler gage is a tool used to measure accurately the space between two surfaces, such as breaker points or the gap between the two electrodes on spark plugs. A feeler gage is a flat blade or round wire made to a very precise thickness. The thickness is written on the gage in thousandths of an inch or hundredths of a millimeter. A feeler gage is used by placing it in the space to be measured. If the gage and the space are the same size, the gage will feel tight as it is moved in and out. Feeler gages usually come in sets. A set of metric feeler gages is shown in Figure 4-15. A set of customary system feeler gages is shown in Figure 4-16.

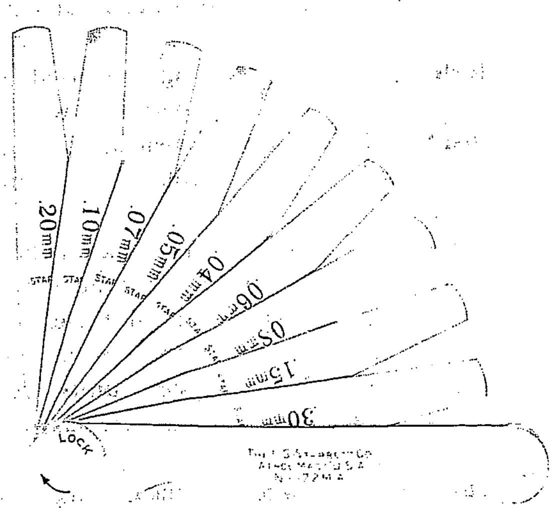

Figure 4-15. Metric feeler gage set. (L. S. Starrett Co.)

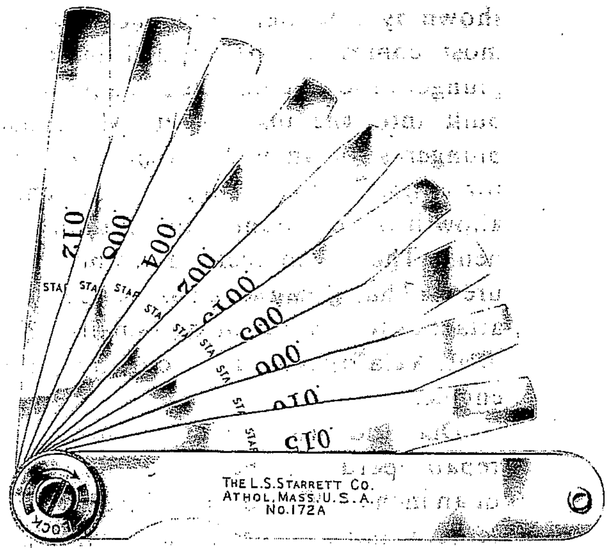

Figure 4-16. Customary feeler gage set. (L. S. Starrett Co.)

Dial Indicator

A dial indicator is a gage that is used to measure the movement, or "play," and the contour, or "runout," of an engine part. The measurement is

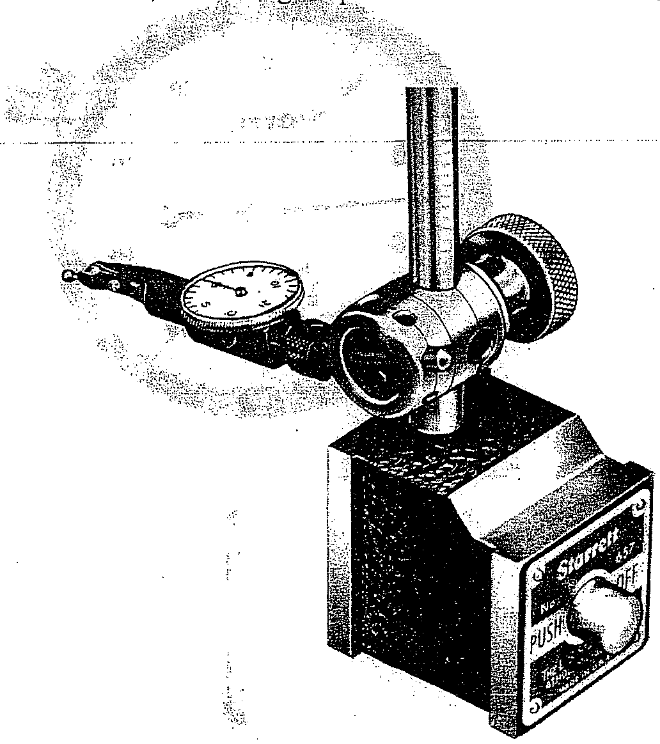

Figure 4-17. A dial indicator attached to a magnetic base. (L. S. Starrett Co.)

shown by a pointer on the face of the gage. The most common type of dial indicator uses a plunger or lever connected to a pointer by a gear built into the instrument. Movement of the plunger is shown by the pointer. The dial indicator is used with a number of attachments that allow it to be mounted on small-engine components. The dial indicator assembly shown in Figure 4-17 has a magnetic base which allows it to be attached to any iron or steel small-engine component. A clamp is used to mount it to an aluminum engine.

Dial indicators used in most small-engine repair operations measure either in thousandths of an inch (0.001″) or in hundredths of a millimeter (0.01 mm). A typical customary dial indicator face is shown in Figure 4-18. The scale is divided into 100 divisions. Each of the divisions represents .001 of an inch. The pointer in Figure 4-18 is pointing to 75 on the scale. This means that t plunger has moved to measure a distance of .0

When mounting a dial indicator, keep the su port arms as short as possible. If the arms are t long, the setup will not be rigid enough, and inaccurate reading may result. The spring load the indicator plunger can move the whole indic tor assembly.

Mount the indicator in a position that w place the plunger directly against the part. If t anvil is at an angle, the anvil plunger will subject to frictional drag, causing an incorre reading. The friction will cause the whole indic tor assembly to move, instead of just the anvil a plunger. Always read the dial indicator straig on. Looking at it from the side can cause consi erable error. Remember that a dial indicator is precision instrument like a watch. It must handled with great care.

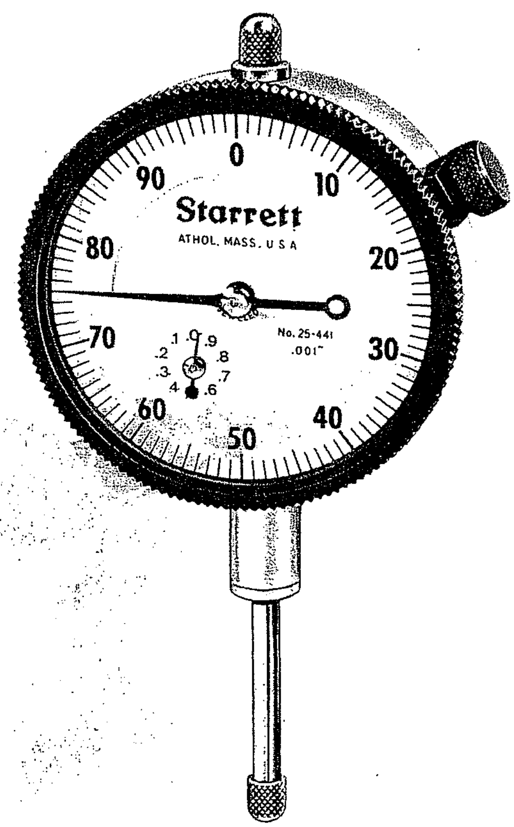

Figure 4-18. A dial indicator reading of .075. (L. S. Starrett Co.)

NEW TERMS

customary measuring system: One of two ma measuring systems in use in the world. Mo common system used in the United States.

customary system units: Units are based on th yard measurement. The yard is divided into fe and inches.

dial indicator: A gage used to measure move ment, or "play," and contour, or "runout," of small-engine part.

feeler gage: A measuring tool used to measu accurately the space between two surfaces.

inside micrometer: A measuring tool used t measure the size of holes such as small-engin cylinders.

metric measuring system: One of the two ma measuring systems in use in the world. Used fo a long time in other countries, it is bein adopted gradually in the United States.

metric units: Metric system units are based o the meter. Measurements are based on decima steps of the meter.

outside micrometer: A measuring tool used t measure the outside of an object such as crankshaft or piston.

rule: The simplest of all measuring tools. It is a flat length of wood, plastic or metal divided into a number of measuring units.

small hole gage: A measuring tool consisting of a split sphere and an internal wedge, used to measure the inside of small holes such as valve guides.

telescoping gage: A measuring tool with a spring-loaded piston that telescopes within a cylinder. It is used to measure the inside of a hole.

SELF CHECK

1. List the divisions of an inch between 1 inch and 1/64 inch.
2. Write the following parts of an inch in numerals: one inch, one-tenth inch, one-hundredth inch, one-thousandth inch.
3. List three prefix symbols used with a meter.
4. Explain how measurements can be converted from one measuring system to another.
5. What is the simplest measuring tool?
6. Describe an outside micrometer and explain its purpose.
7. List the five basic parts of an outside micrometer.
8. Describe the precautions that should be followed when using an outside micrometer.
9. How is the inside of a hole measured?
10. How do telescoping gages work?
11. How is the inside of a small hole measured?
12. Describe a feeler gage and explain how it is used.
13. Describe a dial indicator and explain its purpose.
14. What does the term "play" mean when used with a dial indicator?

DISCUSSION TOPICS AND ACTIVITIES

1. Measure the following objects with customary and metric system rules. Record your results.
   Thickness of a penny
   Diameter of a penny
   Width of your thumb
   Your height
   Length of your shoe
2. Use an outside micrometer to measure the diameter of a hair, the diameter of a paper clip and the thickness of a pencil lead.