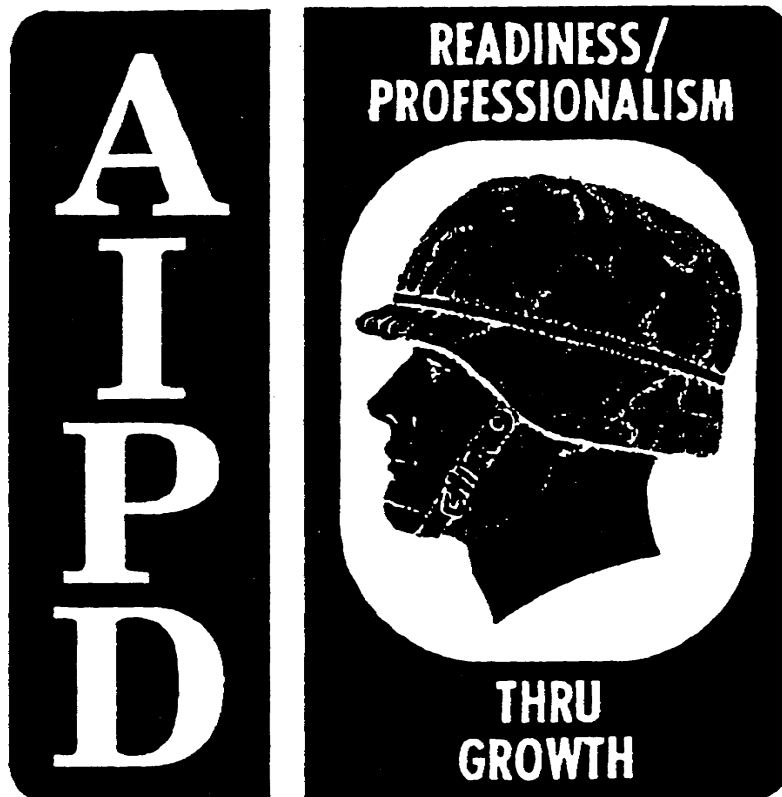
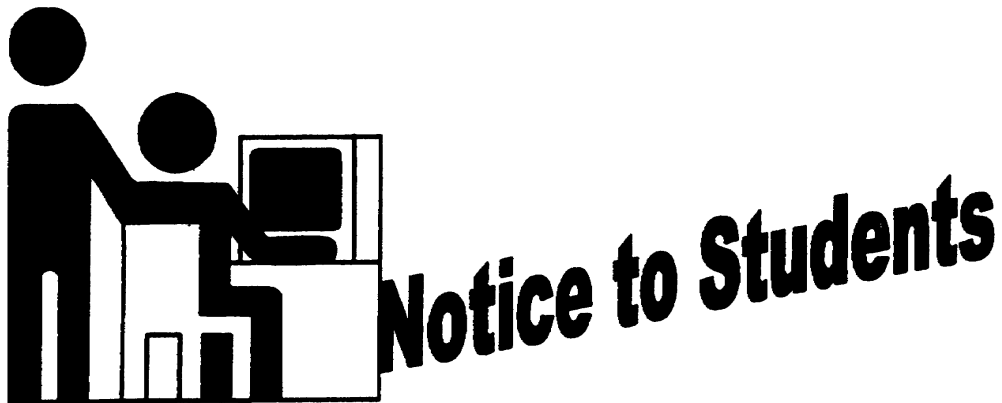

PRECISION MEASURING INSTRUMENTS

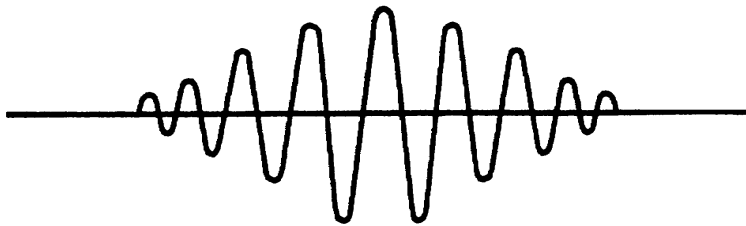


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PRECISION MEASURING INSTRUMENTS

SUBCOURSE OD1401

EDITION 9

**Unites States Army Combined Arms Support Command
Fort Lee, VA 23801-1809**

5 CREDIT HOURS

NEW: 1989

GENERAL

The purpose of this subcourse is to introduce the care and use of three precision measuring instruments: the vernier caliper, the outside micrometer, and the depth micrometer. The proper care, storage, and handling of these instruments will be discussed. The student will learn to interpret readings on and take measurements with the instruments.

Five credit hours are awarded for successful completion of this subcourse.

Upon completion of this subcourse, the student will be able to:

TASK: Care for, interpret readings, and take measurements with a vernier caliper, an outside micrometer, and a depth micrometer.

CONDITIONS: The student will complete the subcourse and examination in a self-study environment, given the subcourse booklet. After successful completion of the examination, the student should be able to perform the task, given TM 9-243.

PRECISION MEASURING INSTRUMENTS - OD 1401

ACTIONS: The student will:

- (1) Care for a vernier caliper, an outside micrometer, and a depth micrometer.
- (2) Interpret readings on a vernier caliper, an outside micrometer, and a depth micrometer.
- (3) Take measurements with a vernier caliper, an outside micrometer, and a depth micrometer.

STANDARD: Demonstrate your comprehension of the task by correctly answering 70% of the questions on the examination.

This subcourse contains one lesson divided into tasks as follows:

LESSON 1: CARING FOR, INTERPRETING READINGS, AND TAKING MEASUREMENTS WITH A VERNIER CALIPER, AN OUTSIDE MICROMETER, AND A DEPTH MICROMETER

TASK 1. Care for a vernier caliper, an outside micrometer, and a depth micrometer.

TASK 2. Interpret readings on a vernier caliper, an outside micrometer, and a depth micrometer.

TASK 3. Take measurements with a vernier caliper, an outside micrometer, and a depth micrometer.

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INTRODUCTION

As a Tank Turret Repairer, you must use many skills each day to perform your job. Some turret components must be replaced or repaired. Others must be overhauled or rebuilt. To do any of these jobs well, you must know how to use the tools of your trade.

Among the many hand tools you must know how to use are three precision measuring instruments: the vernier caliper, the outside micrometer, and the depth micrometer. These precision tools make very accurate measurements. They are used on jobs where tolerances must be exact.

From using other hand tools, you already know that any tool requires proper care and handling. When a tool has proper care, handling, and storage, it will work as it should when you need it. This is especially true of precision measuring tools. Improper care and handling can result in inaccurate measurements. One of the important aspects of this subcourse will be the discussion of how to correctly care for these three tools.

A second task in this subcourse deals with the methods used to correctly read the scales on these tools. When you understand how these scales operate, you will be shown how to interpret the tools' measurement readings.

Finally, in the third task, you will learn the proper methods for using each tool to make an accurate measurement. With normal rules and measuring devices, you rely heavily on your sense of sight. While using these three precision instruments, you must go beyond your sense of sight. You must also learn to "feel" the measurement.

When you finish the subcourse, you should be able to properly care for, use, and interpret readings on a vernier caliper, an outside micrometer, and a depth micrometer. Through proper use and care, these tools will be valuable as you perform your job.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 1

LESSON 1

CARING FOR, INTERPRETING READINGS, AND TAKING MEASUREMENTS WITH A VERNIER CALIPER, AN OUTSIDE MICROMETER, AND A DEPTH MICROMETER

TASK 1. Care for a vernier caliper, an outside micrometer, and a depth micrometer.

CONDITIONS

The student will complete the subcourse and examination in a self-study environment, given the subcourse booklet. After successful completion of the examination, the student should be able to perform the task, given TM 9-243.

STANDARD

Demonstrate your comprehension of the task by correctly answering 70% of the questions on the examination.

GENERAL

The tank turret repairer needs many tools to do a good repair job. Among these are precision measuring tools. These tools make very accurate measurements of size and diameter.

This task will introduce three precision measuring tools: the vernier caliper, the outside micrometer, and the depth micrometer. You will learn about the parts of these tools and the kind of measurement each tool makes. You will also learn the right way to care for these tools.

When you finish this task, you should be ready for task 2. There you will learn to interpret readings taken with each of the three tools. Task 3 will show you how to use the tools to take measurements. First, let's get to know the tools themselves. We start with the vernier caliper.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 1

CALIPERS

Calipers are used to measure point-to-point distances, such as diameters. A diameter is the straight distance across a round object. We also use calipers to compare sizes with standards such as a graduated rule. The vernier caliper is only one of many types of calipers.

Types of Calipers

A tank turret repairer may measure many shapes and sizes. There are several types of calipers to do this job. The repairer's job is easier if the right design of caliper is used. Outside calipers make outside measurements; inside calipers measure inside sizes. Next, we will look at some of the different types of calipers.

Simple Calipers. Simple calipers are used along with a scale. The simple calipers used for outside measurements are bowlegged. Those used for inside diameters have straight legs with feet turned out. You can adjust these calipers by pulling or pushing the legs to open or close them.

Spring-Joint Calipers. The spring-joint calipers are a lot like simple calipers. They are shaped either for inside or outside measurements. They have the same shape of legs, but their legs are joined by a strong spring hinge, screw, and adjustment nut.

Transfer Calipers. Transfer calipers also look a lot like simple calipers. They are used to measure grooves or flanges. One of the legs has a small leaf. Use transfer calipers to measure as you would use simple calipers. Lock the leaf to the leg. Open or close the legs, as needed, to clear whatever is in the way. Then bring the legs back and lock them to the leaf. This brings them to the original setting.

Hermaphrodite Calipers. This caliper is used to find the center of a shaft. It is also used to locate shoulders. It has one straight leg ending in a sharp point. On some models, this point can be removed. One leg is usually bowlegged.

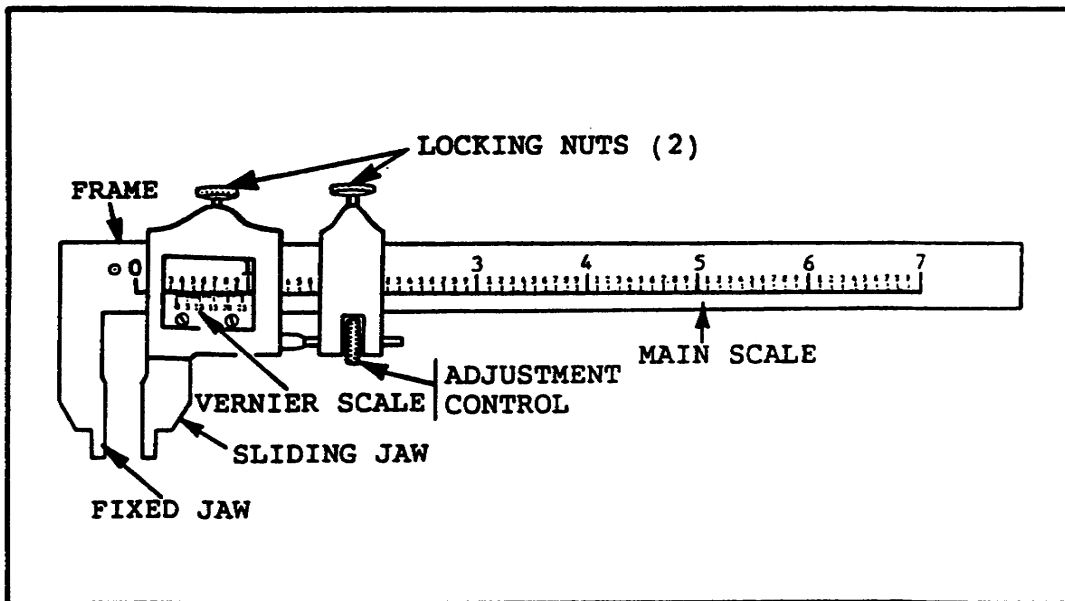
Slide Calipers. Most calipers come in two shapes. One shape measures an outside distance; the other measures an inside distance. A single slide caliper can be used to measure both outside and inside dimensions. One edge of the caliper jaw measures outside, and the other edge measures inside dimensions. Slide calipers have their own scale. The other side of the caliper is used as a straight measuring rule.

Vernier Calipers. Like slide calipers, vernier calipers have jaws that make both inside and outside measures. They have their own scale. They are very accurate. Of the many caliper types, this subcourse only talks about how to use, read, and care for vernier calipers. If you want to know more about other calipers, look in TM 9-243, chapter 6.

THE VERNIER CALIPER

Figure 1 shows a vernier caliper. It has an L-shaped frame with a fixed jaw on one end.

FIGURE 1. THE VERNIER CALIPER.



The long arm of the L has the main (fixed) scale inscribed on it. The main scale is usually a steel rule scale made up of inches divided into 40 increments. Each increment equals 0.025 inch.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 1

Most vernier calipers read "OUTSIDE" on one side and "INSIDE" on the other side. Normally, the scale on the front side is for outside measurements; the scale on the back side is to measure inside dimensions. On some vernier calipers, the metric scale is on the back side. When the metric scale is on the back side, a special method is used to read inside measurements. We will talk about this method in task 2 of this subcourse.

If you loosen the locking nuts, the sliding jaw can move up and down the arm of the caliper. The sliding jaw has the vernier scale on both sides.

The vernier scale is a short scale. It usually has one more graduation on it than the same length on the main scale. For example, 25 divisions on the vernier scale would equal 24 divisions on the steel rule scale.

When the sliding jaw moves up and down the arm, the vernier scale moves up and down the main scale. When you compare the positions of the vernier scale and the main scale, you get a very accurate measurement reading. You will learn how to read these scales in task 2.

The tips of the caliper jaws are formed to make both outside and inside measurements. The inside scale automatically adjusts for the thickness of the jaw tips. The smallest inside measurement with the smallest caliper is 1/4 inch or 6 millimeters (mm).

Vernier calipers are made in standard sizes of 6, 12, 23, 36, and 48 inches; 150, 300, 600, and 900 mm are also standard sizes. The length of the jaws ranges from 1 1/4 inches to 3 1/2 inches. The jaws of all vernier calipers (except the larger sizes) have two center points. These are useful in setting dividers to exact dimensions.

You should now know what a vernier caliper looks like; you should also be able to identify its parts. Next, you will learn how to take care of a vernier caliper. If you take good care of the caliper, you will be able to use it to make very exact measurements.

Care of Vernier Calipers

The accuracy of a vernier caliper depends on how well you have cared for it. This is true no matter what type or size caliper is used. The fit of the sliding jaw and the wear and distortion of the measuring surfaces both effect the accuracy of the caliper. Careful handling and storage habits will also help ensure accuracy.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 1

Care of the Sliding Jaw. The sliding jaw should fit so it moves easily but without any play. You can adjust it by taking off and bending the gib in the sliding jaw assembly. The gib holds the sliding jaw against the blade. The gib uses just the right pressure to give the jaw proper friction.

Care of Measuring Surfaces. Wear on the jaws of the vernier caliper is mostly at the tips. That's where most measurements are made. You can take up some of this wear by adjusting the vernier scale itself. This scale is mounted with screws in long holes. This kind of mounting lets you make small adjustments to make up for wear and distortion. Errors, either in parallelism or flatness, must not be bigger than 0.0002 inch. If larger errors exist, the caliper should be sent to the manufacturer for repair. Check for wear on the jaws by measuring rolls or rings of known sizes.

Handling and Storage. You must handle calipers with care. Do not drop any caliper. Small nicks or scratches can cause inaccurate measurements. Protect the caliper points from damage. Keep the graduations and markings on all calipers clean and readable. Before storing, coat the metal parts of all calipers lightly with oil to prevent rust. Store each caliper in its own container, provided with the caliper.

Vernier Caliper Applications

If you take care of a vernier caliper, it will give you many precise measurements. In fact, the vernier caliper has a wide range of uses. The jaw shape and scale location make this tool more adaptable than a micrometer.

MICROMETERS

Micrometers can make measurements that must be very precise. They are more reliable and more exact than calipers. Standard micrometers can measure distance to the nearest one-thousandth of an inch. Some micrometers have a vernier scale. These micrometers can measure distance to the nearest ten-thousandth of an inch. The measurement is usually written as a decimal.

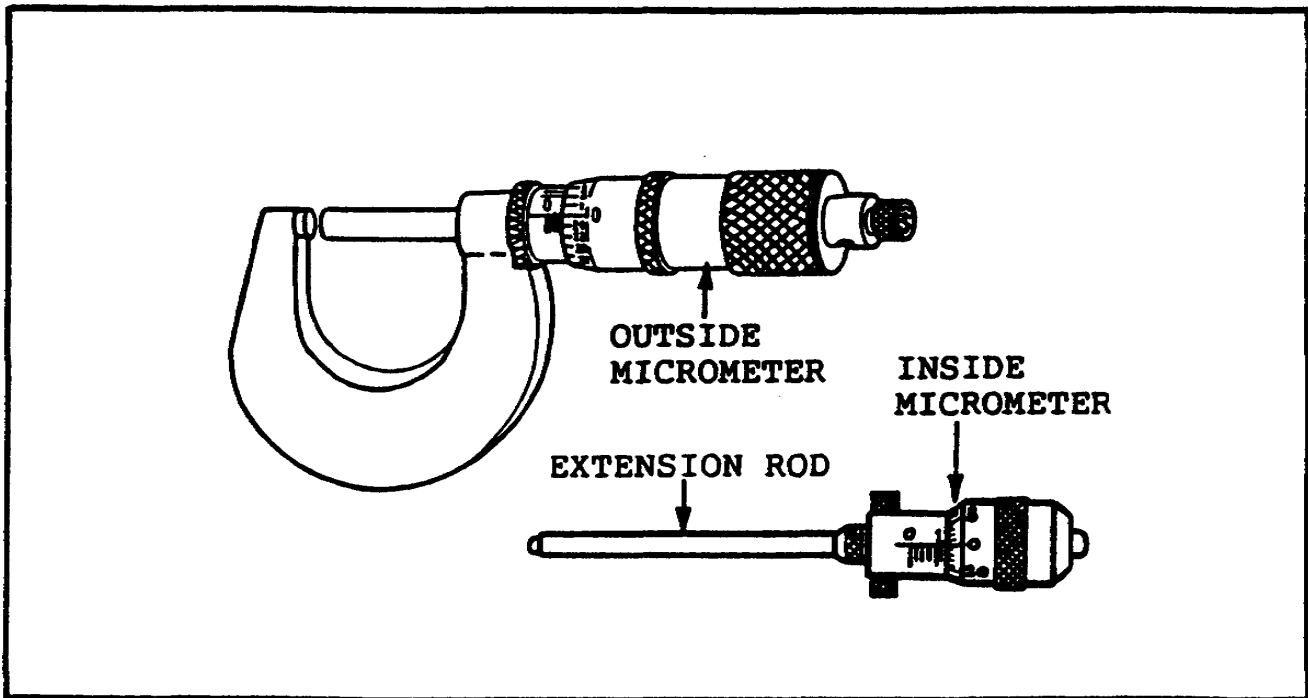
Types of Micrometers

Three types of micrometers are commonly used: the outside micrometer, the inside micrometer, and the depth micrometer.

Outside Micrometers. Outside micrometers (figure 2, below) can measure an outside distance to an accuracy of 0.001 of an inch. Some have a vernier scale. They can measure to the nearest 0.0001 inch. The outside micrometer is sometimes called a micrometer caliper. In this task, you will learn how to care for an outside micrometer. Tasks 2 and 3 will show you how to read and make measurements with outside micrometers.

Inside Micrometers. Inside micrometers (figure 2) measure an inside distance to the nearest 0.001 of an inch. The inside micrometer is just a micrometer head; it uses a set of extension rods to measure a range of sizes. This range is usually from 2 to 10 inches.

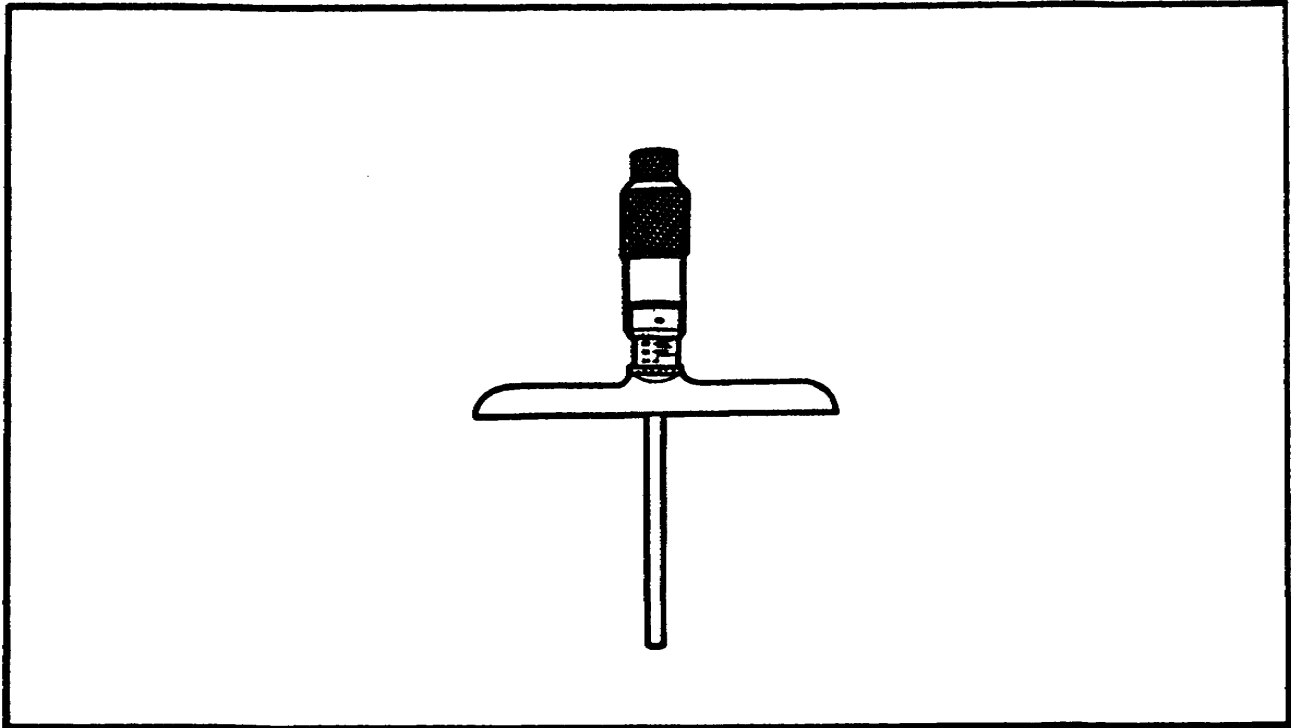
FIGURE 2. OUTSIDE AND INSIDE MICROMETERS.



This subcourse will not describe inside micrometers in detail. If you want to know more about how to use them, look in TM 9-243, chapter 7.

Depth Micrometers. Depth micrometers (figure 3, below) are used to measure depths to the nearest 1/1000 of an inch.

FIGURE 3. DEPTH MICROMETER.



A depth micrometer has a flat base attached to the barrel of a micrometer head. The size of the flat base ranges from 2 to 6 inches. Like the inside micrometer, the depth micrometer uses extension rods in a range of sizes. The hollow micrometer screw itself has a range of either 1/2 or one inch.

You will learn how to take care of a depth micrometer in this task. First, however, it will help to know how a micrometer works.

Micrometer Design

The micrometer design takes advantage of how the straight movement of a screw relates to how much it is turned. Each time you turn a screw, it moves straight forward (or back) by an amount directly related to the turning action. The straight distance a screw moves when turned depends on the thread. When threads are very close to each other, it takes many turns to move the screw a short distance.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 1

The micrometer uses a turning scale and a straight scale. Using these scales together, it can keep precise track of very small distances.

The screw on a micrometer has 40 threads per inch. This means that the screw goes forward (or back) $\frac{1}{40}$ of an inch per full turn. The thimble on a micrometer has its circumference divided into 25 parts. When you turn the screw only the distance of one division on the thimble ($\frac{1}{25}$ of a full turn), its straight movement is $\frac{1}{25}$ times $\frac{1}{40}$ of an inch. This equals $\frac{1}{1000}$ of an inch.

This design lets you use the micrometer to make very exact measurements of different size objects.

Micrometer Size and Range

Since you may need to measure objects in a wide range of sizes, micrometers come in many sizes. On the most common micrometers, the longest movement of the micrometer screw is one inch. This movement is called the range.

On outside micrometers, the longest movement possible between the spindle and the anvil is one inch. The frames of micrometers, however, come in many sizes. Frame size starts at one inch and goes up to as large as 24 inches. The size of an outside micrometer tells the largest size it will measure.

The range of a 1 inch micrometer is from 0 to 1 inch. A 2 inch micrometer has a range from 1 to 2 inches. That is, a 2 inch micrometer will only measure work between 1 and 2 inches thick. A 6 inch micrometer has a range from 5 to 6 inches. It will only measure work between 5 and 6 inches thick.

Inside and depth micrometers also have a 1 inch maximum screw movement. Extension rods are used to measure larger sizes. For example, a depth micrometer fitted with a 2 inch rod will measure depth between 2 and 3 inches. The size of the inside and depth micrometers tells the smallest size it will measure.

Knowing about micrometer design and size will help you to understand how an outside micrometer works. Next we will talk about the parts of outside micrometers.

OUTSIDE MICROMETER

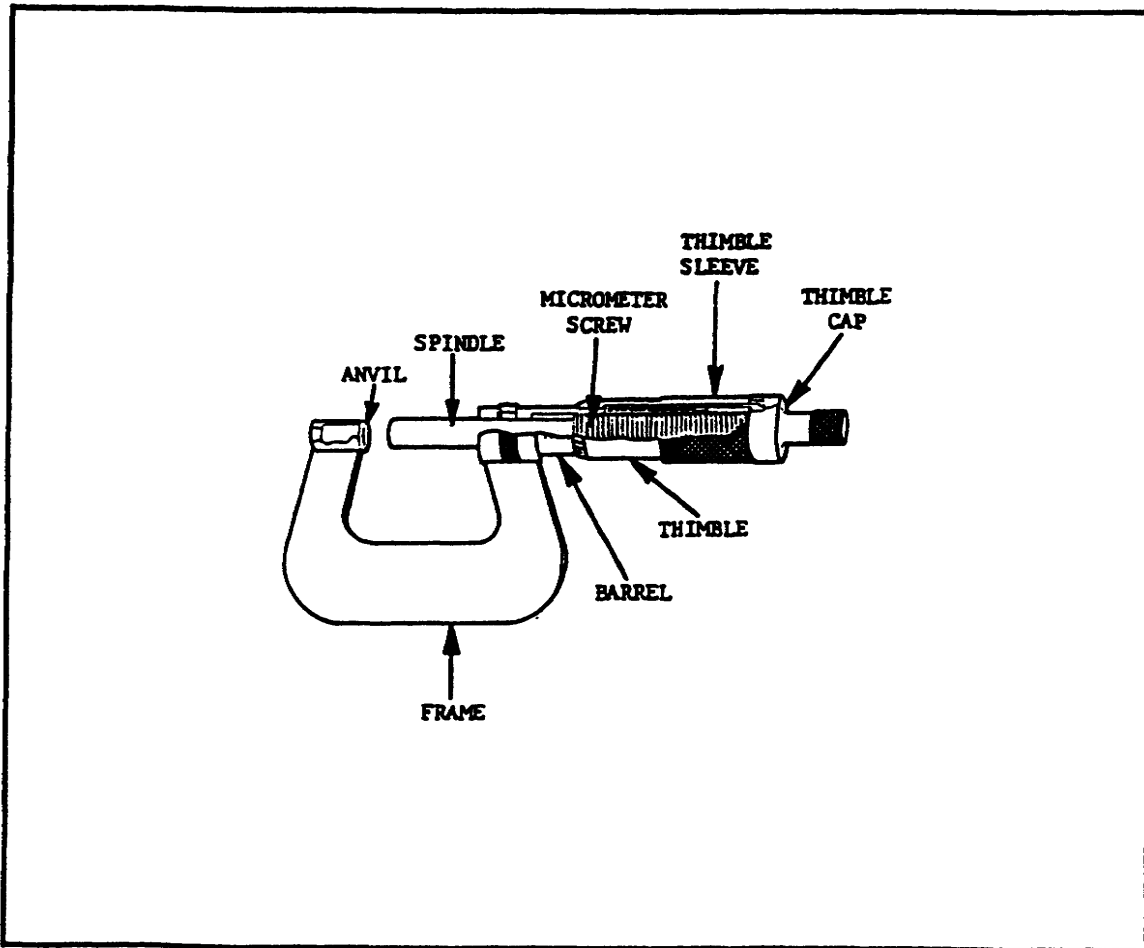
The outside micrometer is the most common type. It reads in thousandths of an inch. Metric outside micrometers read in hundredths of a millimeter. If the micrometer has a vernier scale, it reads in ten-thousandths of an inch. When taking care of, reading, and using an outside micrometer, it helps to know what its parts are called and how they work.

Parts of an Outside Micrometer

The paragraphs which follow talk about the main parts of an outside micrometer as shown in figure 4, below.

Frame. The frame of the outside micrometer is U-shaped. One end holds the anvil. The other end holds the barrel, thimble, and scales.

FIGURE 4. OUTSIDE MICROMETER, CUTAWAY VIEW.



PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 1

Anvil. The anvil is a hard button. It is either pressed or screwed into the frame. Some micrometers let you change anvils. On these, you can use different size anvils for special measuring needs. You can also use special anvils to reduce the micrometer size.

Micrometer Screw. The micrometer screw is inside the hollow barrel. It has 40 threads per inch.

Spindle. The steel spindle is the unthreaded part of the screw. The spindle moves to open or close the open side of the U-frame. The spindle bearing is a plain bearing. It is part of the frame.

Barrel. The barrel is hollow. It extends from the spindle bearing. The micrometer scale is on the side of the barrel. On a standard micrometer, this scale is divided into tenths of an inch. Each tenth of an inch is, in turn, divided into four 0.025 inch parts. The end of the barrel has the nut through which the screw passes. This nut is slotted. Its outer surface has a taper thread and a nut. This makes it possible to adjust the diameter of the slotted nut, within limits, to make up for wear.

Thimble. The thimble is attached to the screw. The thimble is a sleeve that fits over the barrel. The front edge of the thimble has a scale which is broken down into 25 parts. This scale shows parts of a full turn; the scale on the barrel tells the number of full turns.

Thimble Sleeve and Cap. The thimble is connected to the screw through a sleeve. The sleeve allows the thimble to be slipped in relation to the screw. Loosening the thimble cap allows this slippage so adjustment can be made.

Knowing the parts of a micrometer and how they work will help you care for, read, and use the micrometer. Next, you will learn how to take care of this micrometer.

Care of an Outside Micrometer

To make sure a micrometer stays accurate, you must take good care of it. All the parts you have just learned about must be in good condition for the micrometer to work accurately. Good care includes proper storage, care, and handling.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 1

Storage. For storage, coat the micrometer with a light coat of oil to prevent rust. Never store a micrometer with its anvil and spindle closed. Flat surfaces pressed together may corrode. Leave a small gap between the anvil and spindle when storing. Always store the micrometer in its own container, provided by the manufacturer.

Care and Handling. In addition to using proper storage methods, you must follow some rules of good care and handling. These rules are described next.

- o Keep all graduations and markings clean and easy to read.
- o Do not drop a micrometer. Small nicks and scratches can cause inaccurate measurements.
- o Before you use a micrometer, wipe it off. Then pull a piece of paper between the anvil and the end of the spindle.
- o The micrometer should work freely with no play in its travel. Abuse or uneven wear can cause play or binding. If the micrometer has play, or if it binds, return it to the manufacturer to be fixed.
- o Check the micrometer screw now and then with a precision gage block. Check for accuracy in at least four settings other than zero. To do this, select and measure a group of blocks ranging from zero to one inch.
- o Never roll the thimble along the hand or arm. Do not hold the thimble and twirl the frame to open or close the micrometer. This could cause excessive wear on the screw.
- o When the faces of the spindle and anvil become worn, they may no longer be flat and parallel. This can cause errors in parallelism and give inaccurate measurements. To test for error in parallelism, measure a ball at several points over the faces of the spindle and anvil. The error should not exceed 0.0002 inch on a micrometer which measures to 0.001 inch. The error should not exceed 0.00005 inch on a micrometer that measures to 0.0001 inch. If the error is more than that allowed, send the micrometer to the manufacturer to be fixed.

If you follow these rules, your micrometer should keep giving you precise measurements.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 1

DEPTH MICROMETERS

Depth micrometers can take several kinds of distance measurements. You can use them to measure the depth of a very small diameter hole. The hole diameter can be as small as $\frac{3}{32}$ inch. You can also use a depth micrometer for other kinds of measurements. One use measures the distance between the end of a cylinder and a flange on the cylinder.

Parts of a Depth Micrometer

Depth micrometers use many of the same design ideas as outside micrometers. Each has a turning scale and a straight scale. The turning scale is on the thimble; the straight scale is on the barrel. The scales on the thimble and barrel are marked just like on an outside micrometer.

Turning the thimble moves a screw inside the barrel. In a depth micrometer, the screw is hollow. The screw has 40 threads per inch. Instead of a spindle, this micrometer uses extension rods in a range of sizes.

The depth micrometer does not have a U-shaped frame. Instead, it has a flat base attached to the barrel. This base bridges the surface of a hole or rests on the end of a pipe or cylinder.

Like the outside micrometer, the depth micrometer reads in thousandths of an inch. Metric depth micrometers read in hundredths of a millimeter. Micrometers with a vernier scale read in ten-thousandths of an inch.

Care of a Depth Micrometer

The rules for taking care of a depth micrometer are almost the same as for an outside micrometer. To take good care of your depth micrometer, follow these rules:

- o For storage, coat the micrometer lightly with oil to prevent rust.
- o Always store the micrometer in its own container, provided by the manufacturer.
- o Keep all graduations and markings clean and easy to read.
- o Do not drop a micrometer. Small nicks and scratches can cause inaccurate measurements.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 1

- o The micrometer should work freely with no play in its travel. Abuse or uneven wear can cause play or binding. If the micrometer has play, or if it binds, return it to the manufacturer to be fixed.

CONCLUSION

Now you know the parts of a vernier caliper, an outside micrometer, and a depth micrometer. You also know how to take care of these tools. If you had trouble with any part of this task, go back and review. If you had no problems, you are ready to go on to task 2. There you will learn how to read the scales of these tools.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 2

LESSON 1

CARING FOR, INTERPRETING READINGS, AND TAKING
MEASUREMENTS WITH A VERNIER CALIPER, AN OUTSIDE
MICROMETER, AND A DEPTH MICROMETER

TASK 2. Interpret readings on a vernier caliper, an outside micrometer, and a depth micrometer.

CONDITIONS

The student will complete the subcourse and examination in a self-study environment, given the subcourse booklet. After successful completion of the examination, the student should be able to perform the task, given TM 9-243.

STANDARD

Demonstrate your comprehension of the task by correctly answering 70% of the questions on the examination.

GENERAL

Task 1 introduced three precision measuring tools: the vernier caliper, the outside micrometer, and the depth micrometer. You learned what each tool looks like and how to care for it.

For these tools to be of any use, you must be able to read their scales correctly. Very accurate measurements will have no meaning unless you can correctly read what the scales say. The goal of this task is to show you how to interpret readings taken with these three measurement tools. We will start with the vernier caliper.

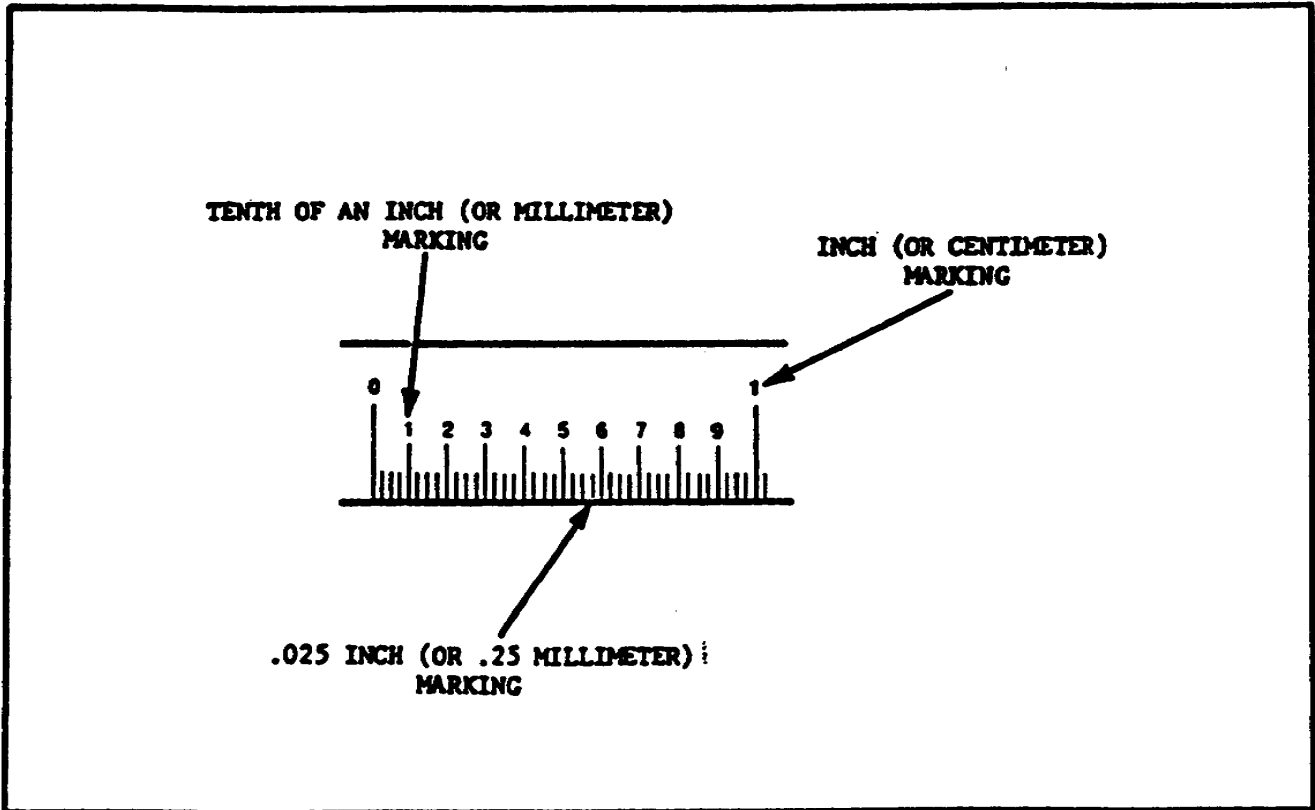
READING A VERNIER CALIPER

To read a vernier caliper, you must understand both the steel rule and vernier scales. The vernier scale is located on the sliding jaw of the caliper. The steel rule scale is located on the caliper's long arm.

Understanding the Scales

Figure 5, below, shows a portion of a typical steel rule scale. The steel rule scale may be graduated by English or metric measure. English measure uses inches. Metric measure uses centimeters and millimeters.

FIGURE 5. THE STEEL RULE SCALE.



Steel Rule Scale. Usually, the steel rule scale on a vernier caliper is in English measure. The longest lines show the whole inch markings. Each inch is divided into tenth inch parts which are numbered. Each tenth inch portion is divided into four parts. Each of these parts equals 0.025 of an inch. Thus, the full inch is divided into 40 equal parts. The smallest graduation is 0.025 (1/40) of an inch.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 2

Metric Scale. Sometimes the back side of a vernier caliper has a metric scale. When this is the case, the steel rule is divided into centimeters (cm). Each full centimeter is divided into ten parts. Each of these parts is equal to one millimeter (mm). There are ten millimeters in one centimeter. The space between each millimeter mark is divided into quarters, each of which is equal to 0.25mm.

Vernier Scale. The vernier scale is divided into 25 parts. These parts are numbered at the 0, 5, 10, 15, 20, and 25 marks. These 25 parts take up the same distance (length) as 24 parts on the steel rule. The difference between the width of one of the 25 spaces on the vernier scale and one of the 24 spaces on the rule equals $1/1000$ (0.001) of an inch.

Relationship of the Scales. Imagine that the tool is set so that the 0 line on the vernier scale lines up exactly with the 0 line on the rule. The 0 lines are said to coincide. The line to the right of the 0 on the vernier scale will differ from the line to the right of 0 on the rule by $1/1000$ (0.001) of an inch. The second line will differ by $2/1000$ (0.002) of an inch. The difference will keep increasing by $1/1000$ of an inch for each division until vernier line 25 coincides with rule line 24. Using this relation, the vernier scale can be used to measure fractional parts of the $1/40$ (0.025) inch spaces on the rule.

Reading a Standard Vernier Caliper: Example 1

Let's look at two examples of how the relationship of the scales works in an actual measurement. Figure 6, on the next page, shows one example of a scale setting on a vernier caliper. To read this measurement, use the following steps:

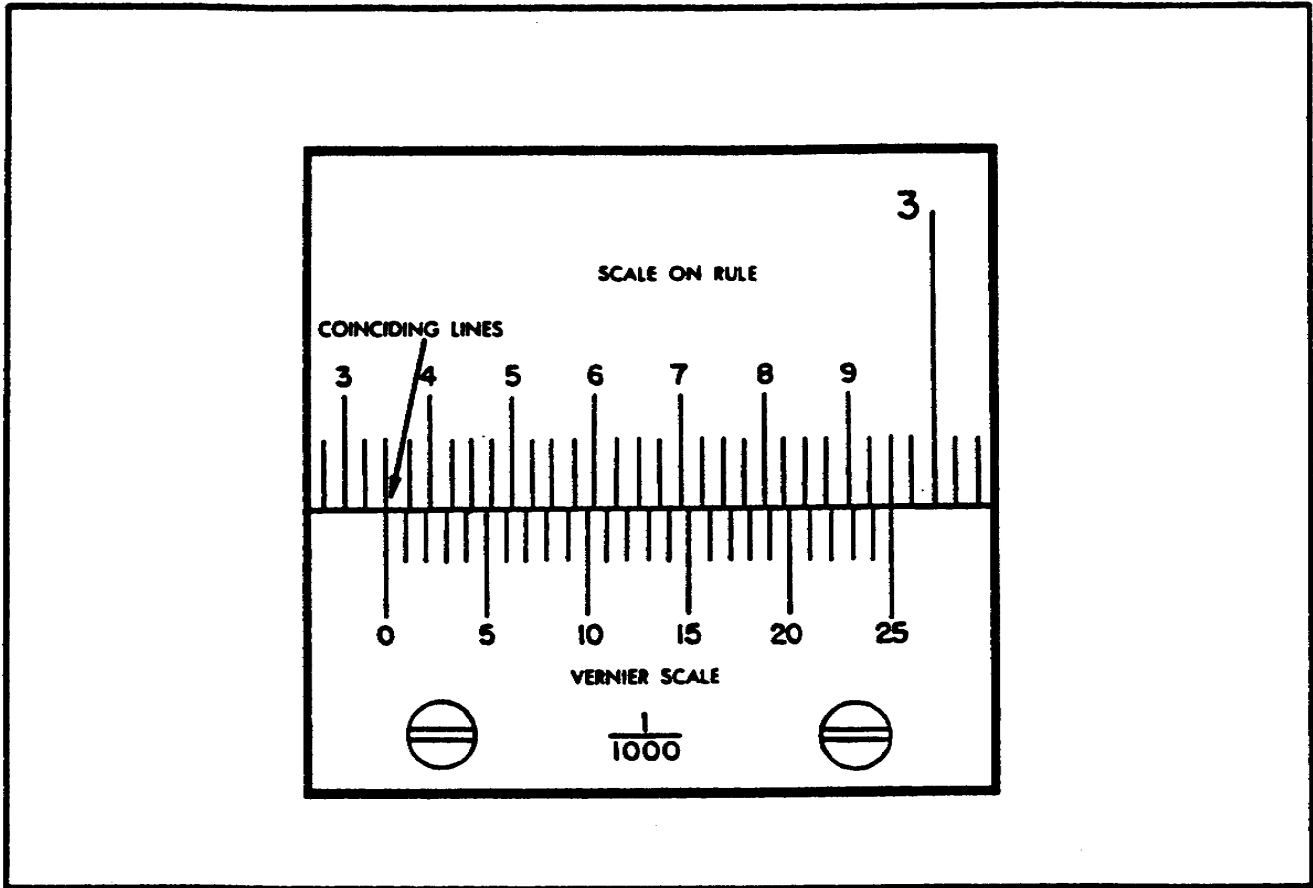
Step 1. Read the number of whole inches on the top (rule) scale to the left of the vernier zero. Record this number. In this example, you would record 2.000 inches.

Step 2. Next, read the number of tenths to the left of the vernier zero. In this case, that number is three tenths of an inch. Record it as 0.300 inch.

You now know how many whole and how many tenths inches the measurement is. In this example, you have 2.000 inches plus 0.300 inch, equaling 2.300 inches.

Step 3. Remember, each tenth inch is divided into four parts. Each of these parts equals 0.025 inch. Read how many of these 0.025 inch parts are between the tenths mark you recorded and the zero on the vernier scale. In the example shown in figure 6, there are two of these 0.025 inch parts. Therefore, multiply 2 times 0.025 inch. This equals 0.05 inch. Add this amount to the 2.300 inches you already have. The total now equals 2.350 inches.

FIGURE 6. READING A VERNIER CALIPER - EXAMPLE 1.



Step 4. For the last part of the reading, find the line on the vernier scale which exactly coincides with a line on the rule. In the example shown in figure 6, the coinciding vernier line is zero. Therefore, there is no fractional part of a 0.025 inch space to calculate. The exact reading for this sample is 2.350 inches.

Reading a Standard Vernier Caliper: Example 2

Now let's look at another sample reading. Figure 7, on the next page, shows a scale setting that is almost the same as the one we saw in figure 6. In fact, the first readings will be identical, as shown below:

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 2

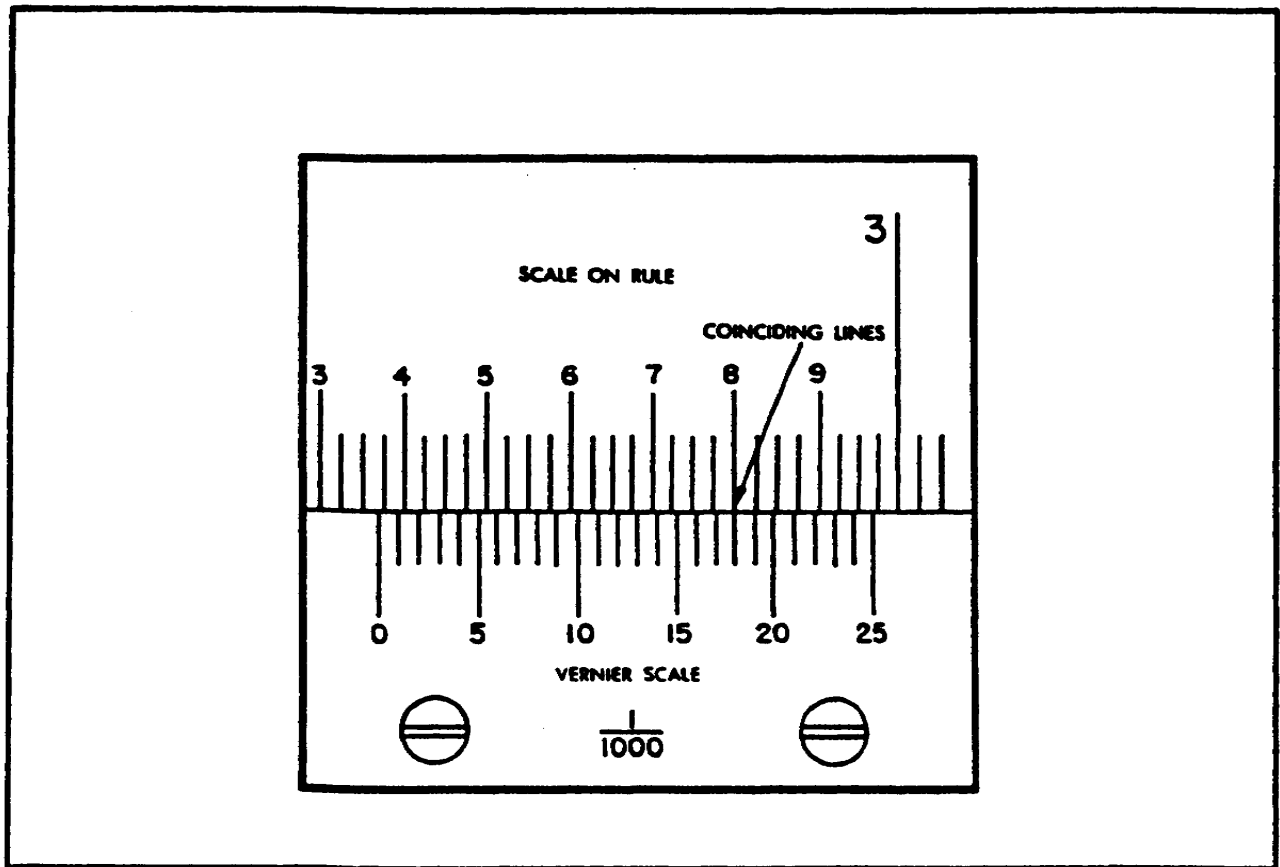
Step 1. The number of whole inches to the left of the vernier scale zero is 2.000 inches.

Step 2. The number of tenths inches to the left of the vernier zero is 3, equaling 0.300 inch.

Step 3. Two whole 0.025 spaces lie between the 3 tenths mark and the vernier zero. Thus, 2 times 0.25 inch equals 0.050 inch.

The total reading so far is 2.000 inches plus 0.300 inch, plus 0.050 inch. This equals 2.350 inches. In this sample, however, the vernier zero does not exactly coincide with a line on the rule scale. The total reading will be 2.350 inches plus a fraction of a space on the rule.

FIGURE 7. READING A VERNIER CALIPER - EXAMPLE 2.



Step 4. To interpret the rest of the reading, find the line on the vernier scale that exactly coincides with a line on the rule scale. In the sample shown in figure 7, the vernier line 18 exactly coincides with a line on the rule scale. This tells you that 18/25 of a whole space must be added to the measurement. Remember that 1/25 of a space

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON' 1/TASK 2

equals 0.001 inch. Therefore, $18/25$ of a space equals 0.018 inch.

Calculate the total reading by adding 2.350 inches and 0.018 inch. The sum is 2.368 inches this is the exact measurement reading shown in figure 7.

Reading a Metric Vernier Caliper

The standard vernier caliper you just learned to read uses the English measurement scales (inches). Some calipers have a metric scale on the back side. Therefore, you must also know how to interpret readings from a metric vernier caliper.

The methods used to interpret a reading from a metric scale on a vernier caliper are nearly the same as those you just learned. The only difference is that you are working in centimeters and millimeters instead of inches.

Assume that the scales shown in figure 7 (on the previous page) are metric. You would interpret the reading as follows:

Step 1. The number of whole centimeters (cm) to the left of the vernier zero equals 2.000cm. Each centimeter equals 10 millimeters. Therefore, the reading in millimeters (mm) is 20.000mm.

Step 2. The number of millimeters (mm) to the left of the vernier zero equals 3mm. The total reading so far is 20.000mm plus 3mm, or 23.000mm.

Step 3. Read the number of 0.25mm spaces between the 3 millimeter mark and the vernier zero. There are two of these spaces, equaling 2 times 0.25mm, or 0.50mm. Added to the previous amount, the total reading so far is 23.50mm.

Step 4. Read the highest line on the vernier scale which lines up exactly with the line on the rule scale. This is line 18. Multiply 18 times 0.01mm. This equals 0.18mm. Add 0.18mm to 23.500mm to get the exact total reading of 23.68mm.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 2

Reading Inside Measurements with a Vernier Caliper

The jaws of a vernier caliper are shaped so that you can use the tool to make inside measurements.

On most vernier calipers, the back side reads "INSIDE." When this is the case, the scale positions on that side of the caliper are set to adjust for the thickness of the jaw tips. Read the scales on the side of the caliper marked "INSIDE" just as you would for an outside measurement.

Sometimes the scale isn't marked. If the scale isn't marked, measure an inside length using the caliper side normally used for outside. Read the scales as you would for an outside reading. Then add the measuring point allowance (the thickness of the tips) to your reading. This point allowance can be found in the manufacturer's instructions. Or you can use table 1, below:

TABLE 1. MEASURING POINT ALLOWANCES FOR INSIDE MEASUREMENTS.

Caliper Size	English Measure ADD	Metric Measure ADD
6 inch or 150mm	0.250 inch	6.35mm
12 inch or 300mm	0.300 inch	7.62mm
24 inch or 600mm	0.300 inch	7.62mm
36 inch or 600mm	0.500 inch	12.70mm

READING A MICROMETER

Interpreting a reading of a micrometer measurement is much like reading a vernier caliper. To read a micrometer, you

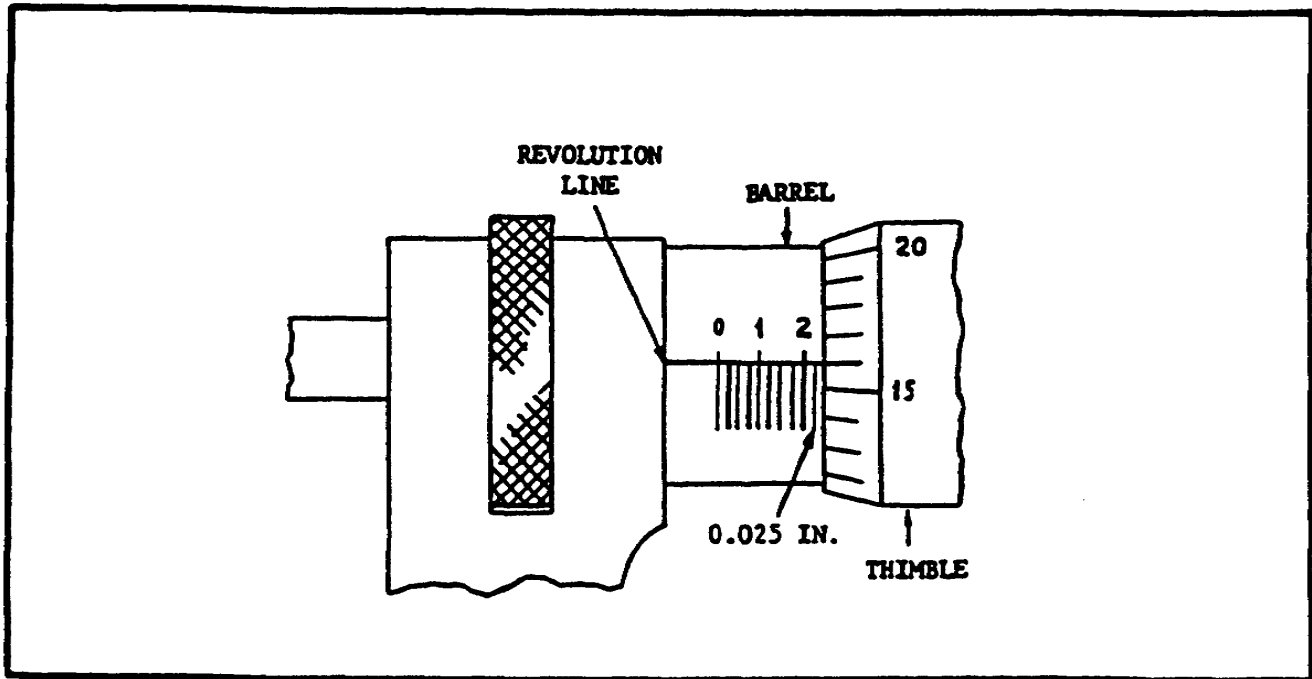
compare the positions of two scales. The scales on an outside micrometer and a depth micrometer work the same. If you learn to read one, you will know how to read the other. The only calculation difference will be the way you count the size (range) of the outside micrometer used or the length of extension rod used on a depth micrometer. First, let's learn how the scales work.

Understanding Standard Micrometer Scales

Again, you must understand how the scales work before you can interpret a reading. The scales on standard and metric micrometers both work on the same idea. However, the meaning of the graduation lines changes. To understand how the scales work, we will use the standard micrometer as an example.

On a standard micrometer, one scale is on the barrel. The other scale is on the thimble. The scale on the barrel is fixed. It does not move. The scale on the thimble moves along the barrel scale (figure 8, below).

FIGURE 8. MICROMETER SCALES.



The lines on the barrel scale stand for full turns of the thimble, and therefore of the micrometer screw. The thimble edge moves one line along the barrel scale for every full turn (revolution) of the thimble.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 2

On a standard micrometer, the measurement is in inches. Each line on the barrel scale equals $1/40$ (0.025) of an inch. For each revolution, the micrometer screw moves forward or back $1/40$ (0.025 of an inch). On an outside micrometer, this means that the screw moves the spindle away from or toward the anvil exactly $1/40$ (0.025) of an inch for every full turn.

The full length of the barrel scale represents one inch of micrometer screw movement forward or back. The long horizontal line on the barrel is called the revolution line. It is divided into the 40 parts which make up the barrel scale. Each line on the barrel scale equals $1/40$ (0.025) of an inch of screw movement. Every fourth line is numbered 1, 2, 3, and so forth. Each numbered line equals $1/10$ (0.10) of an inch of screw movement.

Thimble Scale. The thimble scale moves along the barrel scale. The beveled edge of the thimble is divided into 25 equal parts. As the thimble is turned, each line of the thimble scale will, in turn, line up with the revolution line on the barrel. Each line on the thimble scale stands for $1/1000$ (0.001) of an inch of screw movement. Every fifth line on the thimble is numbered (5, 10, 15, etc.). One complete and exact revolution of the thimble equals $25/1000$, or $1/40$ (0.025) of an inch.

Reading a Standard Micrometer

Once you understand how the scales work, it is not hard to read the micrometer. Just follow these steps:

Step 1. First, check where the thimble edge is on the barrel scale. Read the highest figure visible on the barrel. In figure 8, on the previous page, this number is 2. Therefore, you know that the micrometer screw has moved more than $2/10$ (0.20) of an inch.

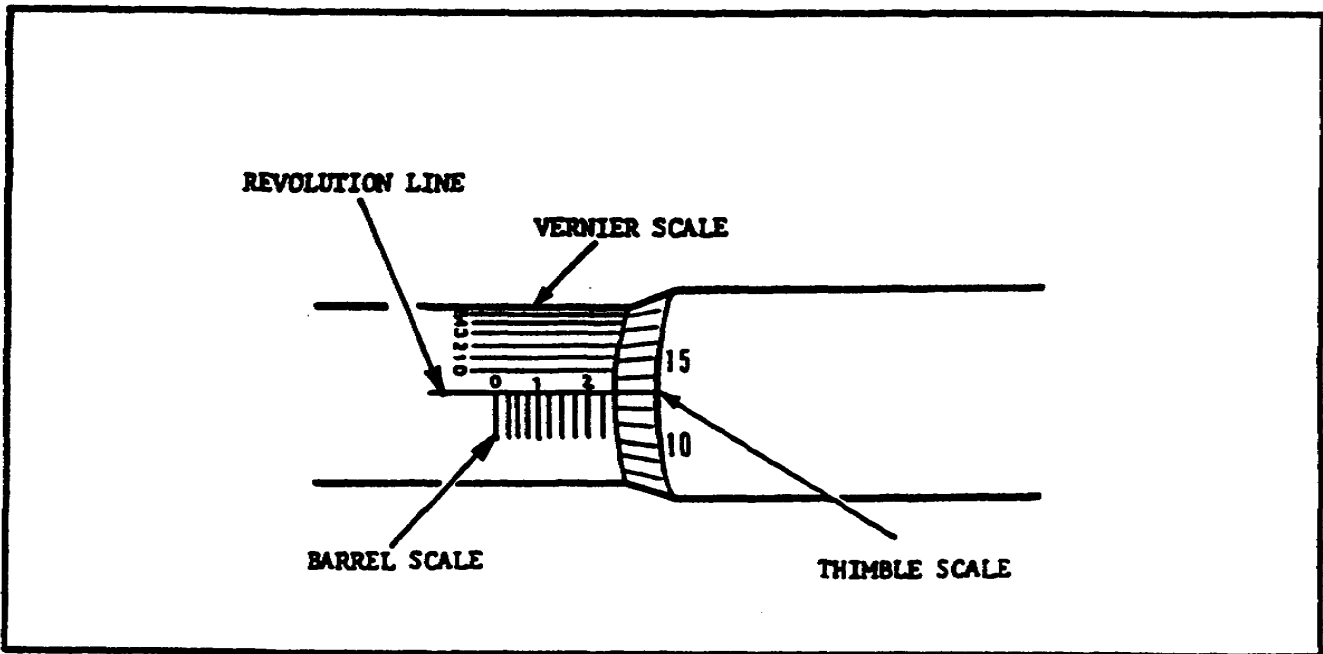
Step 2. Count the number of lines you can see between the number you just read (in this case, 2) and the thimble edge. In the sample in figure 8, you can see only one line. Each line stands for 0.025 inch. Add what you have so far. In this case, you should get (0.20 inch + 0.025 inches) a total of 0.225 inch. You now know that the screw has moved more than 0.225 inch.

Step 3. Now, look at the thimble scale. Find the line on the thimble scale that lines up with or has passed the revolution line in the barrel. In figure 8, this line is number 16 on the thimble scale. Each thimble scale line stands for 0.001 inch, so 16 of these equal 0.016 inch. Add this (0.016 inch) to what you have so far (0.225 inch) and the total measurement is 0.241 inch.

Reading a Vernier Micrometer

A vernier micrometer is just like a standard micrometer except that it has a second scale on the barrel (figure 9, below). This second scale is a vernier scale. With the vernier scale added, the micrometer can be accurate to ten-thousandths (0.0001) of an inch. Use of the vernier scale gives the fine readings between the lines on the thimble. Without the vernier scale, you would have to estimate a ten-thousandth reading.

FIGURE 9. VERNIER MICROMETER SCALES.



This vernier scale is divided into ten spaces. The ten spaces on the vernier scale take up the same length as nine spaces on the thimble scale. Each unit on the vernier scale equals 0.0009 inch. The size difference between the units on each scale is 0.0001 inch.

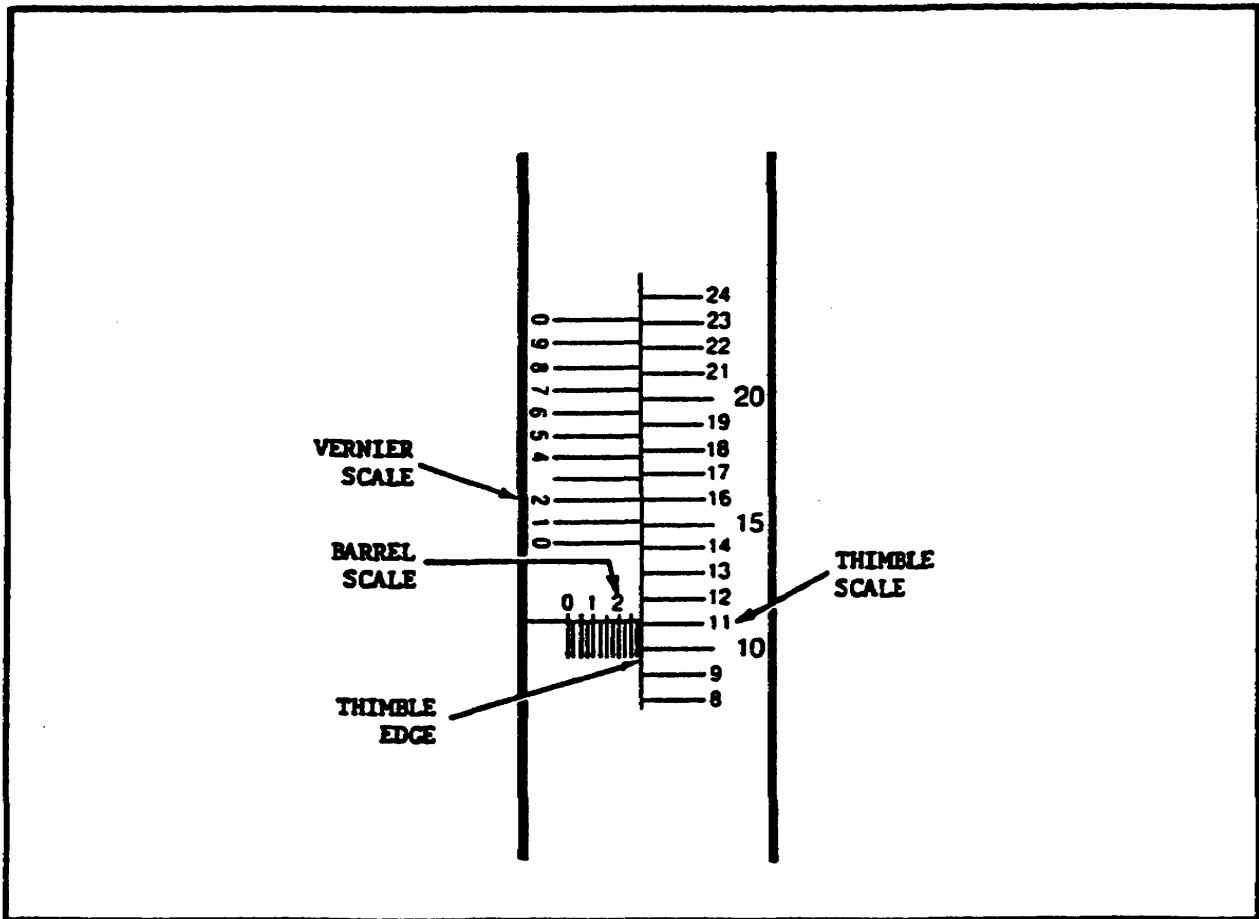
You read the vernier micrometer the same as you read a standard one. However, you must take one more step. This step adds the vernier reading to the total size.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 2

Figure 10, below, shows the relationship of the barrel, thimble, and vernier scales. We will use this figure as a sample. To read the measurement shown in figure 10, use these steps:

Step 1. Read the highest figure showing on the barrel. In this case, that figure is 2. A 2 showing on the barrel means 0.200 inch.

FIGURE 10. READING A VERNIER MICROMETER.



Step 2. Count the number of lines showing between the number you read (in this case 2) and the thimble edge. The sample in figure 10 has 3 lines showing. Each line stands for 0.025 inch. Therefore, 3 times 0.025 inch equals 0.075 inch. Add 0.075 inch to 0.200 inch. The subtotal is 0.275 inch.

Step 3. Find the thimble scale line that lines up with or has passed the revolution line. For the setting in figure 10, the thimble scale line is 11. Each thimble line equals 0.001 inch, so 11 of them equal 0.011 inch. Add this (0.011 inch) to 0.275 inch to get 0.286 inch.

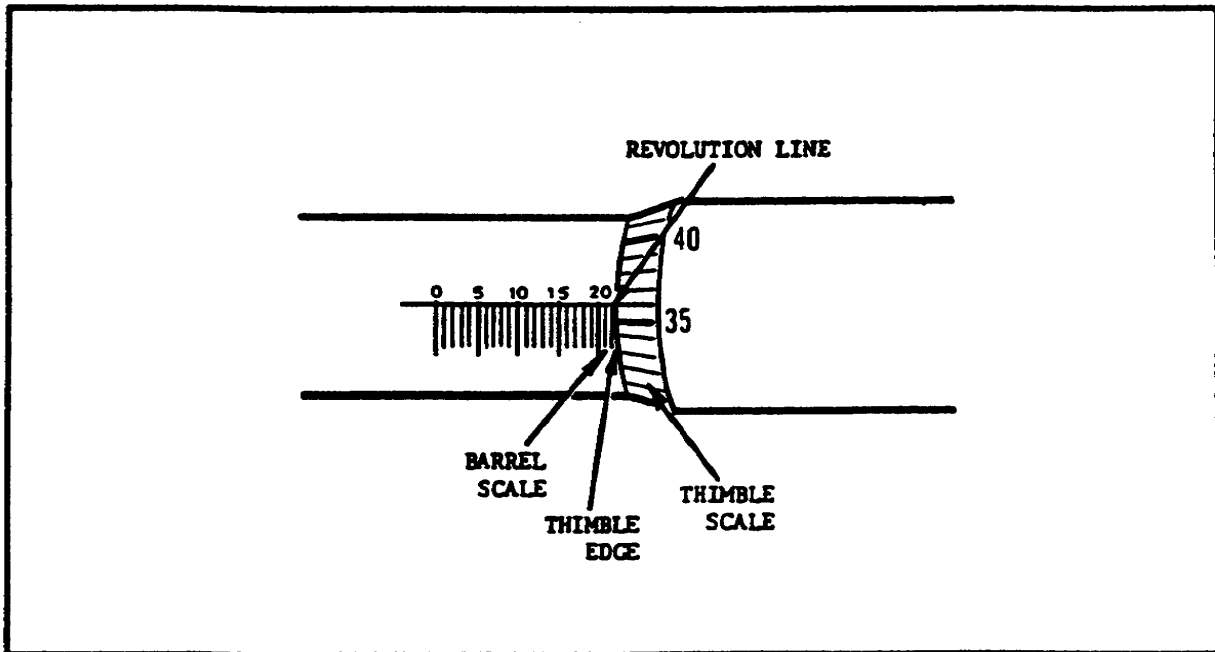
Step 4. So far, the reading is the same as it would have been on a standard micrometer. Now, however, you can use the vernier scale to get even greater accuracy. Find the line on the vernier scale that coincides (exactly lines up with) a line on the thimble. In figure 10, vernier scale line 2 coincides with a thimble scale line. Each line on the vernier scale stands for 0.0001 inch. Therefore, 2 vernier lines equal 0.0002 inch. Add this amount to the subtotal 0.286 inch. The result is 0.2862 inch. This is the exact size measured to the nearest 0.0001 of an inch.

Understanding the Scales on a Metric Micrometer

The metric micrometer uses the same scale/screw movement principle as the standard micrometer. However, the meaning of the lines on the barrel and thimble scales changes.

On a metric micrometer, each full thimble turn moves the screw 0.5 millimeter (mm). The lines on the barrel scale (figure 11, below) read in millimeters, from 0 to 25. It takes two full thimble revolutions to move the screw 1.0mm.

FIGURE 11. READING A METRIC MICROMETER.



The thimble scale has 50 lines. Every fifth line is numbered. As you turn the thimble, each thimble line passes the revolution line on the barrel. A turn equal to one thimble line moves the micrometer screw 1/50 of 0.5mm, or 1/100mm. Two thimble lines equal 2/100mm, and so forth.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 2

Reading a Metric Micrometer

Read a metric micrometer much like you read a standard one. Remember, it takes two full turns for the thimble edge to move one full space (one millimeter) on the barrel scale. To read the metric micrometer shown in figure 11 (on the previous page), use these steps:

Step 1. Read the highest number you can see on the barrel. In figure 11, the number is 20. This equals 20.0mm. Record this number.

Step 2. Count the number of lines you can see between the number 20 (the highest number you could see on the barrel) and the thimble edge. Each of these lines equals 1.0mm. In this case there are two lines. Two times 1.0mm equals 2.0mm. Add 2.0mm to 20.0mm, and the reading so far is 22.0mm.

Step 3. Find the thimble line that lines up exactly (coincides) with or has passed the revolution line (long line) on the barrel. In figure 11, this line is 36. Because each line on the thimble equals 0.01mm, 36 lines equals 0.36mm. Add this value to 22.0mm to arrive at the total measurement reading of 22.36mm.

NOTE

When finding the value for step 3 above, remember that each full turn of the thimble is equal to only 0.5mm. It takes two full turns of the thimble to move the spindle one whole millimeter. You found the number 36 in step 3 by assuming that the thimble was on its first turn. This was true because the thimble edge nearly touched the barrel mark. If the thimble was on its second turn, the edge would be away from the barrel line. In that case, the reading would have been 86 (50 + 36).

The Effects of Outside Micrometer Size (Range) on a Reading

Remember that the total movement between the anvil and spindle on an outside micrometer is only one inch. To make readings on items of various sizes, you must choose the right size outside micrometer. When you interpret the reading you take with an outside micrometer, you must consider the size of micrometer you are using. The size of

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 2

outside micrometer you are using tells you the biggest distance that you can measure with that micrometer.

A two inch micrometer has a range between one and two inches. That means that it will only measure items that are between one and two inches in size. The biggest measurement reading you can get with this micrometer is two inches. A three inch micrometer has a range from 2 to 3 inches. It will measure items that are between 2 and 3 inches in size. The biggest measurement you can make with a three inch micrometer is 3 inches.

Let's use a three inch outside micrometer as an example. To interpret the reading of a measurement you might take with a three inch micrometer, use these steps:

Step 1. Because it is a three inch micrometer, it will measure items between 2 and 3 inches in size. This tells you that the size of the item you are measuring is at least 2 inches; however, it can't be more than 3 inches. Therefore, the first number you record is 2.0 inches. You will find out how much bigger than 2.0 inches the size is by reading the micrometer scales.

Step 2. You read the scales exactly as you did before. First read the highest figure you can see on the barrel. Remember, each number on the barrel equals 0.1 inch. For example, if the number you see is 2, you would multiply 2 times 0.1 inch. The result is 0.2 inch. Record 0.2 inch. Add 0.2 inch to 2.0 inches. The reading so far is 2.2 inches.

Step 3. Count the number of lines you can see between the highest figure seen on the barrel and the edge of the thimble. Remember, each of these lines equals 0.025 inch. For the current example, assume that you can see three lines. You would multiply 3 times 0.025 inch. The value is 0.075 inch. Add 0.075 inch to the 2.2 inches recorded from step 2. The subtotal for this example (2.2 inches + 0.075 inch) equals 2.275.

Step 4. Find the line on the thimble that coincides with or has passed the revolution line (long line) on the barrel. Assume that this line on the thimble is 24. Each thimble line is equal to 0.001 inch. Multiply 0.001 inch by 24. You should get 0.024 inch. Add this to the subtotal from

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 2

step 3 (2.275 inches). Your grand total for the measurement should be 2.299 inches (2.275 inches + 0.024 inch).

As you can see, the size of outside micrometer you are using will add whole inch values to your final reading. The outside micrometer size tells you the biggest reading you can get by using that micrometer.

The Effects of a Depth Micrometer Extension Rod on a Reading

Just as the size of outside micrometer effected your measurement reading, the size of the extension rod you select for your depth micrometer will have an effect. However, the kind of effect it has is slightly different.

The outside micrometer size told you the biggest reading you could get with that micrometer. The size of the extension rod you choose for your depth micrometer tells you the smallest distance it will span. Using this knowledge as a guide, the first number you should record for a measurement reading taken with a depth micrometer is the size of the extension rod.

For example, suppose your are taking a measurement using a depth micrometer with a 5 inch extension rod. The first number you should record is 5.0 inches. Then read the micrometer scales just as .you would for any micrometer measurement. Suppose the scales read 0.294 inch. Add this number to the 5.0 inches you have already recorded. The total depth measurement would be 5.294 inches.

CONCLUSION

This task has shown you how the scales on a vernier caliper and on a micrometer work. You have learned how to interpret the readings of these scales to come up with accurate measurements. Now you must learn how to actually use the tools to make precision measurements. Task 3 will show you the techniques for using these tools.

LESSON 1

CARING FOR, INTERPRETING READINGS, AND TAKING
MEASUREMENTS WITH A VERNIER CALIPER, AN OUTSIDE
MICROMETER, AND A DEPTH MICROMETER

TASK 3. Take measurements with a vernier caliper, an outside micrometer, and a depth micrometer.

CONDITIONS

The student will complete the subcourse and examination in a self-study environment, given the subcourse booklet. After successful completion of the examination, the student should be able to perform the task, given TM 9-243.

STANDARD

Demonstrate your comprehension of the task by correctly answering 70% of the questions on the examination.

GENERAL

As you perform your job, you will need to measure different items in many sizes and shapes. Sometimes you will measure flat stock; other times the stock will be round. When needed, you will use a depth micrometer to make measurements such as hole depths or the distance between a cylinder end and a flange on the cylinder.

So far, you have learned how to take care of vernier calipers, outside micrometers, and depth micrometers; you have also learned how to read their scales. Now you must learn how to select the right tool for a precision measurement, then to use that tool properly.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 3

CHOOSING THE RIGHT MEASURING TOOL

Which tool you select to take a measurement depends on the type of measurement you are taking and the accuracy you need. When taking inside and outside measurements, you can use either a vernier caliper or a micrometer (inside or outside). For depth measurements, you will be able to select from several depth instruments. There are advantages and disadvantages to each type of tool.

Inside and Outside Measurements

You can make inside or outside precision measurements with either a vernier caliper or with a micrometer (inside or outside). Vernier calipers tend to be more adaptable than micrometers. Micrometers, however, are more accurate.

You can use the vernier caliper for many different kinds of measurements. You can use this one tool for both inside and outside measurements. Because of the shape of the jaws and their position with respect to the scale, the vernier caliper is more adaptable than a micrometer. However, the vernier caliper is not as accurate as a micrometer. If you need a very precise measurement, use a micrometer. A micrometer is more reliable and more accurate than a caliper.

Vernier Caliper. You may decide a vernier caliper is best for the measurement you are making. If this is so, you must choose a vernier caliper in a size that is larger than the measurement you want to make. Vernier calipers come in 6, 12, 24, and 36 inch sizes. Standard metric sizes are 150mm, 300mm, and 600mm.

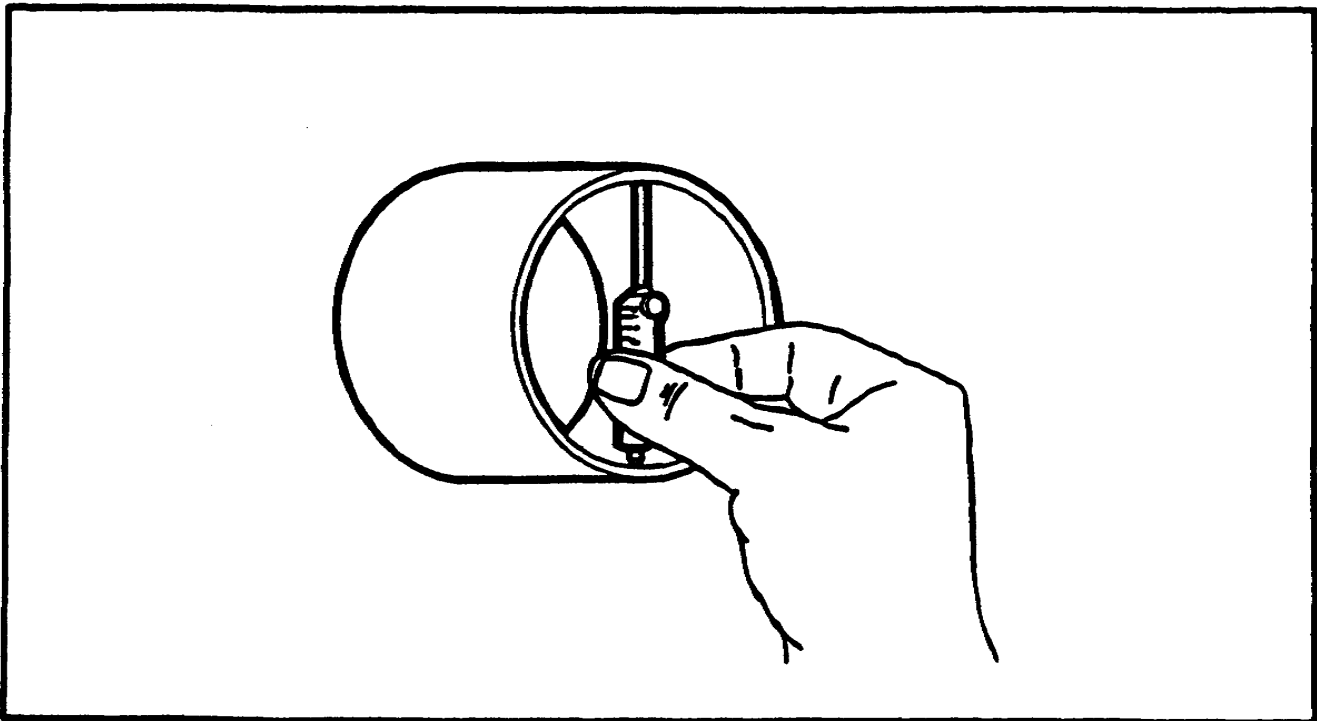
Remember that vernier calipers are not as accurate as micrometers. However, you can rely on given standards of accuracy from a well maintained caliper. If you check any one inch of its length, the caliper should be accurate within 0.001 inch. In any 12 inches, you should obtain accuracy within 0.002 inches. At most, this amount of inaccuracy should only increase by about 0.001 inch for each additional 12 inches.

Inside Micrometers. You may choose to use an inside micrometer to make an inside measurement. This subcourse will not show you the specific techniques for using an inside micrometer. We will, however, take a brief look at how to select the right inside micrometer extension rod. If you want to know more about inside micrometers, look in TM9-243, chapter 7.

You must choose an inside micrometer (figure 12, below) with a range that includes the approximate size you want to measure. This means you must consider the size of the micrometer unit, the range of its screw, and the length of the extension rods available. The smallest size you can check is equal to the size of the micrometer unit with its screw set to zero and its shortest anvil in place.

The average inside micrometer set has a range from 2 to 10 inches. You use extension rods to cover the steps (by 1 inch increments) of this range. The micrometer set may also have a collar. This collar is 0.5 inch long. It is used for splitting the inch step between two rods. The collar extends a rod another 0.5 inch. This allows the range of each step to overlap the next.

FIGURE 12. CHOOSING AN INSIDE MICROMETER.



The range of the micrometer screw itself is very short. The smallest models have a 0.25 inch screw. Average models have a 0.5 inch screw. The largest inside micrometers have only a 1 inch screw.

There are several things to consider if you want to properly choose an inside micrometer to make a measurement. First you must estimate the inside measurement you want to make. This estimate should be within the range of the micrometer screw. The size of the extension rod you need depends on the size and range of the inside micrometer. With the

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 3

inside micrometer screw set to zero, you will fit an extension rod to the micrometer. If you choose the right extension rod, the total length of the micrometer and rod will be less than (but within the micrometer screw range of) the estimated distance to be measured.

Depth Measurements

You can use a depth micrometer to get very accurate depth measurements. Two other types of measuring tools are available for depth measurements. One of these is the rule depth gage; the other is the vernier depth gage. Although you will only learn how to use a depth micrometer in this subcourse, we will describe the other two depth gages briefly (page 38). This is so that you can be familiar with the tools that might be available to you in the shop. If you want to learn more about using the rule depth gage or a vernier depth gage, look in TM 9-243, chapter 14.

Rule Depth Gage. The rule depth gage (figure 13, on the next page) is a graduated rule. You may use it to measure the depth of holes, slots, counterbores, and recesses. This gage has a sliding head designed to bridge a hole or slot. The head holds the rule perpendicular to the surface from which you are measuring.

The rule depth gage has a range of zero to five inches. The sliding head has a clamping screw so that it can be clamped in any position. The sliding head is flat. It is perpendicular to the axis of the rule. The head ranges in size from 2 to 2 5/8 inches wide and from 1/8 to 1/4 inch thick.

Depth Micrometer. The depth micrometer has a flat base attached to the barrel of a micrometer head. It usually has a range from zero to nine inches. Its range depends on the length of extension rod used. The hollow micrometer screw itself has a range of either 1/2 inch or 1 inch. The size of the flat base from 2 to 6 inches. The depth micrometer can enter a hole only 3/32 of an inch in diameter.

Vernier Depth Gage. The vernier depth gage (figure 14, on the next page) consists of a scale and a sliding head. The scale is either 6 or 12 inches long. The sliding head is a lot like the one on a vernier caliper. This head is specially designed to bridge holes and slots.

FIGURE 13. CHOOSING A RULE DEPTH GAGE.

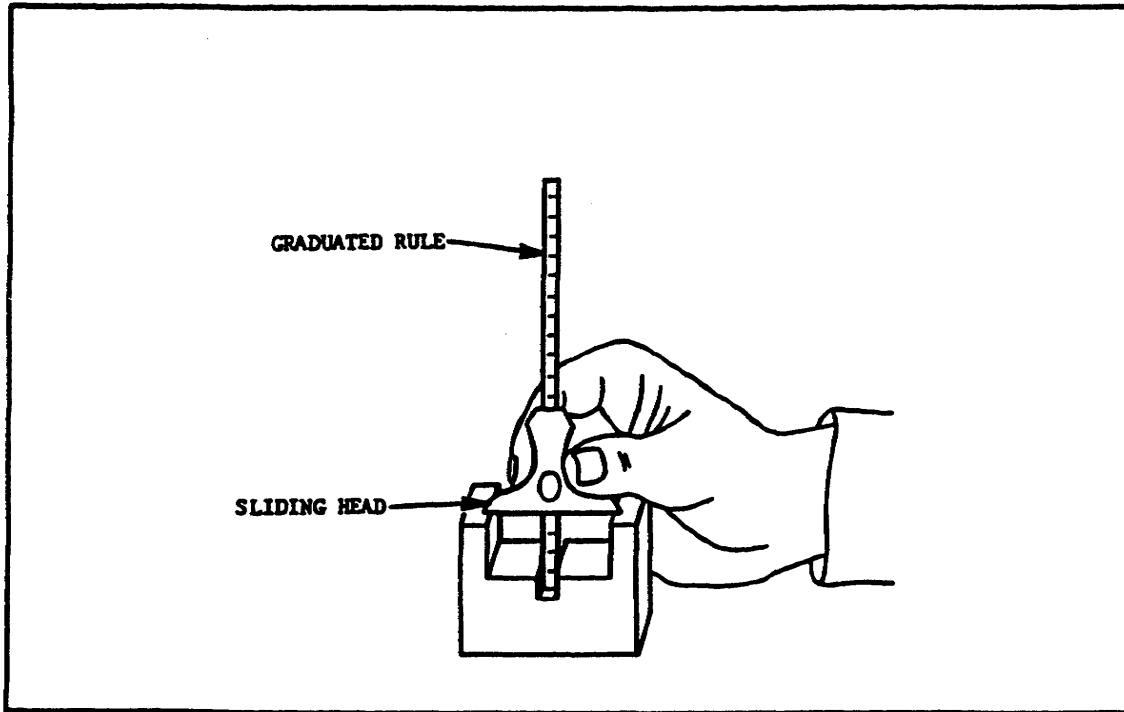
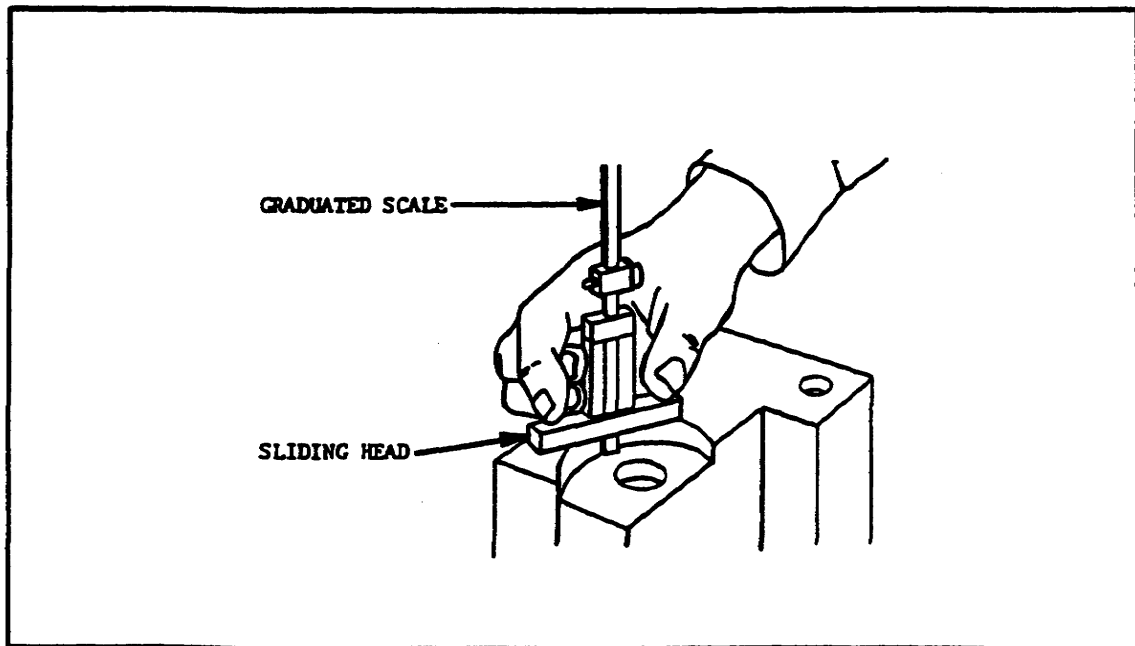


FIGURE 14. CHOOSING A VERNIER DEPTH GAGE.



The vernier depth gage has the range of the rule depth gage. It is not quite as accurate as a depth micrometer. It cannot enter holes that are less than 1/4 inch in diameter.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 3

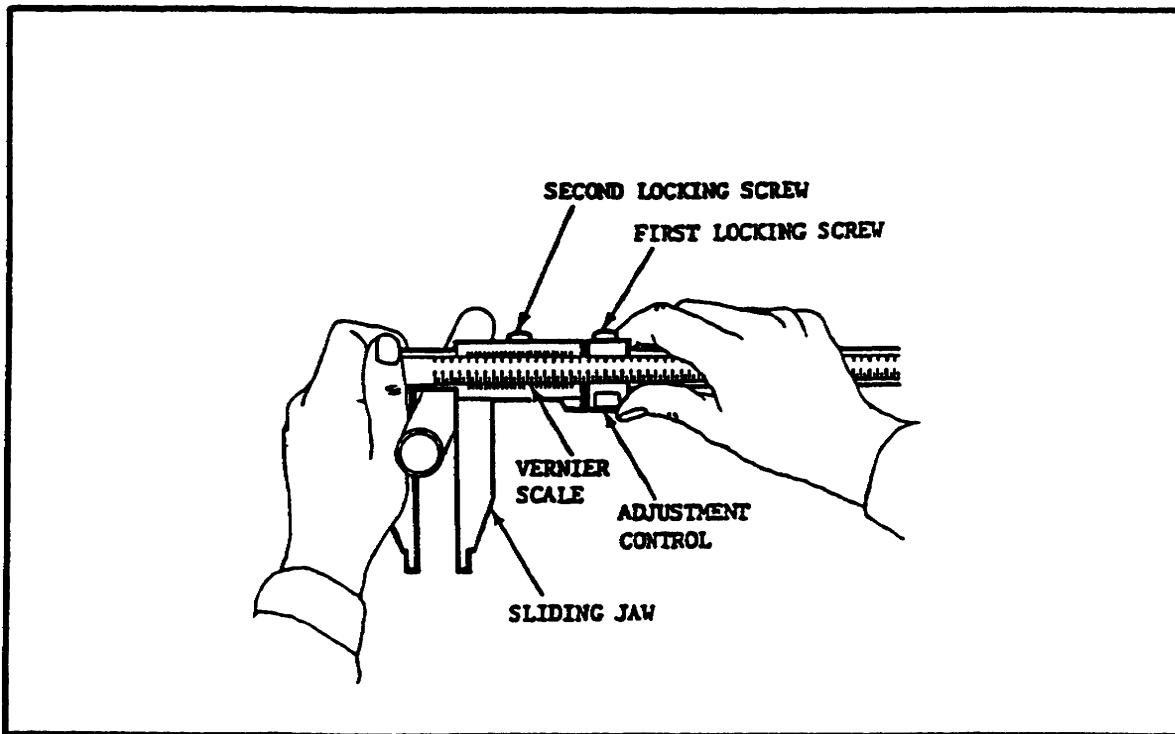
The depth micrometer is able to enter holes that have a $3/32$ inch diameter. However, the vernier depth gage will enter a $1/32$ inch slot, while the depth micrometer cannot.

Selecting the proper tool for a measurement is important. It will help you get the best measurement with the least amount of trouble. After you select a tool, you must know how to use it properly. First we will look at how to use a vernier caliper to make a measurement.

USING A VERNIER CALIPER

Vernier calipers work a lot like slide calipers. You can use a vernier caliper to make a very accurate outside measurement (figure 15, below). You can also use it to make an inside measurement (figure 16, on the next page). To make an accurate measurement, you must not only know how to operate the caliper, but how to use the right amount of pressure.

FIGURE 15. USING A VERNIER CALIPER TO MAKE AN OUTSIDE MEASUREMENT.

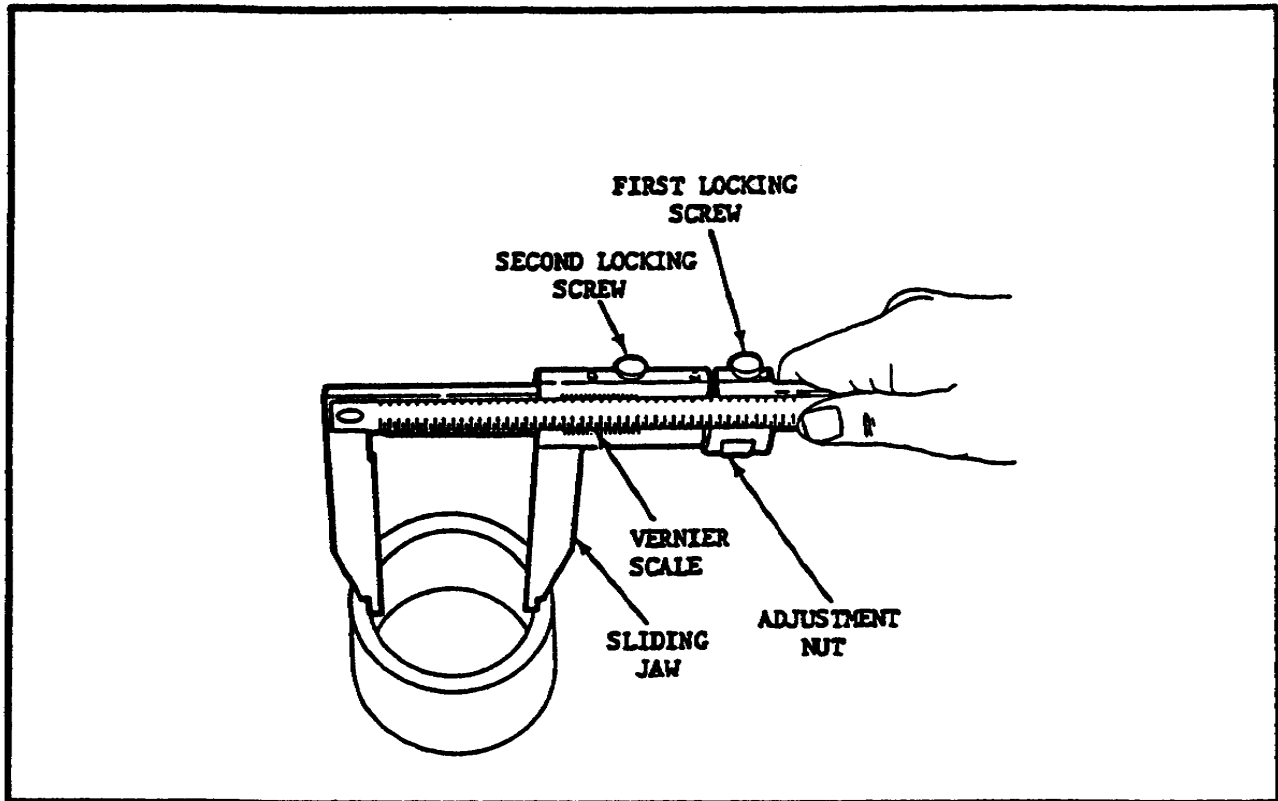


Operating the Vernier Caliper

To use a vernier caliper, first loosen both locking screws. This will allow you to move the sliding jaw along the rule. Hold the fixed jaw in one hand, and move the

sliding jaw with your other hand. When the jaws are in the position you want, secure the sliding jaw. Do this by tightening the locking screw above the adjustment control. Use the adjustment control to make any needed fine adjustments to the vernier scale. Tighten the second locking screw. If you are using the right amount of measuring pressure, you can now read an accurate measurement on the vernier caliper.

FIGURE 16. USING A VERNIER CALIPER TO MAKE AN INSIDE MEASUREMENT.



Using the Right Pressure

You will not get an accurate measurement with a vernier caliper unless you use the right amount of measuring pressure. If you use too much pressure, you might get a wrong reading because of play in the sliding jaw. Too little pressure can also result in the wrong reading.

To get the right amount of pressure, you must be able to "feel" the measurement. The jaws of the caliper are long, and there can be some play in the sliding jaw, especially if you use too much pressure. This can cause inaccurate measurements. Therefore, you must develop the ability to handle the caliper. One way to do this is to practice by using the caliper to measure known standards. You might try measuring gage blocks or gage plugs until you consistently get accurate readings.

PRECISION MEASURING INSTRUMENTS - OD 1401 - LESSON 1/TASK 3

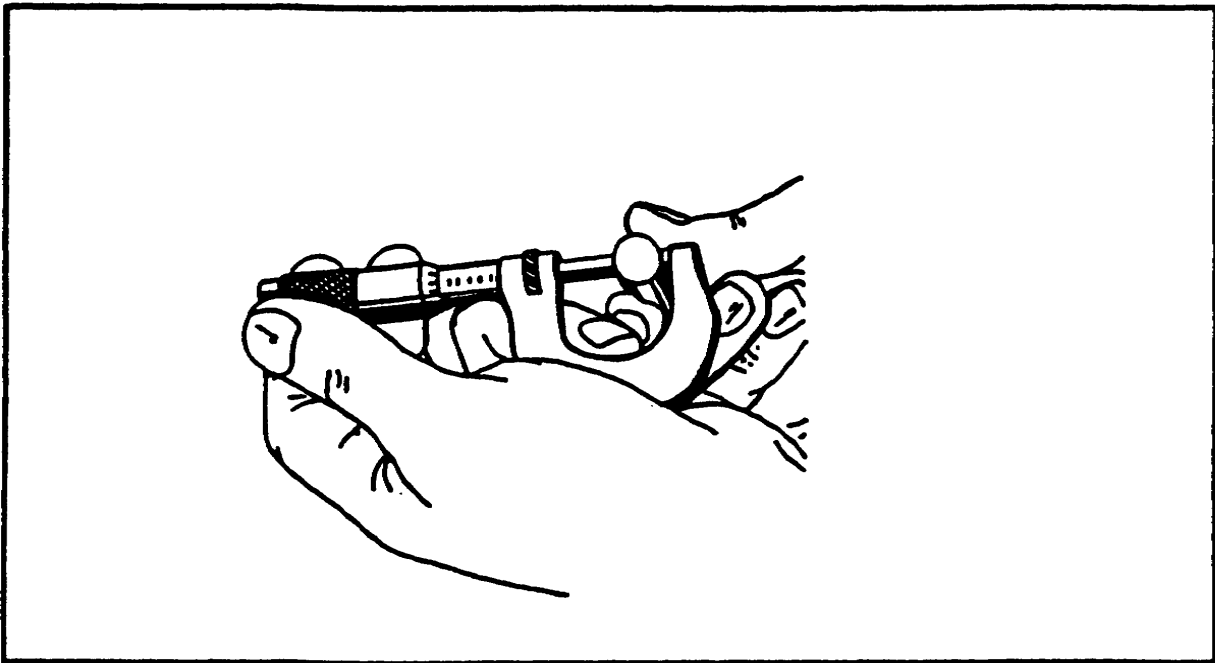
USING AN OUTSIDE MICROMETER

If you choose an outside micrometer instead of a vernier caliper, you will also get accurate readings of outside dimensions. Just as with the vernier caliper, the technique you use will effect the accuracy of your measurement.

Measuring Small Parts

Figure 17, below, shows how you should hold your hands when you use an outside micrometer to measure a small part. You should hold the part in one hand; hold the micrometer in the other hand. Hold the micrometer so that the thimble rests between your thumb and your forefinger. From this position, you can use your third finger to hold the frame against the palm of your hand. If you support the frame this way, it will be easy to guide the part you are measuring over the anvil. Your thumb and forefinger are in a position to turn the thimble so that the spindle will move over against the part.

FIGURE 17. MEASURING A SMALL PART USING AN OUTSIDE MICROMETER.

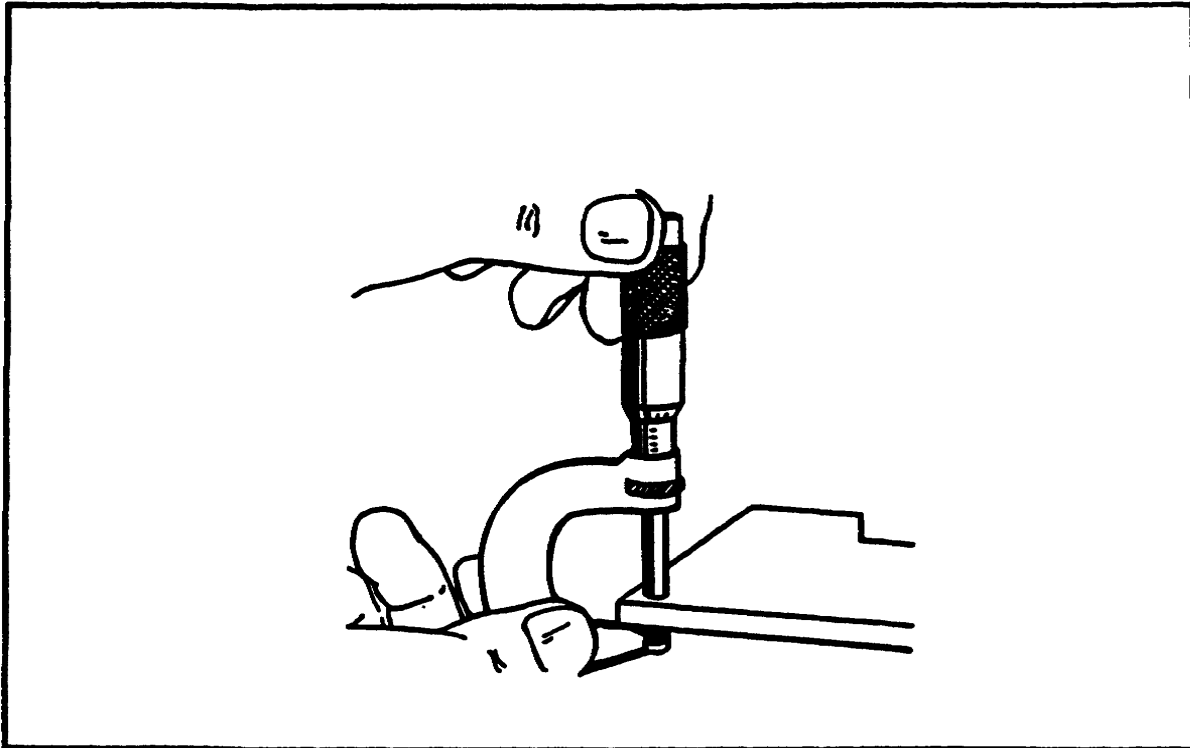


Measuring Larger Work

When you measure larger work, you must hold the workpiece still, in a position where you can get at it with the micrometer. When you check a part too large to be held in one hand, you should use the method shown in figure 18, on the next page. Hold the frame in one hand to position it

and to locate it square to the measured surface. Use your other hand to turn the thimble. A large, flat part should be checked in several places. This will tell you how much variation there is in the thickness of the part.

FIGURE 18. USING AN OUTSIDE MICROMETER TO MEASURE LARGER WORK.



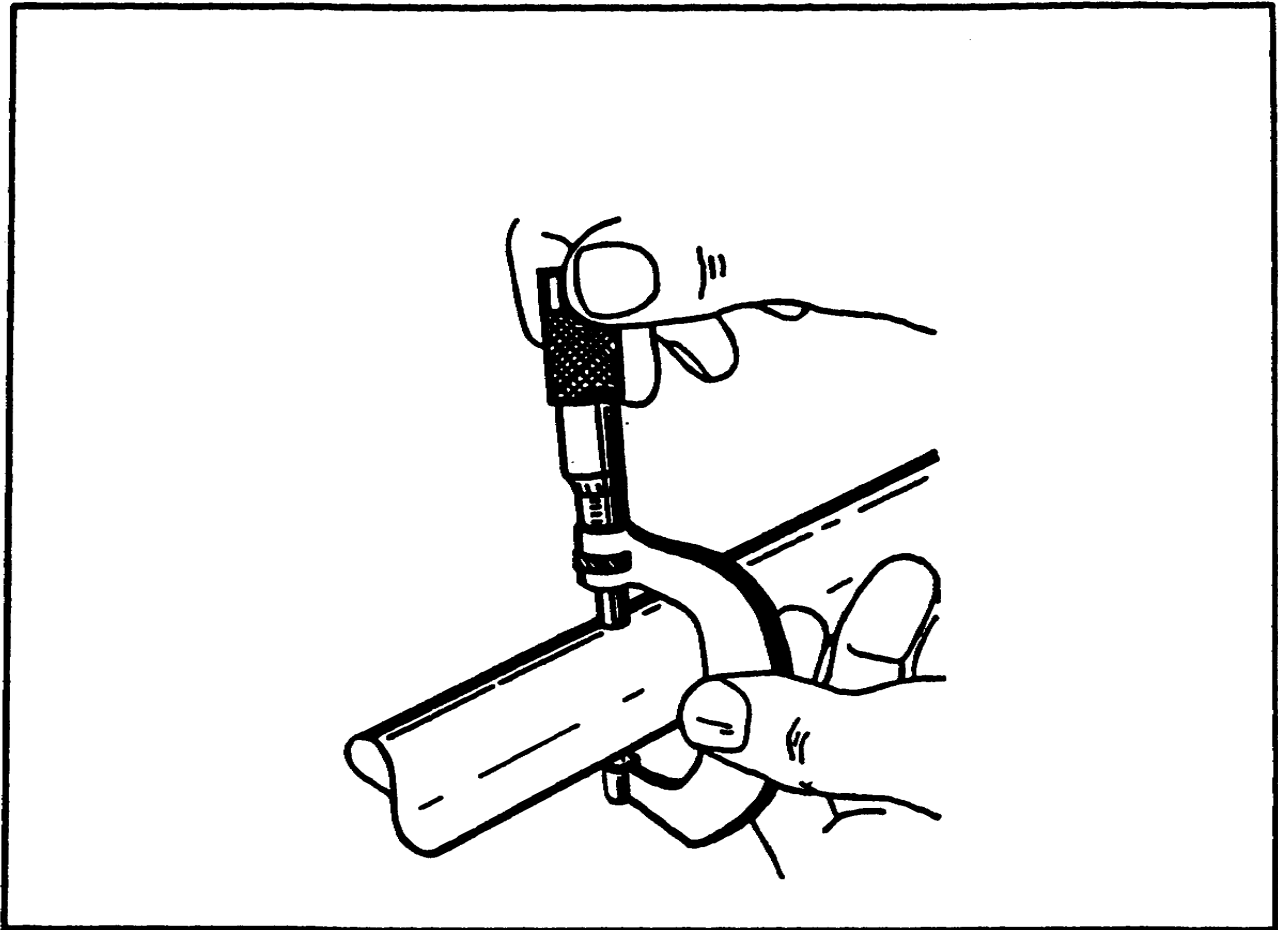
Techniques for Gaging a Shaft

The hand positions you should use when gaging a shaft are shown in figure 19, on the next page. You hold the frame in one hand while turning the thimble with the other hand. When you gage a cylindrical part with a micrometer, you must be able to "feel" the setting. This is the only way you can be sure that the spindle is on the diameter. You must also check the diameter in several places to determine the out-of-roundness of the shaft.

Measuring Very Large Diameters

When you need to measure very large diameters, you may need to screw a special anvil to the frame of a micrometer. Outside micrometers are made in various sizes up to 168 inches. You can reduce the range of one of these micrometers by using a special anvil. A set of different length anvils lets you use a large micrometer over a wide range of sizes even though the spindle only moves one inch.

FIGURE 19. USING AN OUTSIDE MICROMETER TO GAGE A SHAFT.



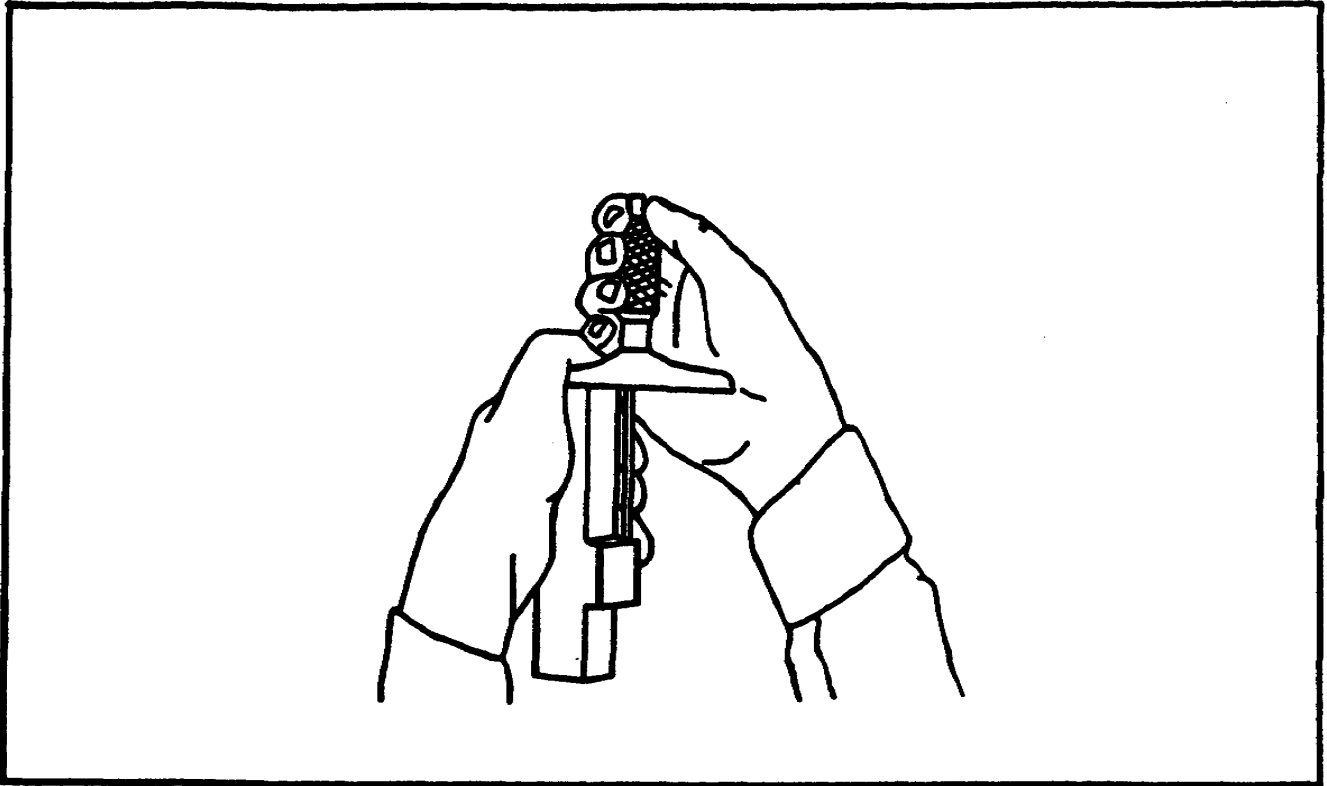
USING A DEPTH MICROMETER

When using a vernier caliper and an outside micrometer, you used special hand positions and techniques to get accurate measurements. The depth micrometer also requires special hand positions.

Figure 20, on the next page, shows a depth micrometer being used to measure a projection. Look at the hand positions. You will use one hand to hold the flat base firmly against the measuring surface. In the other hand, you will hold the depth micrometer so that you can turn the thimble with the thumb and forefinger.

When you use a depth micrometer, you must remember to select the proper extension rod. The rod you choose should be less than one inch shorter than your estimate of the measurement. For example, if you estimate that the measurement will be 4 1/4 inches, you should set the screw to zero and then fit a 4 inch extension rod to the micrometer. The one inch movement of the micrometer screw allows accurate measurement of the remaining distance.

FIGURE 20. USING A DEPTH MICROMETER.



CONCLUSION

You should now be able to select the right tool for the measurement you want to make. After selecting either a vernier caliper, an outside micrometer, or a depth micrometer, you should be able to use the techniques needed to get an accurate measurement. With the chosen tool in place, you will be able to read its scales accurately. You also now know how to properly care for one of these tools after you use it.

Before you take the examination, try the practice exercise on the next page. It will help you check what you have learned about these three tools.

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PRACTICE EXERCISE 1

INSTRUCTIONS

This practice exercise will show you how much you have learned in this lesson. Answer each question. When you are done, turn the page to check your answers.

PART A:

You need to measure, to the nearest 1/1000 of an inch, both the inside and outside diameters of a pipe, using your vernier caliper. Answer these questions.

1. Before you make your measurement, you notice that the tips of the jaws on your vernier caliper are showing slight wear. What can you adjust to make up for some of this wear?
2. You measure the outside of the pipe with the vernier caliper. You hold the fixed jaw of the caliper in one hand.
 - a. What do you hold in the other hand?
 - b. What must be loosened so that the sliding jaw will move?
 - c. What can happen if you use too much pressure during the measurement?
 - d. What part of the caliper is used to make fine adjustments after the caliper is in place?
3. Using the side of your caliper marked "INSIDE," you measure the inside diameter of the pipe. You get a reading that has these characteristics:
 - o The whole inch line to the left of the vernier zero is 3.
 - o The tenth inch line to the left of the vernier zero is 3.
 - o There are 3 spaces between the tenth inch line marked 3 and the vernier zero.
 - o Line 10 on the vernier scale exactly coincides with a line on the rule scale.

In inches, what is the correct inside measurement for this pipe?

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4. After you finish measuring, you store your vernier caliper. With what should you coat the metal parts of the caliper?

PART B:

You have a piece of tubing that is about $2 \frac{3}{4}$ inches in diameter. It has a projection which is located about $5 \frac{1}{4}$ inches from the end of the tubing. You need to know the exact outside diameter of the tube and the distance from the end of the tube to the flange. You decide to use an outside micrometer to measure the diameter and a depth micrometer to measure the distance to the flange.

5. As you take the outside micrometer from storage, you notice that the last person to use it left a gap between the anvil and the spindle when storing it. Why should you leave this gap when storing the micrometer?

6. What size outside micrometer must you select to make the measurement?

7. As you gage the tube, you check the diameter in several places. What are you trying to determine?

8. As you interpret the reading you get on the micrometer, what is the value (in inches) of:

a. each numbered line on the barrel?

b. each space between the numbered lines on the barrel?

c. Each increment marking on the thimble?

9. What length of extension rod do you choose for the depth measurement?

10. After you are done, in what type of container should you store the depth micrometer?

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LESSON 1. PRACTICE EXERCISE - ANSWERS

PART A:

1. You can make up for some of the wear by adjusting the vernier scale. (page 5, para 2)
2.
 - a. The sliding jaw. (page 35, para 1)
 - b. The locking nuts. (page 34, para 4 through page 35 para 1)
 - c. You may get inaccurate measurements. (page 35, para 2)
 - d. The adjustment control. (page 35, para 1)
3. The correct reading is 3.385 inches, as shown below: (page 17, para 3 through page 19, para 2)
 - o The whole inch line to the left of the vernier zero is 3. = 3.000 in
 - o The tenth inch line to the left of the vernier zero is 3. = 0.300 in
 - o There are 3 spaces between the tenth inch line marked 3 and the vernier zero. = 0.075 in
 - o Line 10 on the vernier scale exactly coincides with a line on the rule scale. = 0.010 in

TOTAL = 3.385 in

4. Coat the metal parts with a light coat of oil before storing. (page 5, para 3)

PART B:

5. Flat surfaces that are pressed together for any length of time may corrode. Store the micrometer with a small gap between the anvil and the spindle. (page 11, para 1)
6. You must select a three inch micrometer because its range will be between 2 and 3 inches. You have estimated the diameter to be 2 3/4 inches. (page 27, para 1 & 2)

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7. The amount of out-of-roundness. (page 37, para 2)
8.
 - a. Each numbered line on the barrel equals 0.10 inch. (page 22, para 2)
 - b. Each space between the numbered lines on the barrel is equal to 0.025 inch. (page 22, para 2)
 - c. Each increment marking on the thimble is equal to 0.001 inch. (page 22, para 3)
9. You should choose a 5 inch extension rod. (page 38, para 3)
10. Store the depth micrometer in its own container, provided by the manufacturer. (page 12, para 8)

If you had a hard time getting the right answers, go back and review the lesson. If you did well on this practice exercise, you should be ready to take the exam.