Suggested Unit Course in

MEASUREMENT

Machine Shop Series

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Albany, New York

MACHINE SHOP SERIES

This series of texts covers six major occupational areas of Machine Shop Practice: (1) *Measurement*, (2) *Bench Work*, (3) *Drill Press*, (4) *Lathe*, (5) *Milling Machine*, and (6) *Shaper Work*.

The instructional material in each book is written in simple trade terminology and illustrated through the generous use of line drawings. The range of technical information (*Why-to-do*) and fundamental process units (*How-to-do*) provides basic instruction for beginning students, apprentices and home workshop enthusiasts; and advanced reference material for skilled craftsmen, engineers, supervisory personnel and teachers.

MACHINE SHOP MEASUREMENT

A beginner's text and workbook which covers basic mathematical principles of linear, circular, and angular measurement from the standpoint of related mathematics and machine shop practice.

65 pages (7¾ x 10¼); 109 line drawings

BENCH WORK

A basic text which describes the theory of *Bench Work* and the operations performed with measuring, layout and bench tools.

88 pages (7¾ x 10¼); 159 line drawings; formulas; tables

DRILL PRESS WORK

An introductory text dealing with the theory and operation of drill presses; uses of accessories and holding devices; cutting speeds and feeds; drilling, reaming, countersinking, counterboring and tapping.

42 pages (7¾ x 10¼); 48 line drawings; 6 tables

LATHE WORK

A comprehensive text covering the related technical information and fundamental processes which are basic for *Lathe Work* held between centers and in a chuck. A partial list of topics includes: centering, mounting work; grinding tool bits; facing, straight turning; speeds and feeds; turning shoulders, chamfering, knurling, thread cutting, angle and taper turning; mandrel and chuck work; drilling, boring, reaming and tapping.

164 pages (7¾ x 10¼); 197 line drawings; formulas; tables

MILLING MACHINE WORK

An exhaustive study of modern milling machines and accessories. The instructional units cover in minute detail the theory and practice of basic and advanced milling machine operations, with emphasis on dividing head work.

298 pages (7¾ x 10¼); over 300 illustrations including phantom and cut-away sections

SHAPER WORK

A new and complete treatise on modern types of crank and hydraulic shapers. The text covers all the basic and advanced operations and related technical information required to do *Shaper Work*.

326 pages (7¾ x 10¼); 582 illustrations including phantom and cut-away sections

PREFACE

The production of interchangeable parts, which is the keystone of our present day manufacturing system, depends largely on the skill of the individual machine operator and of the all-around craftsman in operating machine tools and using measuring instruments so that each machine part is held within certain prescribed limits of accuracy.

Over a period of years careful analyses were made to determine essential occupational areas of training for machine shop practice. As a result of these studies, the following six main divisions of the trade were defined and a series of texts were prepared to cover them: (*1*) *Measurement*, (2) *Bench Work*, (3) *Drill Press*, (4) *Lathe*, (5) *Milling Machine*, and (6) *Shaper Work*.

Further study revealed that each operation in machine shop practice involves the teaching and learning of basic trade theory and fundamental processes. Following this line of reasoning, two types of instructional units are included in each monograph: (1) *Trade Theory Series* and (2) *Fundamental Process Series*. A brief description of each type follows.

Trade Theory Series

The basic trade theory and related technical information, such as principles governing machine shop operations, the derivation and application of formulas, and descriptions of machine tools and accessories, are covered in the *Trade Theory Series*. This technical information furnishes the student with background trade knowledge necessary to perform machine shop operations skillfully. The *Trade Theory* units which are directly related to the *Fundamental Process* units may be used as text or reference material for class, laboratory or home study.

Fundamental Process Series

The term *Fundamental Process* covers those manipulative processes which involve the use of hand and machine tools and are common to machine or bench work. The manipulative phases of an operation are described in common trade terminology and are well illustrated with line drawings. As the *Fundamental Process* units provide reference material for the actual performance of operations, they may be used as supplementary text material for the teaching of fundamental processes either in a school or an industrial plant.

The selected series of instructional units in each text includes those fundamental operations which are common for a specific division of the trade and which apply under all conditions. Throughout the series the units are arranged in the natural order of dependence of one operation on the next; i.e., in a sequence which conforms to the logical order of teaching and learning difficulty. However, this arrangement may be changed to meet exacting industrial and educational training course requirements without altering the effectiveness of any one of the suggested unit courses.

Sincere appreciation is expressed to the Bureau of Industrial and Technical Education, The New York State Education Department for permission to reproduce this instructional material.

The Editor

Albany, New York

MEASUREMENT

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ASSIGNMENT SERIES

* Key to unit numbers
- 1 First year or beginner level
- M - Unit course in measurement
- T Trade theory series
- P Fundamental process series
- BP Basic principle series
- A Assignment series
- -3 Sequence of units of instruction

Examples:
- 1M-T3 First year course in Measurement, Trade Theory unit number three
- 1M-BP3 First year course in Measurement, Basic Principle unit number three

SECTION I

Units of Instruction in

MACHINE SHOP MEASUREMENT

MACHINE SHOP MEASUREMENT

SECTION I

Machine Shop Practice | Unit IM-T1 | Trade Theory Series

DESCRIPTION OF MEASURING TOOLS

OBJECTIVES OF UNIT

1. To acquaint the learner with the common fraction and decimal fraction systems of measuring.

2. To explain the application of the steel rule, outside caliper, inside caliper, micrometer caliper, and the steel square in measuring.

3. To explain the construction, reading, and use of the micrometer caliper.

INTRODUCTORY INFORMATION

The measuring of material and machined work involves the use of a number of measuring tools to secure sizes of length, width, thickness, and diameter. One or more of these factors may be involved when determining the size of material or a piece of work.

The English system of linear measure, of which the yard is the unit of length, is the standard used in American industry. In machine shop work, the more commonly used unit is the inch, the thirty-sixth part of a yard. The inch may be divided into smaller parts by means of either common or decimal fractional divisions.

The fractional divisions of an inch are found by dividing the inch into equal parts; the more common of which are: halves, quarters, eighths, sixteenths, thirty-seconds, and sixty-fourths. When smaller units of measurement are required, the decimal system is used in which the inch is divided into tenths, hundredths, thousandths, and ten-thousandths of an inch (Figure 1).

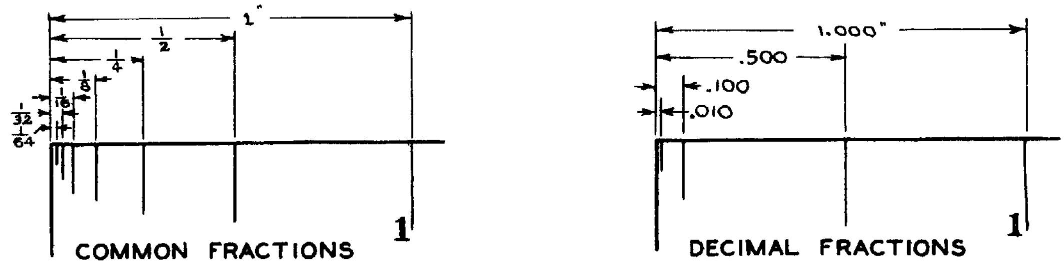

FIG. 1 TWO SYSTEMS OF DIVIDING THE INCH

In machine shop it is common practice to use fractions of an inch expressed in decimals, called decimal equivalents of an inch; i.e. 1/8" is expressed as .125" (one hundred twenty-five thousandths of an inch), or 1/4" as .250" (two hundred fifty thousandths of an inch), etc.

DESCRIPTION OF MEASURING TOOLS

THE STEEL RULE

The steel rule is used for measuring either common fractions up to sixty-fourths of an inch, or decimal fractions up to one-hundredths of an inch. These rules are made in various lengths, widths, thicknesses, and methods of graduation. Two types are illustrated below. The first type (Fig. 2) is the more common machinist's rule--with graduations of one-eighth inch on one edge and sixteenths on the other.. Turning the scale over, thirty-seconds are on the top edge and sixty-fourths on the other.

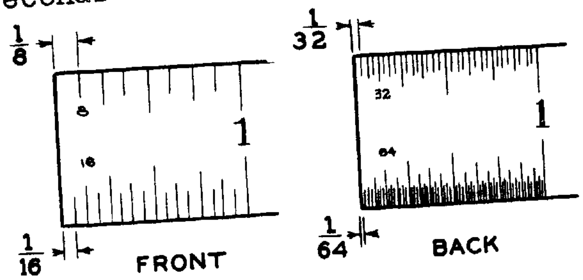

FIG. 2 MACHINIST'S STEEL RULE

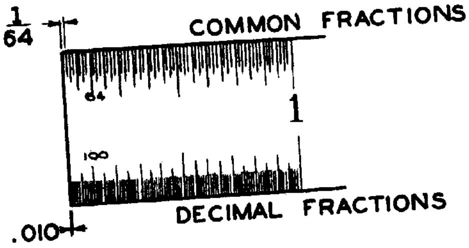

FIG. 3 COMBINATION STEEL RULE

On another type of scale (Fig. 3), divisions of common fractions in sixty-fourths of an inch are on the top edge, and decimal fractions in one-hundredths of an inch are on the bottom edge. One-hundredths of an inch are the smallest divisions found on machinist's rules.

The steel rule may be used for two purposes: setting or securing dimensions and measurements, and as a straight edge (Fig. 4). With practice it can be read accurately and is one of the most valuable shop tools.

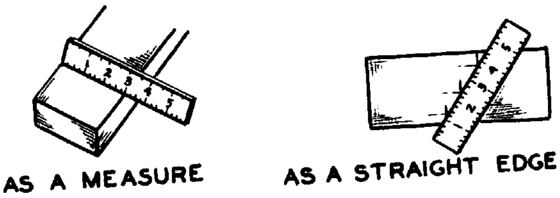

FIG. 4 TWO USES OF STEEL RULE

OUTSIDE AND INSIDE CALIPERS

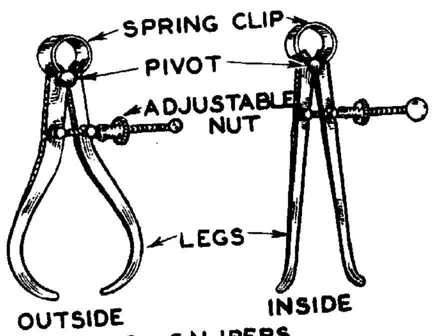

FIG. 5 CALIPERS

The two tools most commonly used to transfer measurements from the work to the scale or from the scale to the work are the outside and inside calipers.

As their names imply, they are constructed to take external or internal measurements and are built on that basis (Fig. 5).

DESCRIPTION OF MEASURING TOOLS

The legs of the calipers are attached to a pivot at the upper end. This end is held together above the pivot by a spring clamp. The clamp tends to hold the legs firmly against the adjusting nut and on the pivot. The working tips of the legs should be kept in line to preserve the accuracy of the tool (Fig. 5).

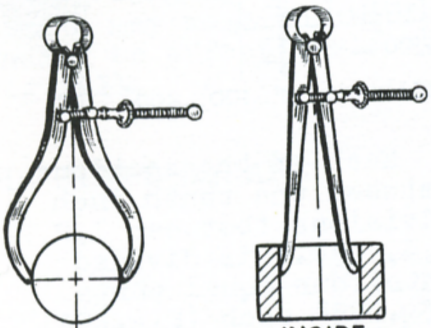

FIG. 6 MEASURING WITH CALIPERS

The accurate use of calipers depends upon the "feel" which is developed through use. They should never be forced over or into the work. Likewise, they should always be used square with the axis of the work and the surface being measured (Fig. 6).

The caliper can be used in two ways to make a measurement. They can be set over the object (as illustrated) and then tested on a steel measuring rule, or they can be set from the rule and the measurement transferred to the work.

Calipers are made in a variety of sizes depending upon the size of opening: 2", 3", 4", 5", 6", etc.

THE MICROMETER CALIPER

The smallest measurement which can be made with the use of the caliper and steel rule are, in the case of common fractions, 64ths of an inch; in decimal fractions, hundredths of an inch. To measure finer than these (thousandths and ten-thousandths of an inch), a micrometer caliper is used.

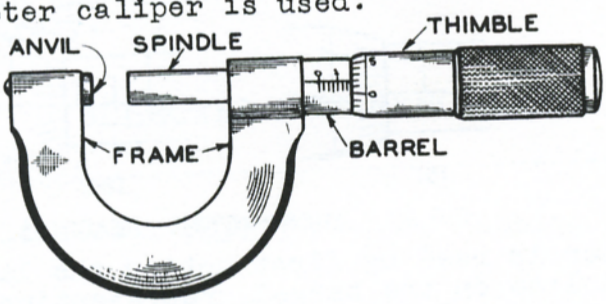

FIG. 7 PARTS OF THE MICROMETER CALIPER

If a dimension in common fractions is to be measured with the micrometer, it must be converted to its decimal equivalent.

The principal parts of the micrometer are: the anvil, frame, barrel, spindle and screw, and thimble (Fig. 7). The micrometer caliper operates on a screw which is free to move in the threaded portion inside the barrel.

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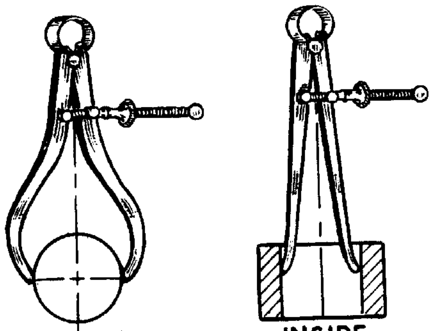

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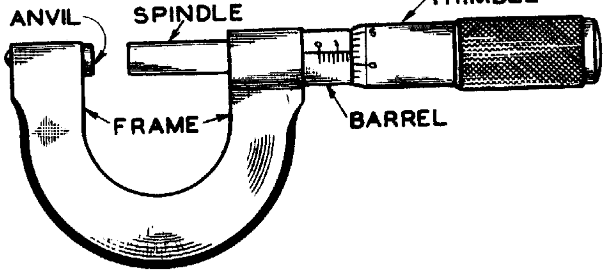

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DESCRIPTION OF MEASURING TOOLS

The movement of the screw provides an opening between the anvil and the end of the spindle where the work is measured. The size is indicated by the graduation on the barrel and the thimble.

The lines on the barrel marked 1,2,3,4, etc., indicate measurements of .100", .200", .300", .400", etc., respectively. (Fig. 8).

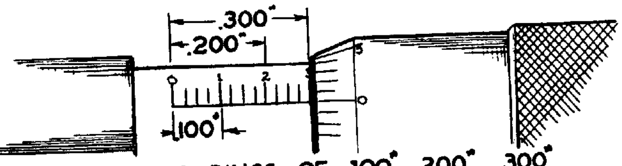


FIG.8 READINGS OF .100", .200", .300"

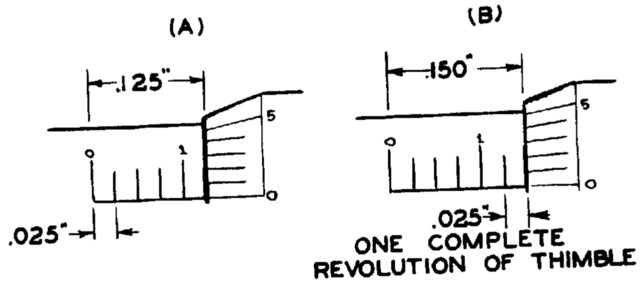


FIG. 9 DIVISIONS OF .025"

Each of the sections between the tenth inch divisions (between 1,2, 3,4, etc.) is divided into four equal parts of .025" each (Fig. 9A)

One complete revolution of the thimble from its zero to zero, moves it one of these .025" divisions as in Figure 9B.

The bevel edge of the thimble, in turn, is divided into twenty-five equal parts. Each of these parts represents one twenty-fifth of the distance the thimble travels along the barrel in moving from one of the .025" divisions to another. Thus each division on the thimble represents a thousandth (.001") of an inch. These divisions are marked for convenience at every five spaces by 0, 5, 10, 15, and 20. When 25 of these graduations have passed the horizontal line on the barrel, the spindle (having made one revolution) has moved .025".

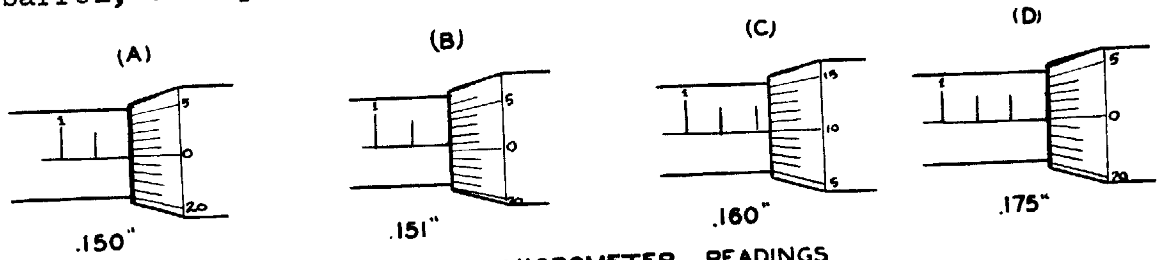


FIG. 10 MICROMETER READINGS

The micrometer is read by first noting the last visible figure on the horizontal line on the barrel, representing tenths of an inch. Add to this the amount represented by the visible graduations beyond this figure (by multiplying the number of them by 25), and the number of divisions on the bevel edge of the thimble that coincides with the line of the graduation. The sum, of the tenths of an inch, plus the number of divisions beyond the last tenth of an inch graduation multiplied by 25, and the divisions on the bevel edge of the thimble, is the reading (Figures 10-A,B,C, and D).

DESCRIPTION OF MEASURING TOOLS

The ability to measure to a thousandth of an inch with micrometers makes them an accurate tool with which to work. If they are dropped and the screw which moves the spindle is damaged, their accuracy may be permanently affected. Likewise, continually sliding work between the anvil and spindle may wear the surfaces, tending to affect their accuracy (Fig. 11).

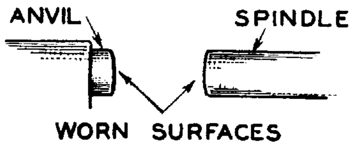


FIG. 11 WEAR ON SPINDLE AND ANVIL

THE STEEL SQUARE

FIG. 12 MEASURING RIGHT ANGLES

The steel square is used to measure an angle of ninety degrees (90°). Surfaces at 90° to each other are said to be "square" with each other (Fig. 12).

The steel square is made of high grade tool steel, hardened, tempered, and ground to a fine degree of accuracy. The right angle, or perpendicular as it is also called, may be found on either the inside or outside of the square (Fig. 13).

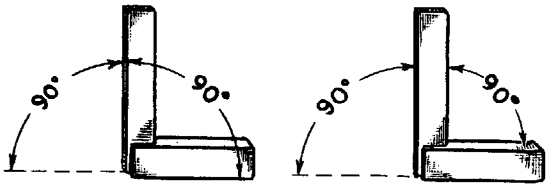


FIG. 13 THE STEEL SQUARE

NOTE: Care must be taken not to damage the square as any change in the position of the surfaces will destroy its accuracy.

SELECTED REFERENCES

Henry Ford Trade School ------------------------------ Shop Theory

Burghardt ----------------- Part I ------- Machine Tool Operation

MEASUREMENT

HOW TO USE MEASURING TOOLS

OBJECTIVES OF UNIT

1. To point out general practices in the application of the most commonly used measuring tools.

2. To show how to measure with the steel rule, outside caliper, inside caliper, micrometer caliper, and steel square.

INTRODUCTORY INFORMATION

To become proficient in the use of measuring tools, a beginner must develop judgment and a sense of "feel" which will enable him to measure accurately and skillfully.

The steel rule, when used alone or in combination with the setting of calipers, is employed to obtain "scale" dimensions which are only approximate. For measurements that require greater accuracy (to within one thousandth of an inch or finer), the micrometer caliper is used either alone or in combination with inside calipers and other special measuring tools.

A good mechanic is known by the manner in which he cares for his tools. Abuse and careless handling of measuring tools destroys their usefulness.

TOOLS AND EQUIPMENT

Steel Rule
Outside Caliper
Inside Caliper
Micrometer Caliper
Steel Square

PROCEDURE

STEEL RULE

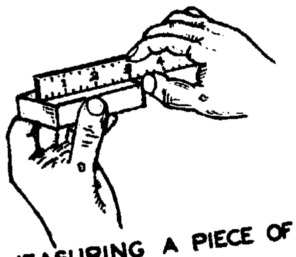


FIG. 1 MEASURING A PIECE OF STO[CK]

1. To measure a piece of stock, place the rule flat across the surface or distance to be measured; holding or steadying the work with the left hand.

2. With rule held in the right hand and guided by the thumb nail, extend the rule until its end is even with the left hand edge of the work (Fig. 1).

HOW TO USE MEASURING TOOLS

3. Read the graduations on the rule from left to right by noting which line on the rule coincides closest with the right hand edge of the stock (Fig. 2).

   NOTE: Select that edge of the rule which is graduated in fractional divisions of an inch in which the desired dimension is wanted; i.e. eighths, sixteenths, thirty-seconds, and sixty-fourths (Fig. 3).

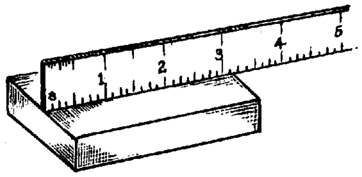


FIG. 2 READING A STEEL RULE

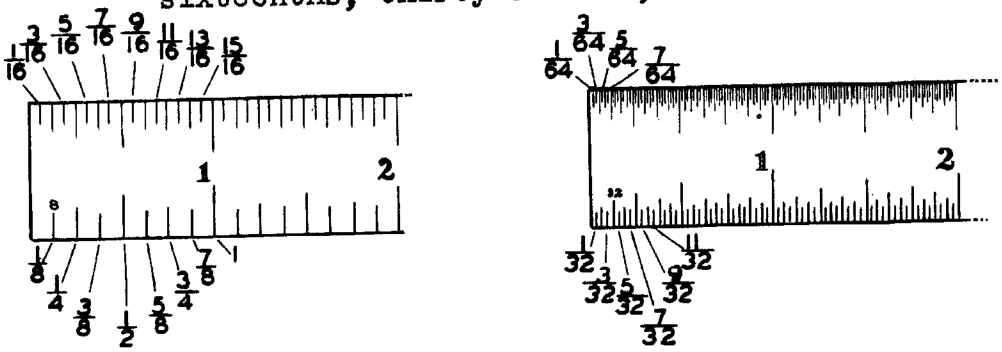


FIG. 3 GRADUATIONS ON A STEEL RULE

OUTSIDE CALIPERS

1. To measure a piece of work with the outside calipers, hold the calipers in the right hand and, with the thumb and forefinger, grasp the knurled adjusting nut (Fig. 4).

2. Turn the adjusting nut with the thumb and forefinger until the caliper will just slide over the work by its own weight.

   NOTE: At all times keep the calipers square with the work to be measured. A piece of round stock is calipered as shown in Figure 4.

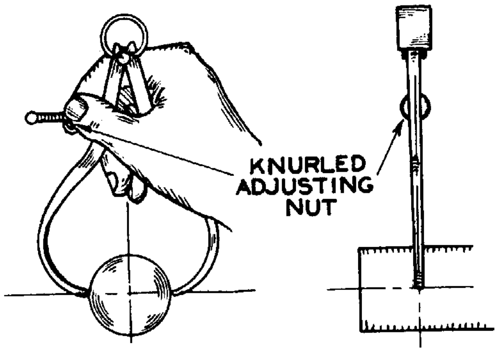


FIG.4 TAKING A MEASUREMENT WITH AN OUTSIDE CALIPER

3. Remove the caliper from the work, being careful not to disturb the setting.

HOW TO USE MEASURING TOOLS

4. To measure the distance between the caliper legs with the aid of a steel rule, hold the rule in the left hand with the second finger at the bottom and behind the rule.

5. Place one of the legs at the end of the rule, and the other leg on the graduated face of the rule in line with the first leg, and read the measurement.

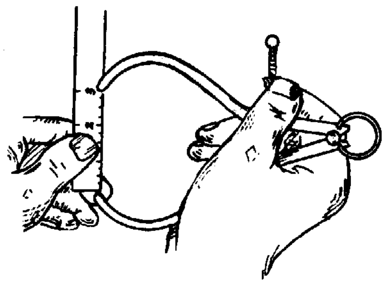


FIG. 5 SETTING AN OUTSIDE CALIPER

NOTE: The caliper may be used to check a given size by first setting it to the desired dimension from a steel rule (Fig. 5). Then use the caliper as a gage in selecting a piece of the required size.

INSIDE CALIPERS

1. To take an inside measurement, hold the caliper in the right hand with the thumb and forefinger grasping the knurled adjusting nut (Fig. 6).

2. Rest one leg of the inside caliper slightly inside of the edge of the space to be measured. Turn the adjusting nut until the caliper is felt striking the high point of the arc on entering the space to be measured (Fig. 6).

NOTE: Make sure that the tips of the caliper legs are square with the largest portion of the diameter being measured.

With the calipers held in this position, test to see whether they can be moved sideways. If necessary, readjust so that no side motion can be felt.

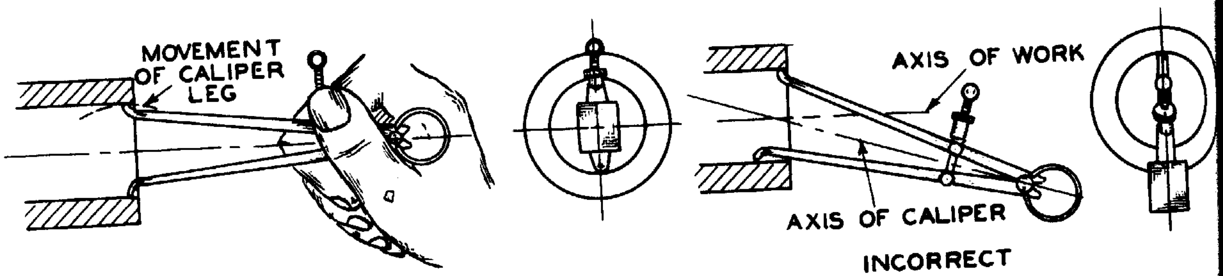


FIG. 6 CORRECT AND INCORRECT USE OF CALIPER

HOW TO USE MEASURING TOOLS

3. To measure the distance over the caliper legs with the aid of a steel rule, place one end of the steel rule against a vertical surface. Hold the caliper leg against the vertical surface, keeping the ends level at the same time. Read the dimension from the rule (Fig. 7).

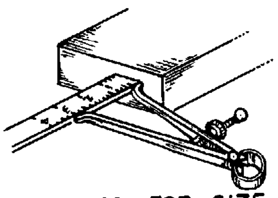


FIG. 7 CHECKING FOR SIZE

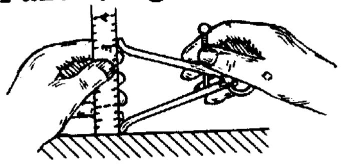


FIG. 8 SETTING AN INSIDE CALIPER

NOTE: An inside caliper may be used to check a given size by first setting it to the desired dimension from the steel rule (Fig. 8), and then using the caliper as a gage to check the internal measurement.

MICROMETER CALIPER

A. TO MEASURE A PIECE OF WORK WITH THE MICROMETER WHEN THE WORK IS HELD IN THE HAND

1. The frame of the micrometer is held in the palm of the right hand by the little finger (or the third finger, whichever is more convenient), allowing the thumb and forefinger to be free to revolve the thimble for the adjustment (Fig. 9).

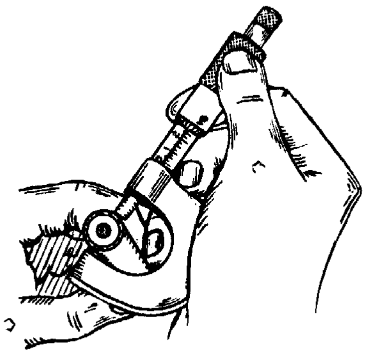
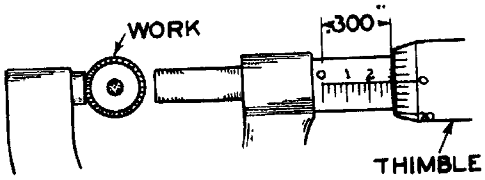


FIG. 9 MEASURING STOCK

2. Place the work between the anvil and the spindle. Turn the thimble until its movement has brought the spindle and the anvil in contact. (Fig. 9).

NOTE: The beginner must develop a sense of "feel" in adjusting the micrometer to the work. Avoid the tendency to cramp the micrometer by using too much pressure.



READING .300

FIG. 10 START TURNING THIMBLE

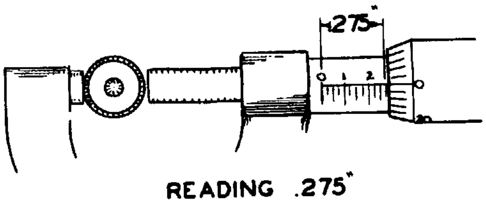
3. The measurement is taken from the graduations on the barrel and thimble by:

   a first noting the last figure visible on the graduations of the horizontal line along the barrel, which represent the tenths of an inch (Fig.11);

HOW TO USE MEASURING TOOLS

3. b adding the number of twenty-five thousandth inch (.025") spaces beyond this figure, (Fig. 11) and then;

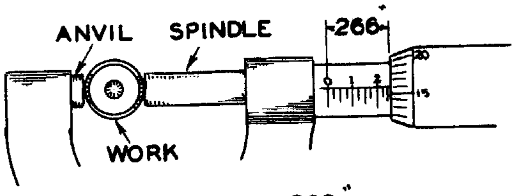
   c adding the number of the division on the beveled edge of the thimble that coincides with the line of the graduations on the barrel (Fig. 12).



READING .275"

FIG. 11 THIMBLE TURNED ONE REVOLUTION

The sum of these expressed in thousandths gives the measurement. The steps in securing this measurement are illustrated in Figures 10, 11, and, for the final reading, Figure 12.



READING .266"

FIG. 12 FINAL READING
ANVIL, WORK, AND SPINDLE IN CONTACT

NOTE: After the measurement has been determined, open the micrometer screw before removing it from the work. This practice prevents wear on the ends of the spindle and anvil, which impairs the accuracy of the tool.

B. TO MEASURE WITH THE MICROMETER CALIPER WHEN WORK IS MOUNTED IN A MACHINE.

1. Grasp the frame of the micrometer near the anvil with the thumb and forefinger of the left hand. The frame is steadied with the second and third fingers of the right hand while the thumb and forefinger are used to rotate the thimble (Fig. 13).

2. Open the micrometer and place it over the work to be measured. Turn the thimble until its movement has brought the spindle and anvil in light contact with the work (Fig. 13).

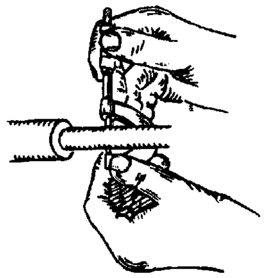


FIG. 13 MEASURING WORK MOUNTED IN A MACHINE

3. Read the micrometer as indicated in the preceding section.

   NOTE: The reading is taken while the micrometer is held on the work. Always open the micrometer before removing from the part being measured.

   CAUTION: The micrometer should never be used to measure rotating work or while the machine is running. Personal injury may result or the tool may be damaged.

HOW TO USE MEASURING TOOLS

C. TO TRANSFER A MEASUREMENT ON THE INSIDE CALIPERS TO THE MICROMETER CALIPERS.

1. Set the calipers to the space being measured.

2. Lay the calipers in the left hand with the tips of the caliper legs extending beyond the fingers (Fig.14).

3. Hold the micrometer in the right hand so that the thimble may be adjusted with the thumb and forefinger (Fig.14).

4. Rotate the thimble until the tips of the caliper legs can be felt in light contact with the anvil and the end of the spindle.

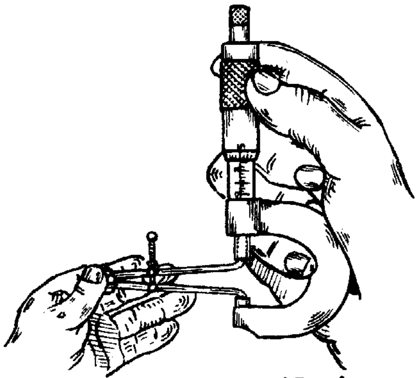


FIG.14 TRANSFERRING A MEASUREMENT

5. By placing the tip of one leg on the micrometer anvil, a fine adjustment of the setting is made by swinging an arc with the other leg until contact is felt at the high point of the arc (Fig. 15A).

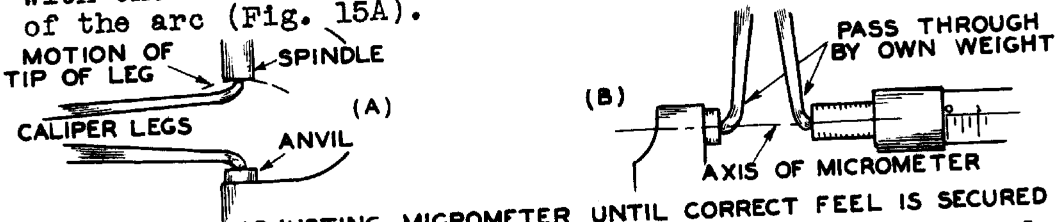


FIG. 15 ADJUSTING MICROMETER UNTIL CORRECT FEEL IS SECURED

The tips of the caliper legs must also be held parallel to the axis of the micrometer spindle; and when accurately set, should pass between the end of the spindle by their own weight (Fig. 15B).

NOTE: When reading the micrometer, remove the thumb and forefinger from the thimble so that the setting is not disturbed.

NOTE: An inside caliper may be used as a gage to check an internal measurement by first setting the inside caliper to a micrometer caliper reading.

THE STEEL SQUARE

1. Remove all burrs from the surface of the work to be checked. Wipe work clean of chips, oil, and dirt.

2. Wipe the square clean, and draw the edges to be used over the palm of the hand to insure absolute freedom from small particles.

HOW TO USE MEASURING TOOLS

3. Face the source of light so that it will shine on the work.

4. Hold the work with the left hand; grasp the beam of the square with the right hand. Place the inside of the square against a finished surface of the work, so that the beam is in full contact with one side and a slight space remains between the blade and the other surface of the work. (Fig. 16 - Position A).

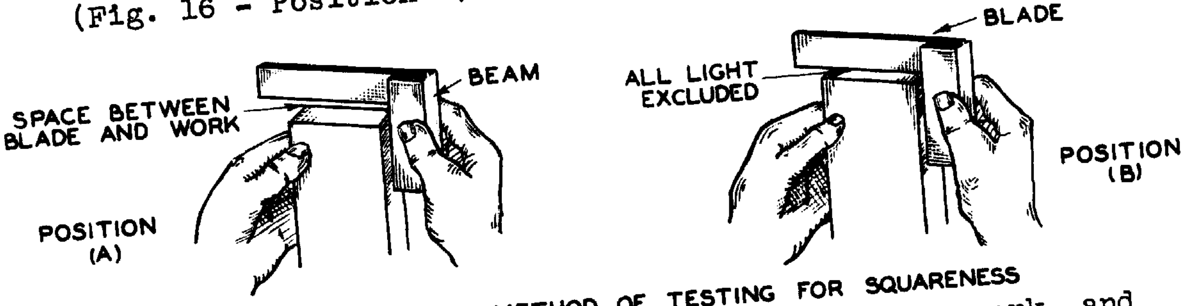


FIG. 16 CORRECT METHOD OF TESTING FOR SQUARENESS

5. Lower the blade carefully to the surface of the work, and note where the blade first comes in contact with the surface. If the angle is square, all light will be excluded (Fig. 16 - Position B).

NOTE: If the angle is not square, light will be seen at either end of the blade (Fig. 17).

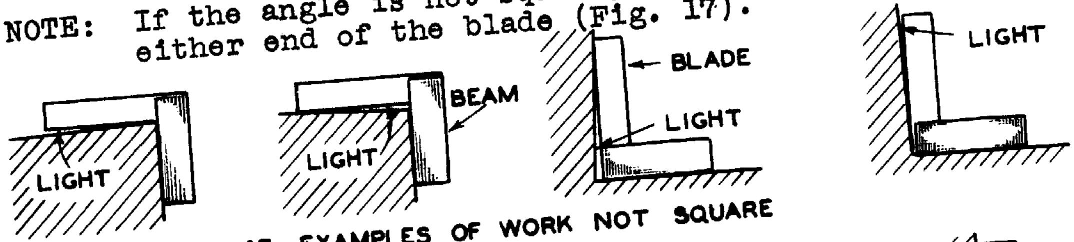


FIG. 17 EXAMPLES OF WORK NOT SQUARE

NOTE: The error resulting from burred edges, when attempting to check the squareness of work, is shown in Fig. 18.

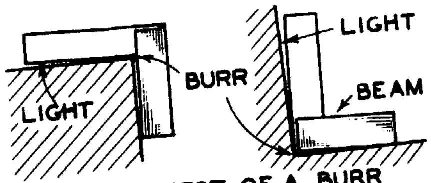


FIG. 18 EFFECT OF A BURR

NOTE: The method of checking an inside right angle with the outside edges of the square is illustrated in Figure 19, Positions (A) and (B).

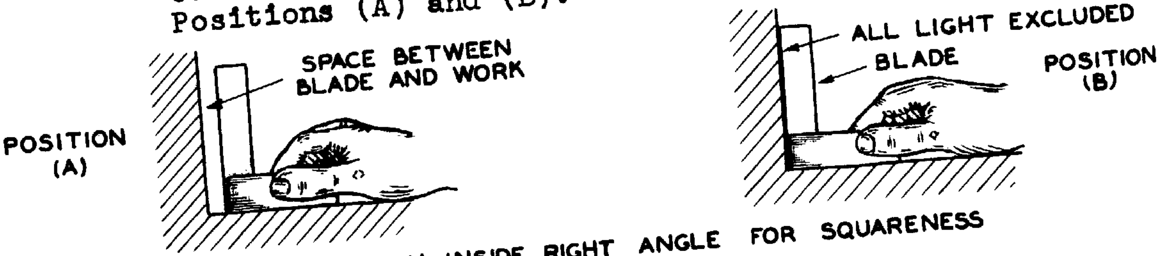


FIG. 19 TESTING AN INSIDE RIGHT ANGLE FOR SQUARENESS

MEASUREMENT

DESCRIPTION OF LAYOUT TOOLS

OBJECTIVES OF UNIT

1. To describe the various tools commonly used in layout work.

2. To point out the application of simple layout tools.

INTRODUCTORY INFORMATION

Layout tools are made in a variety of designs to aid the machinist in transferring information and dimensions from the drawing to the surfaces of the job. (Fig. 1). The general uses of these tools are to scribe lines involving circles, arcs, angles and straight lines which indicate intersections and the outlines of the shape of the work. They are also used to indicate centers of holes to be machined.

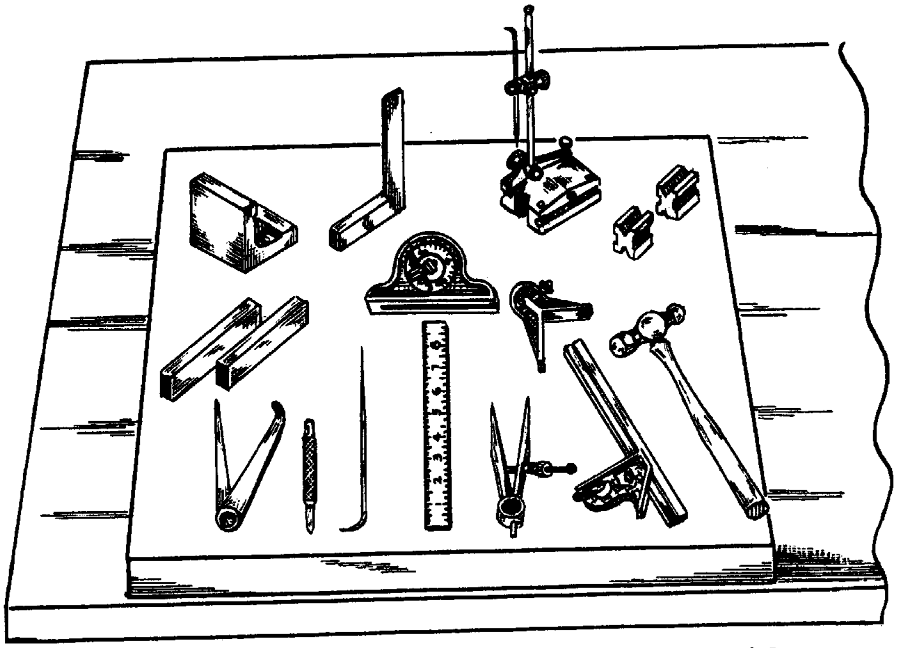


FIG. 1 BENCH PLATE AND COMMON LAYOUT TOOLS

Straight, sharp and keen-edged tools are essential for accuracy since a clean but distinctly scribed layout guides the workman more closely to desired sizes and shapes of the finished article. Therefore, it is important that the workman keep his tools in the best condition and use them only for the purpose for which they are intended.

DESCRIPTION OF LAYOUT TOOLS

BENCH PLATE

The bench plate is a cast iron plate carefully machined to a flat surface. (Fig. 2). Bench plates vary in size. An average size for the work bench is about 18" square by 1-1/2" thick. It is used as a base upon which to work. The work may lie directly on the bench plate, be clamped to an angle plate, or held on "V" blocks while being marked or scribed. The bench plate is used for ordinary layout work where great accuracy is not required.

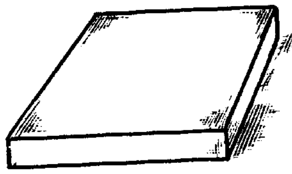
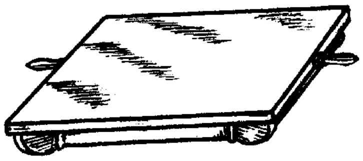


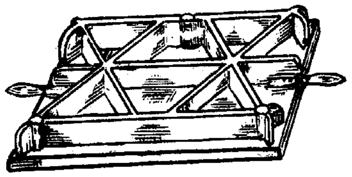
FIG. 2
BENCH PLATE

SURFACE PLATE

The surface plate is used where a finer degree of accuracy is required. This plate is an expensive piece of equipment and must be used with care. It is made of a special grade of close grained cast iron and is well ribbed on the under side to prevent warping of the surface (Fig. 3).

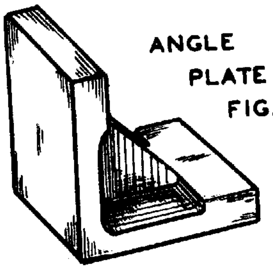


SURFACE PLATES
FIG. 3



After being carefully machined, the plate is hand scraped to a flat smooth surface. Besides being used for precision layout work, it is also used for checking accurate work such as gages, jigs, fixtures, etc.

ANGLE PLATE



ANGLE
PLATE
FIG. 4

The angle plate is an "L" shaped piece of cast iron or steel carefully machined to an angle of 90 degrees. (Fig. 4). The angle plate is used when the work must be held at right angles to the bench or surface plate. The work is clamped in this position on the angle plate while being laid out or checked.

DESCRIPTION OF LAYOUT TOOLS

"V" BLOCKS

"V" blocks are made of either cast iron or steel in various sizes to accommodate a wide range of work. (Fig. 5). They are machined with a "V" shaped slot of 90° on top and bottom. The sides usually are grooved to receive the clamp yoke which is used to hold the work securely in place while being laid out or drilled.

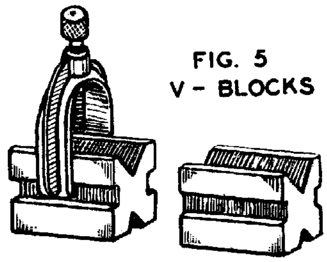


FIG. 5
V - BLOCKS

PARALLELS

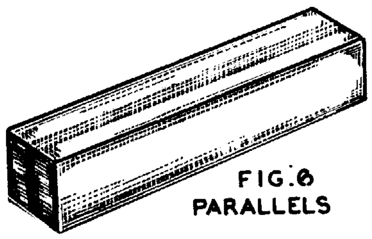


FIG. 6
PARALLELS

Parallels are bars of steel or cast iron, square or rectangular in shape and carefully machined for accuracy. (Fig. 6). They are made in pairs of various sizes and lengths depending upon the nature of the work for which they are to be used.

Precision layout work requires hardened and ground parallels. For ordinary work, cold drawn steel, or planed cast iron bars are commonly used.

Parallels may be used for mounting work parallel to the surface of a bench plate, surface plate, or other surface. They may also be used for leveling work on a flat surface when projections on the work prevent setting the job directly upon the plate.

THE COMBINATION SET

The combination set (Fig.7) is a tool consisting of four parts:

1. The stock (square). One side is 90°, the other 45°.
2. The protractor head.
3. The center head.
4. The steel rule or blade which fits any of the three heads.

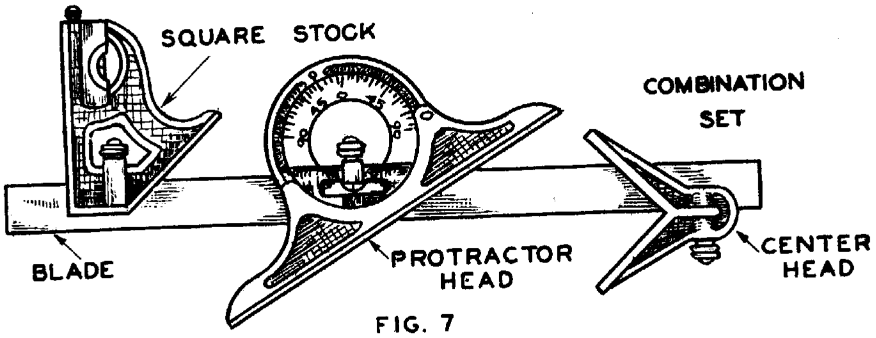


FIG. 7

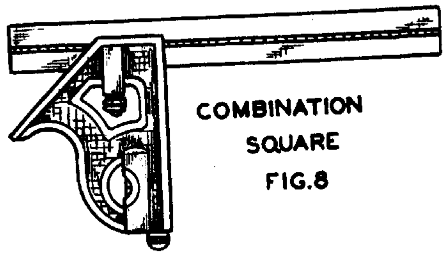
DESCRIPTION OF LAYOUT TOOLS

The combination set is one of the most useful and convenient tools for layout work.

1. The stock can be moved along the steel blade and clamped in any position desired. (Fig.8). It is used as a square for checking angles of 90°, as a depth gage, for scribing lines at right angles to a surface, or for angles of 45°.

By setting the end of the steel rule flush with the stock, it may be used as a height gage directly or in combination with a surface gage.

A spirit level is mounted in the stock. A scriber is held in the lower end by a friction bushing. The scriber may be drawn out when needed.



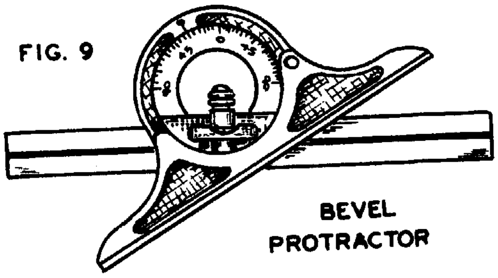
COMBINATION SQUARE FIG.8

2. The protractor head is provide with a swivel or turret to which the ste rule is clamped. (Fig.9). The revolving turret is graduated in degrees from 0 to 180. On some standard makes, it is grad uated in degrees from 0 to 90 in either direction.

It can be accurately adjusted to show any angle and is clamped in positi with a knurled nut.

The protractor is used for laying out lines at any given angle and for measuring angles.

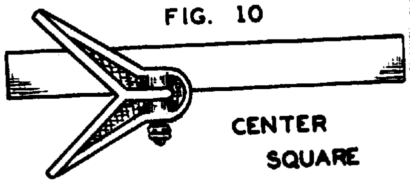
FIG. 9



BEVEL PROTRACTOR

3. The center head forms a center square when clamped to the steel rule. (Fig.10). The sides of the center head are placed on the outer surface of round jobs and the center is found by scribing lines along the edge of the rule.

FIG. 10



CENTER SQUARE

STEEL RULE

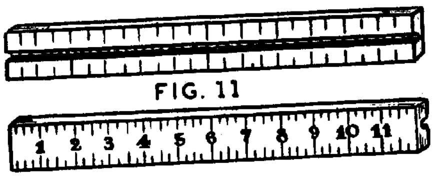


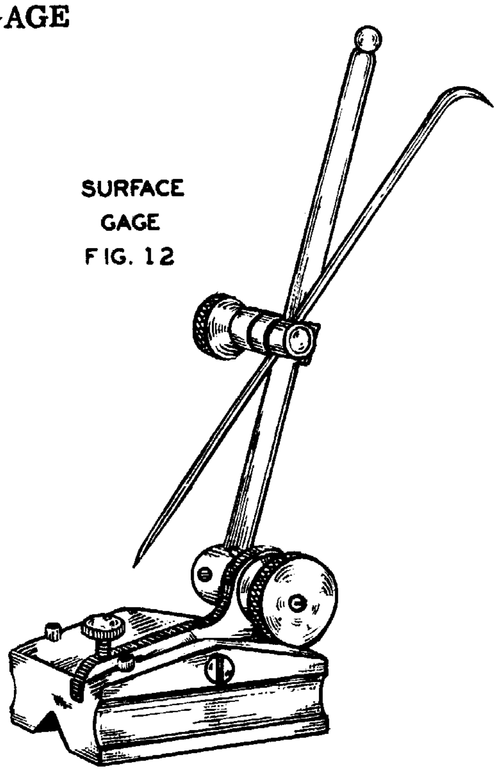
FIG. 11

4. The steel blade or rule, which is part of the combination set, may be fitted to either the square stock, the center head, or the protractor head. (Fig. 11). It may be set at any desir position and clamped. It is sometimes used separately for measuring or used as a straight edge.

DESCRIPTION OF LAYOUT TOOLS

THE SURFACE GAGE

The surface gage is an instrument used for scribing lines at a given height from some face of the work or for the construction of lines around several surfaces of the job. (Fig.12). The gage consists of a heavy base and a spindle pivoted upright, to which is attached a scriber held by a clamp. The scriber may be turned through a complete revolution.



SURFACE GAGE FIG. 12

By resting both the surface gage and the work upon a plane surface, it is possible to set the point of the scriber at a given height, either by use of a scale or some other standard, and draw lines at this height on all faces of the work or on any number of pieces when duplicate parts are being made.

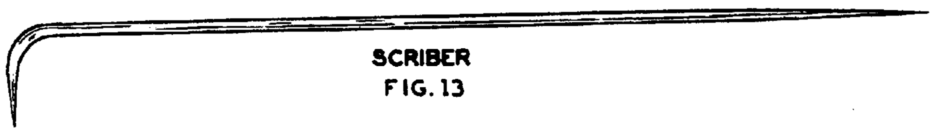
The use of the surface gage is not restricted to the scribing of horizontal lines, but may also be used on other surfaces from which it can be conveniently guided or held.

It can be used as a height gage and also for leveling work on a machine vise or plate.

The bent end on the scriber permits lines to be drawn on horizontal surfaces, while a groove in the base of the gage makes it possible to mark out desired distances from the outside of a circular piece.

THE SCRIBER

The scriber is a piece of tool steel, usually drill rod, about 1/8" in diameter, 8" to 12" long, tapered at both ends to a needle



SCRIBER FIG. 13

point. (Fig.13). One end is bent to be used in reaching through holes, etc. The scriber is hardened and tempered. It is used to scribe or mark lines on metal surfaces which have been prepared with chalk or blue vitriol.

DESCRIPTION OF LAYOUT TOOLS

DIVIDERS

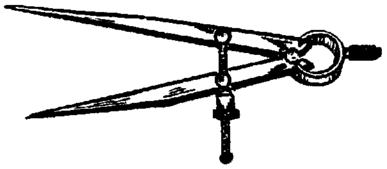


FIG. 14 DIVIDERS

Dividers have two straight legs, both tapered to a needle point and adjusted for opening by screw and knurled nut (Fig.14).

They are used for scribing circles and radii; and in combination with the steel rule or other standard, to measure distances between points, or to transfer distances taken directly from the steel rule.

HERMAPHRODITE CALIPERS

The hermaphrodite calipers are made with two legs; one blunt and bent at the end, the other with scriber point. (Fig.15). The scriber point is usually adjustable so that it can be adjusted for length when the bent leg is resting on an outer edge.

FIG. 15

HERMAPHRODITE CALIPERS

It is used for locating centers of round pieces, centers of bosses, etc. It may also be used to scribe a line or locate a point parallel with a surface or shoulder.

PRICK PUNCH

The prick punch is made of tool steel, usually from 4" to 6" long, and is hardened and tempered. It is knurled to give a good finger grip. One end is tapered to a point that is ground to an angle of about 30°. The prick punch is used for making small indentations along scribed lines, for marking the location of points, and centers for divider points.

CENTER PUNCH

The center punch is similar in design to the prick punch, except that the tapered point is ground to an angle of about 90°. (Fig.16)

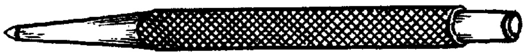


FIG. 16 CENTER PUNCH

The center punch is used for making indentations along scribed lines, for marking the location of points and the centers of holes to be drilled.

SELECTED REFERENCES

Burghardt ----------------- Part I -------- Machine Tool Operation

Henry Ford Trade School ------------------------------ Shop Theory

MEASUREMENT

HOW TO USE LAYOUT TOOLS

OBJECTIVES OF UNIT

1. To point out how to care for layout tools.

2. To show how to use layout tools.

INTRODUCTORY INFORMATION

The more commonly used layout tools are: the scriber; the combination set consisting of the protractor head, center head, square, and the steel blade; hermaphrodite calipers; the center and prick punches; the spring dividers; and the surface gage.

Care should be taken in the use of these tools so that sharpened and pointed edges are kept in good condition to prevent impairing the accuracy, which is essential to a good layout job. Tools which have pointed ends should only be used for the purpose for which they are intended and not on hardened surfaces.

TOOLS AND EQUIPMENT

Scriber
Steel rule
Oil stone
Combination set
Hermaphrodite caliper
Spring dividers

Center punch
Prick punch
Machinist's hammer
Surface plate
Surface gage

PROCEDURE

SCRIBER

1. Inspect the point of the scriber to make sure that it is sharp. If the point is dull, sharpen it on an oil stone by rotating the scriber between the thumb and forefinger while moving it back and forth. (Fig. 1).

2. Wipe the surfaces of the work to be scribed clean and free of oil, dirt, and chips.

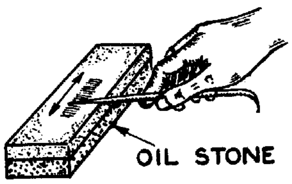


FIG. 1 SHARPENING A SCRIBER

HOW TO USE LAYOUT TOOLS

3. Place the steel rule flat on the work in position for scribing. Grasp the scriber in the right hand as a pencil is gripped. (Fig.2).

4. Hold the rule firmly by exerting pressure with the tips of the fingers of the left hand (Fig.2).

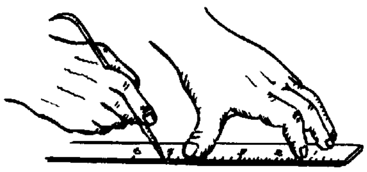


FIG. 2 SCRIBING A LINE

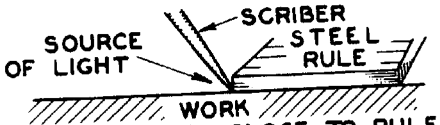


FIG. 3 SCRIBING CLOSE TO RULE

5. Set the point of the scriber as close to the edge of the rule as possible by tipping the top of the scriber outward (Fig.3).

6. Scribe the line by exerting pressure on the scriber and drawing it along the edge of the rule, inclining the top of the scriber slightly in the direction in which it is to be moved. (Fig.4).

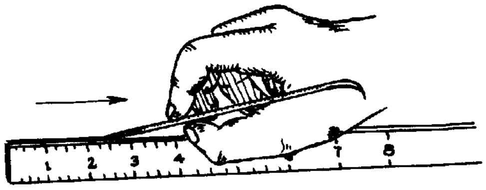


FIG. 4 INCLINING SCRIBER

NOTE: Make sure that the light shines on the portion of the work being scribed.

COMBINATION SET

A. CENTER HEAD

1. Insert the blade through the slot in the head so that the round clamping groove in the blade engages with the end of the clamping bolt.

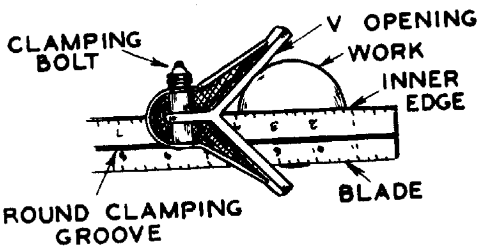


FIG. 5 SCRIBING A CENTER LINE USING A CENTER HEAD

2. Extend the blade, through the V-opening a length equal to the diameter of the work to be centered. Clamp the blade in position by tightening the knurled nut.

3. Place the V-opening against the diameter of the work to be centered.

4. Scribe a line along the inner edge of the blade (Fig. 5).

HOW TO USE LAYOUT TOOLS

B. COMBINATION SQUARE

1. Insert the blade through the slot in the head so that the round clamping groove in the blade engages with the end of the clamping bolt (Fig.6).

2. Extend the blade through the slot at the required length and clamp in position by tightening the knurled nut.

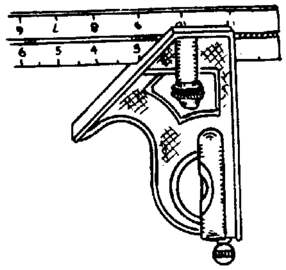


FIG. 6 COMBINATION SQUARE

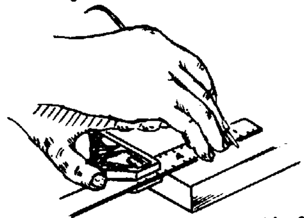


FIG. 7 USING COMBINATION SQUARE FOR LAYING OUT LINES

3. Place the head of the square against the side of the work to be scribed, and scribe lines from either side or the end of the square according to the requirements of the job at hand. (Fig.7).

C. PROTRACTOR

1. Insert the blade through the slot in the swivel turret so that the rounded groove in the blade engages with the clamping bolt.
2. Extend the blade to the required length and tighten (Fig.8).

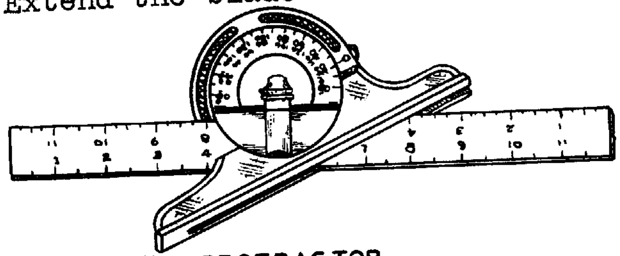


FIG.8 BEVEL PROTRACTOR

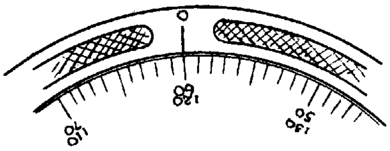


FIG.9 READING PROTRACTOR

3. Loosen the clamping screw on the body of the protractor and swing the revolving turret to the desired angle. This angle is read at the index line on the body and the graduations on the turret. (Fig.9) Tighten the clamping screw.

4. Place the base of the protractor against the side of the work and scribe lines as desired. (Fig.10).

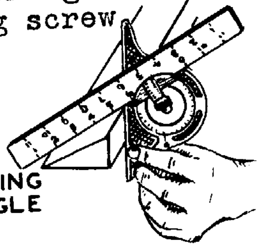


FIG. 10 MEASURING AN ANGLE

HERMAPHRODITE CALIPERS

1. Inspect the scriber leg of the caliper to make sure that the point is sharpened. If the point is dull, sharpen on oil stone.

HOW TO USE LAYOUT TOOLS

2. Adjust the length of the scriber leg so that it is even with the inside edge of the rounded caliper leg when it is to be used to scribe lines from the outside edge of the work. (Fig. 11).

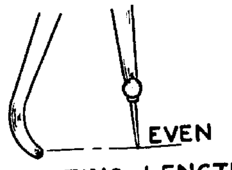


FIG. 11 ADJUSTING LENGTH OF SCRIBER LEG

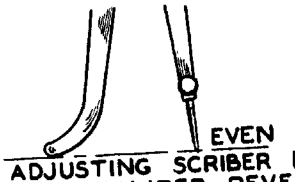


FIG. 12 ADJUSTING SCRIBER LEG WITH CALIPER REVERSED

3. When scribing lines with the caliper reversed, set the scriber point to the full length of the caliper leg. (Fig.12).

4. Case 1

To set the caliper at the desired dimension, loosen the lock nut slightly. Place the caliper leg against the end of the steel rule and adjust the scriber leg to the required graduation on the steel rule. Tighten the clamp nut. (Fig.13-Case 1).

FIG. 13 SETTING HERMAPHRODITE CALIPERS

Case 2

To set the caliper at the desired dimension with the legs reversed, place the end of the steel rule against a straight surface and set the end of the caliper even with the end of the rule. Adjust the scriber leg so that the point of the scriber coincides with the required graduation on the rule (Fig.13-Case 2). Tighten the clamping nut.

5. Grasp the top of the caliper with the thumb and forefinger of the right hand. Place the curved tip of the caliper against the surface from which the line is being located, keeping the tip of the caliper leg square with the surface from which it is guided and in contact with the surface. Scribe the line by exerting a slight pressure on the scriber and drawing the caliper along the surface being scribed. (Fig.14).

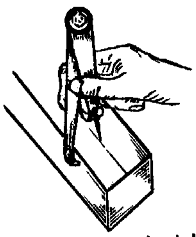


FIG. 14 SCRIBING A LINE

HOW TO USE LAYOUT TOOLS

CENTER PUNCH AND PRICK PUNCH

1. Inspect the point of the punch to make sure that it is sharp.

   NOTE: The point of the prick punch is usually sharpened to an angle of 30°, while the center punch is usually ground to an angle of 90° (Fig.15).

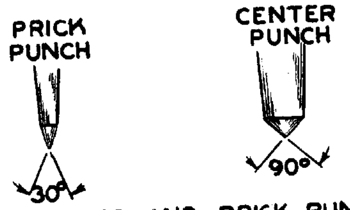


FIG. 15 CENTER AND PRICK PUNCH

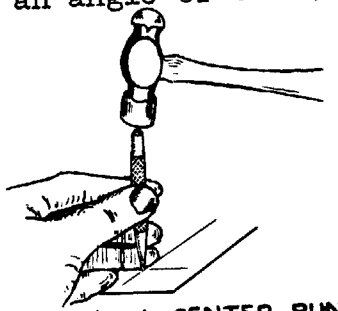


FIG. 16 USING A CENTER PUNCH

2. Grasp the punch in the left hand and punch directly on the line or intersection of lines to be marked. (Fig.16).

   NOTE: With a little practice, the beginner can feel the point of the punch when it strikes the scribed line or meets the intersection.

3. Hold the punch in a vertical position and tap it lightly with a machinist's hammer. Repeat blow if indentation is not deep enough.

   NOTE: Tap the prick punch lighter than the center punch. The prick punch is used for making light indentations, as for the point of the divider. The center punch is used to make heavier indentations such as the starting point for a drill.

DIVIDERS

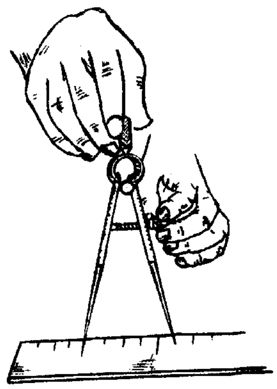


FIG. 17 SETTING DIVIDERS

1. Inspect the points of the dividers to make sure they are sharp.

2. To set the dividers, hold them in the left hand and place the point of one leg in a graduation on the steel rule. By turning the knurled adjusting nut with the thumb and forefinger of the right hand, adjust the divider until the point of the other leg rests on the graduation of the steel rule, which gives the required measurement. (Fig.17).

3. To scribe an arc or circle with the dividers, grasp the knurled thumb attachment on the top of the dividers with the thumb and forefinger of the right hand.

HOW TO USE LAYOUT TOOLS

4. Place the point of the pivoting leg on the punched mark. With pressure exerted on both legs, swing in a clockwise direction and scribe the desired arc or circle. (Fig. 18).

   NOTE: By inclining the dividers in the direction in which they are being rotated, the tendency to slip is avoided.

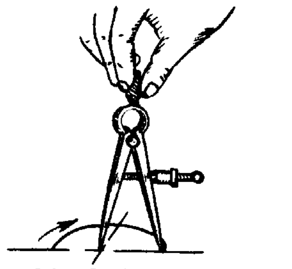


FIG. 18 SCRIBING A CIRCLE

SURFACE GAGE

1. Clean the surfaces of the surface plate, the base of the surface gage, and the work.

2. Decide on the best position in which to set the spindle and scriber of the surface gage.

   NOTE: The surface gage will be more rigid if the scriber is clamped close to the spindle and as near the base as possible.

3. To set the surface gage to a given dimension, adjust the position of the spindle by loosening the swivel bolt lock nut and adjusting the spindle to a convenient position. Clamp in position. (The position of the spindle depends on the nature of the job. Ordinarily, it can be set in a vertical position but may be tilted as the job demands).

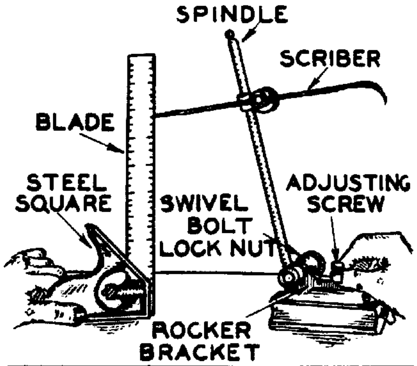


FIG. 19 ADJUSTING SURFACE GAGE

   Then, set the scriber at approximately the given dimension by loosening the scriber clamp nut and adjusting it for its position on the spindle and its extension from the swiveling head. Clamp in position (Fig.19).

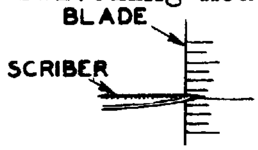


FIG. 20 ADJUSTING SCRIBER TO DESIRED DIMENSION

   To make the final adjustment, turn the small adjusting screw at the rear of the rocker bracket so that the scriber is elevated or depressed to the given dimension.

4. To scribe lines, grasp the surfac gage at the base and move it along the surface plate with the scriber point bearing against the surface to be laid out.

MEASUREMENT

DESCRIPTION OF LAYOUT WORK

OBJECTIVES OF UNIT

1. To define the meaning of layout as it applies to machine shop practice.

2. To indicate the kinds of work where laying out is required and the necessity for laying out work prior to machining.

3. To describe the materials used for preparing surfaces for marking.

INTRODUCTORY INFORMATION

Laying out is the planning of the work on the surface of the job prior to machining. It is the scribing of lines which are used to indicate the boundaries, centers, and other locations which guide the workman in making the job to given dimensions.

Through layout, the machinist is able to analyze the sequence of operations and thereby plan his work in more efficient and orderly steps.

The accuracy of the finished job depends largely upon the care taken in the original layout. The nature of the job determines the kind of tools to be used.

NECESSITY FOR LAYOUT

Laying out is frequently used on work that is to be machined on shaper, planer, milling machine, or drill press. Much layout work is done on castings. This requires skill and judgment on the part of the workman to see that the job is properly machined. Quite often a casting is uneven or scant in places and, therefore, needs some calculation and judgment in layout.

Machined parts and finished surfaces can be laid out more readily and to a finer degree of accuracy than rough castings or unfinished work, since it is possible to set up the work on a surface plate or angle plate before scribing lines and locations.

In layout work, some "base" line or finished surface is selected from which to begin to make measurements. This serves as a starting point from which to lay out dimensions and as a location from which to check, should the work be shifted during the layout process.

DESCRIPTION OF LAYOUT WORK

MARKING MATERIALS

When scribing lines on metal surfaces, it is necessary to prepare the surface with a marking material so that the lines and markings are more legible. Several materials are used for this purpose.

1. Chalk is used for rough castings or unfinished steel that has an oxidized surface. Chalk rubbed on the surface before marking will make the scribed lines and markings much plainer.

2. A soapstone pencil is also very useful in marking the surface of rough castings.

3. Blue vitriol is generally used in preparing a finished surface for layout. The blue vitriol solution contains copper sulphate, water, and sulphuric acid. As much copper sulphate as will dissolve is added to four ounces of water and then ten drops of sulphuric acid are added to the solution.

CAUTION: To prevent personal injury when mixing the solution, add the acid to the water. Never add water to acid.

This solution gives a reddish-brown color against which the lines will show.

CAUTION: Care should be exercised in the use of blue vitriol solution so that none is spilled on the bench, surface plate, tools, or machinery. This solution is likely to rust or damage the tools and impair their accuracy. Blue vitriol spilled on clothing will cause the fabric to rot.

4. Coloring by heat is sometimes used on jobs where the tempe of the metal is not to be considered. Heating the metal to a blue will give a satisfactory coloring through which scribed lines are plainly visible.

SELECTED REFERENCES

Burghardt ----------------- Part I -------- Machine Tool Operatio

Henry Ford Trade School ------------------------------ Shop Theor

Machinery's Handbook

MEASUREMENT

HOW TO LAY OUT WORK ON A BENCH OR SURFACE PLATE

OBJECTIVES OF UNIT

1. To explain the method of preparing a surface prior to laying out.
2. To explain how to lay out work on rough castings.
3. To explain how to lay out work on flat surfaces of a squared piece.
4. To explain how to lay out work on the bench, surface, or angle plate.

INTRODUCTORY INFORMATION

Practically all layout work is done on a bench plate or surface plate. The bench plate is generally used for rough and approximate layout; while the surface plate is used for precision work as well as checking the accuracy of tools and finished jobs. Each job of layout is a problem in itself involving judgment on the part of the workman according to the requirements peculiar to the job at hand.

TOOLS AND EQUIPMENT

Bench Plate
Surface plate
Parallel bars
Angle plate
Surface gauge
Combination square set
Scriber
Center punch and hammer
Dividers

Hermaphrodite Calipers
Clamps
Solid steel square
Steel rule
Marking materials
- a. Chalk
- b. Copper sulphate (Blue Vitriol)

Swab for copper solution

PROCEDURE

A. LAYOUT WORK ON ROUGH CASTINGS

1. Check casting with the blueprint or drawing to determine starting point and also to ascertain the amount of material to be removed.

HOW TO LAY OUT WORK ON A BENCH OR SURFACE PLATE

NOTE: Remove all rough projections and fins from surfaces upon which lines are to be scribed as well as those upon which the work rests.

2. Level the casting on the bench plate, using a square, or surface gage.

3. Rub chalk over surface upon which lines are to be scribed.

4. Refer to the drawing or blueprint for dimensions and determine the distance from the base of the bench plate to the first line to be scribed.

SETTING A SURFACE GAUGE
FIG. 1

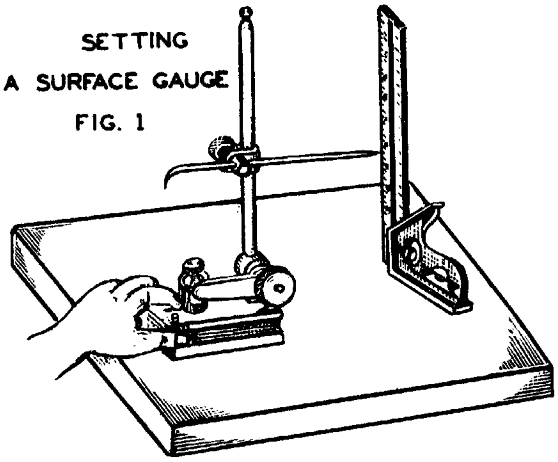
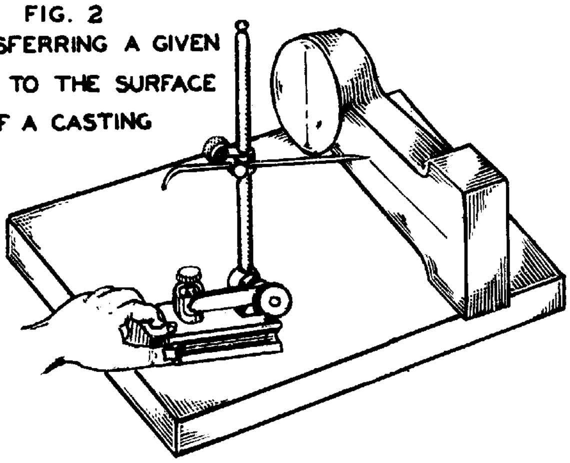


FIG. 2
TRANSFERRING A GIVEN HEIGHT TO THE SURFACE OF A CASTING



Horizontal lines may be scribed by use of the surface gage resting on the bench plate.

The surface gage should be set to the desired height with the aid of the steel rule, combination square or other gage. (Fig.1). Transfer the given height to the surface of the casting by sliding the surface gage along the bench plate with the scriber in contact with the casting (Fig. 2).

5. Vertical lines are next laid out by using the combination square or solid steel square and scriber. Intersections and centers are then marked off on the horizontal lines from the first vertical line by use of the dividers. The subsequent vertical lines are marked with the dividers, square, and scriber. (Fig.3). Angular lines may be laid out by using the bevel protractor. (Fig. 4).

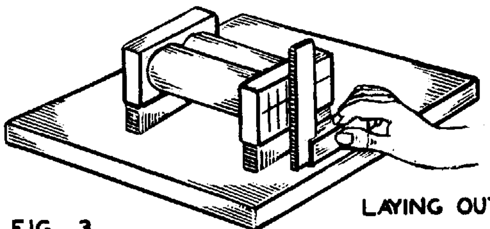


FIG. 3 LAYING OUT VERTICAL LINES

HOW TO LAY OUT WORK ON A BENCH OR SURFACE PLATE

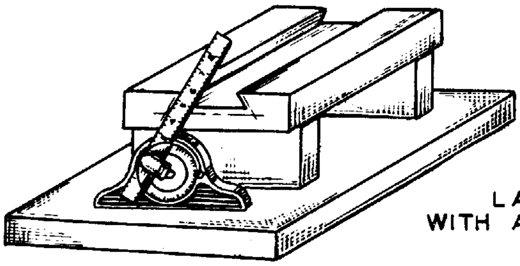
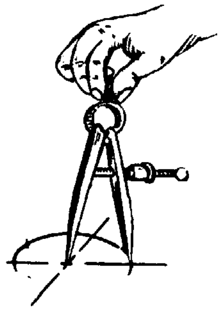
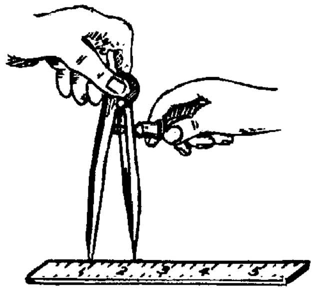


FIG. 4
LAYING OUT ANGULAR LINES WITH A BEVEL PROTRACTOR



SCRIBING A CIRCLE
FIG. 5

6. Light indentations are made at points of intersection with a prick punch. Using these marks as centers, circles are scribed with dividers to the diameter of the hole to be drilled and prick punched around the circle to guide the workman. After the circles are scribed, make a deeper indentation at the center so that the drill will start centrally.
7. Check layout with the blueprint for errors.



SETTING DIVIDERS
FIG. 6

B. LAYOUT WORK ON FLAT SURFACES OF A SQUARED PIECE

1. Remove all burrs.

2. Clean or polish surface to be laid out before applying copper sulphate (Blue Vitriol). Surface must be kept free of grease or oil.

   CAUTION: Copper sulphate is a poisonous substance and should be handled with care.

3. Using a swab or clean piece of cloth, apply copper sulphate (blue vitriol) solution to the prepared surface and rub it until a copper coating appears.

   NOTE: Blue vitriol solution has a corrosive action and should be kept away from tools and polished surfaces.

4. Refer to drawing or blueprint for dimensions and determine the distance from the squared edges to the first line to be scribed.

5. Set the hermaphrodite calipers by placing the blunt leg on the end of the scale and the pointed leg to the graduation at the desired distance. (Fig. 7).

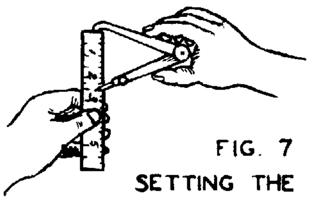
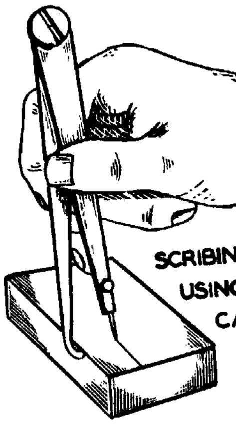


FIG. 7
SETTING THE HERMAPHRODITE CALIPER

HOW TO LAY OUT WORK ON A BENCH OR SURFACE PLATE

6. By setting the blunt leg against the squared edge of the piece, scribe a line parallel to the edge with the scriber point of the caliper (Fig. 8). Repeat the process for other parallel lines.



SCRIBING PARALLEL LINES USING A HERMAPHRODITE CALIPER
FIG. 8

7. Parallel lines may also be scribed by using the combination square. Set the blade of the square at the desired dimension and scribe lines at each end as shown in Figure 9. Connect these lines with the steel rule or combination square placed on edge.

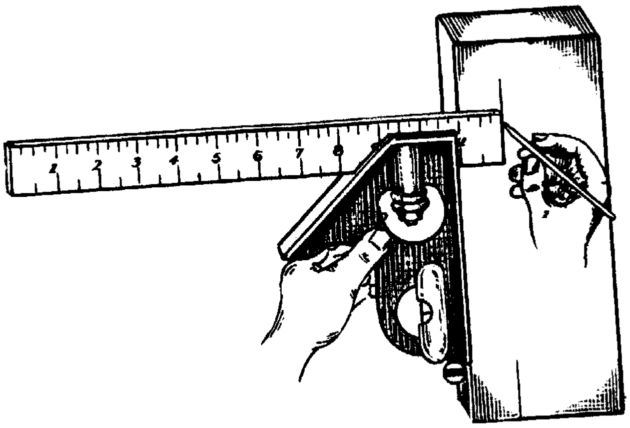


FIG. 9
SCRIBING PARALLEL LINES USING A COMBINATION SQUARE

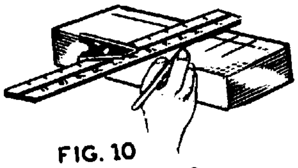


FIG. 10
SCRIBING LINES AT RIGHT ANGLES

8. Lines are drawn at right angles by using the combination square or st square. The blade is held at righ angles to the work and the lines a scribed along the edge of the blad (Fig. 10).

9. Distances may be laid off along an of the lines by using the dividers or the steel scale and scriber.

10. Angular lines may be laid out by using the bevel protractor.

11. Check layout with the blueprint for errors.

HOW TO LAY OUT WORK ON A BENCH OR SURFACE PLATE

C. LAY OUT WORK ON THE ANGLE PLATE

1. Check work with the blueprint or drawing to determine the locations of lines to be scribed.

2. Select an angle plate of a size suitable for the job at hand.

3. Remove all burrs from surfaces of the work.

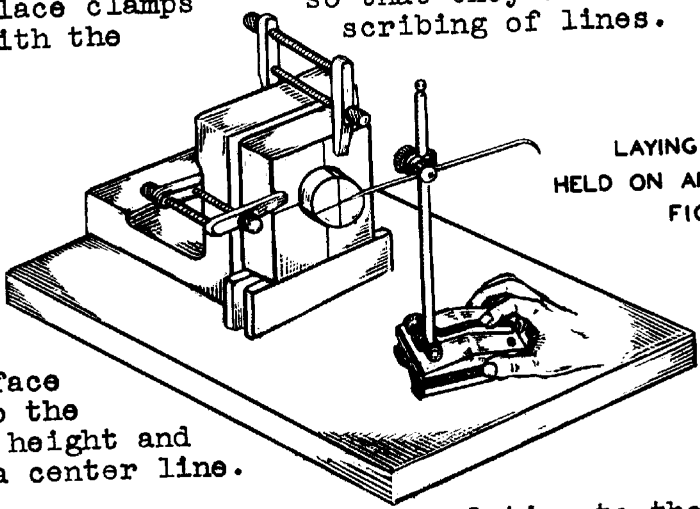
4. Prepare the surfaces for marking:
   a) If rough casting, use chalk.
   b) If machined surface, use copper sulphate.

5. Clean bench plate, angle plate, parallel bars, and work.

6. Set the angle plate and parallel bars on a bench or surface plate.

7. Place the machined surface of work against the angle plate and rest the lower edge on parallel bars prior to clamping. Secure the work with clamps. (Fig. 11)

NOTE: Place clamps so that they do not interfere with the scribing of lines.



LAYING OUT WORK HELD ON AN ANGLE PLATE
FIG. 11

8. Set surface gauge to the desired height and scribe a center line.

9. Scribe other parallel lines in relation to the center line.

10. Turn angle plate on end to scribe lines at right angles to other lines.

11. Repeat steps 8 and 9.

12. Remove work from angle plate and center punch intersections.

13. Check layout with blueprint for errors.

SECTION II

Units of Instruction in

MACHINE SHOP MATHEMATICS

SECTION II

Units of Instruction in

MACHINE SHOP MATHEMATICS

INTRODUCTION TO THE UNITS OF MEASURE

A. THE UNITS OF MEASURE ARE STANDARDIZED FOR EACH TRADE.

1. THE BASIC UNITS OF MEASURE

The basic units of measure, such as length, weight, capacity, temperature, etc., are determined in Washington, D. C. by the properly authorized Federal organization to do such work, the Bureau of Standards.

These units are in accord with those used throughout the world, and the United States standards are set up to be in agreement with them.

The measuring tools of industry are periodically sent to this bureau and there the Bureau of Standards furnishes the inquirer the information to show how closely that measuring tool (used within some factory as a standard) agrees with the universally accepted standard.

2. THE STANDARDS OF MEASURE WITHIN THE VARIOUS TRADES

For almost every industry, there is a committee on standardization of some sort which determines the units, specifications, forms, and practices for that industry.

To secure a closer working agreement between those different industries, one great body has been formed, the greatest of its kind, representative of every great industrial organization in this country, the American Standards Association. This body passes on the standards set throughout this country and secures the cooperation of other similar organizations throughout the world to establish and maintain standards of measure, specification, and practice.

MEASUREMENT

CONCEPTS OF UNITS OF MEASURE

1. List several examples of the necessity for a general agreement on measurement and the units of measure for:

   a. The assembly of unit parts in a single manufacturing plant.

   b. The production of parts and assemblies throughout a whole country for a single industry or by closely related industries.

2. Name one or two of the units of measure used in determining:

   a. Length

   b. Surface

   c. Weight

   d. Volume

   e. Temperature

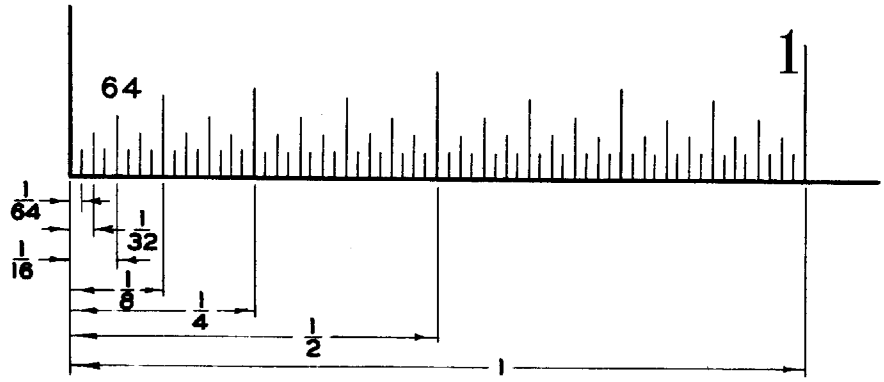
MEASUREMENT

THE UNITS OF LINEAR MEASURE

TABLE OF LINEAR MEASURE

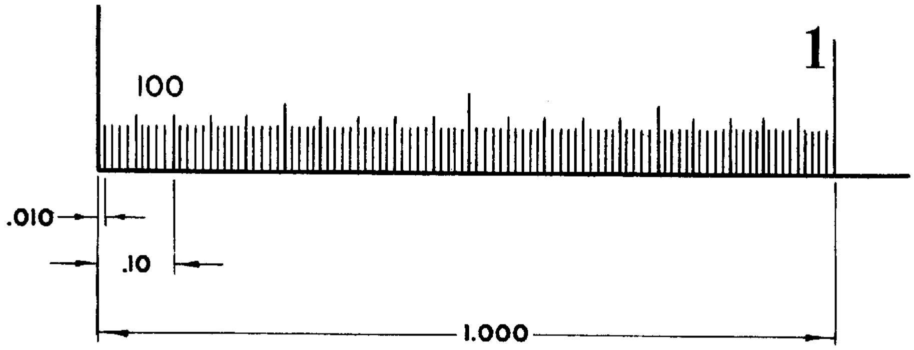
unit	=	1 inch
12 inches	=	1 foot
3 feet	=	1 yard

The divisions of the inch, binary system.



The divisions of the inch, decimal system. Divisions of the inch with the denominator of the fraction a power of ten.

1.	=	1.000	=	one
$\frac{1}{10}$	=	.10	=	one-tenth
$\frac{1}{100}$	=	.010	=	one-hundredth
$\frac{1}{1000}$	=	.0010	=	one-thousandth
$\frac{1}{10000}$	=	.00010	=	one ten thousandth



MEASUREMENT

APPLICATION OF LINEAR MEASURE

A. USE OF SCALE IN TAKING LINEAR MEASUREMENTS

1. With the steel scale, construct straight lines of the following lengths:

   a. 2-1/4 inches

   b. 3-3/4 inches

   c. 4-1/2 inches

   d. 1-1/8 inches

   e. 2-5/8 inches

   f. 4-3/8 inches

   g. 5-7/8 inches

   h. 2-1/16 inches

   i. 4-5/16 inches

   j. 5-9/16 inches

   k. 3-15/16 inches

   l. 5-7/32 inches

   m. 1-19/32 inches

   n. 2-1/64 inches

   o. 1-9/64 inches

   p. 3-3/64 inches

   q. 4-47/64 inches

   r. 1-7/10 inches

   s. 2-9/10 inches

   t. 3-7/100 inches

   u. 5-29/100 inches

   v. 4-31/32 inches

LINEAR MEASURE

2. Measure these lines to the nearest quarter of an inch.

   a.

   b.

   c.

   d.

3. Measure these lines to the nearest eighth of an inch.

   a.

   b.

   c.

   d.

4. Measure these lines to the nearest sixteenth of an inch.

   a.

   b.

   c.

   d.

5. Measure these lines to the nearest thirty-second of an inch.

   a.

   b.

   c.

   d.

6. Measure these lines to the nearest sixty-fourth of an inch.

   a.

   b.

   c.

   d.

LINEAR MEASURE

7. Measure these lines to the nearest tenth of an inch.

a.

b.

c.

d.

e.

f.

g.

h.

i.

j.

8. Measure these lines to the nearest one hundredth of an inch.

a.

b.

c.

d.

e.

f.

g.

h.

i.

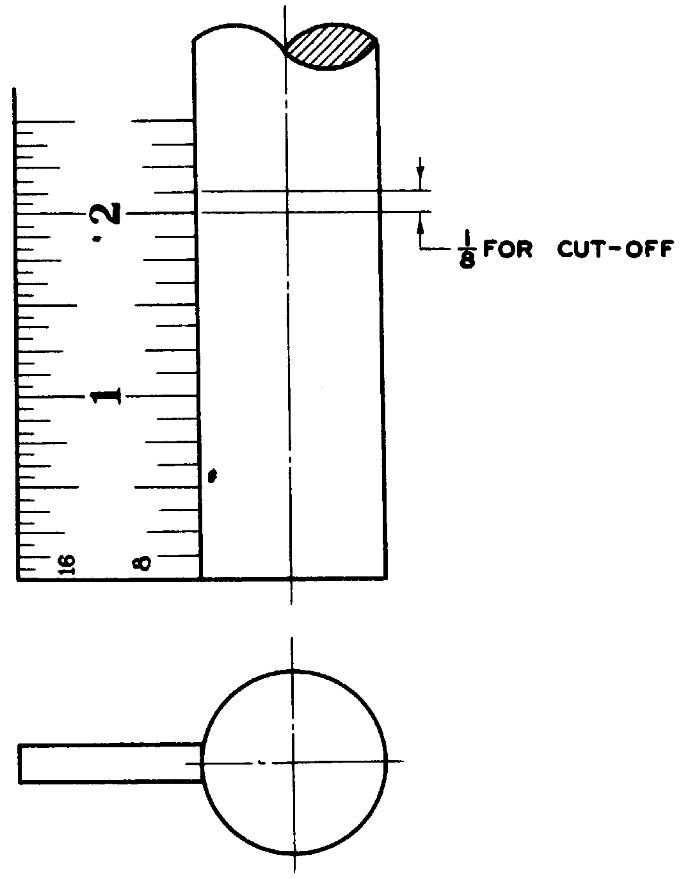
j.

k.

LINEAR MEASURE

B. PRACTICAL APPLICATION OF LINEAR MEASURE

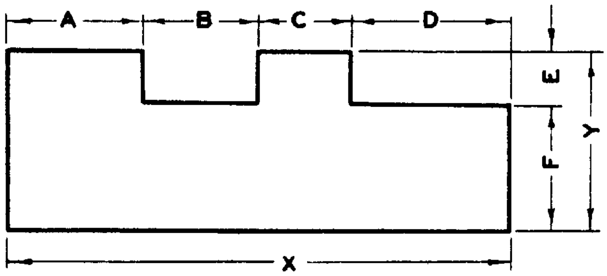
Allowances For Cutting Off Stock



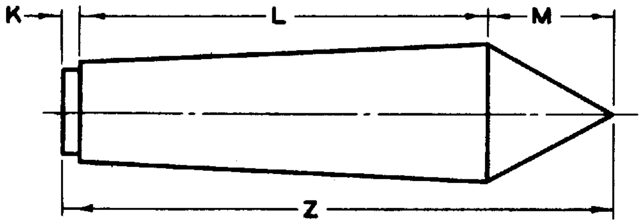
1. How much stock is required for 4 pieces of C. R. S. $2\frac{1}{4}$" long, if 1/8" must be allowed for each piece for cutting off?

LINEAR MEASURE

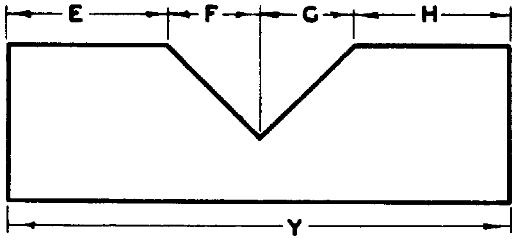
2. In this milled block, measure lengths A, B, C, and D and check the sum of these against the overall dimension X. Do the same for dimensions E, F, and Y.



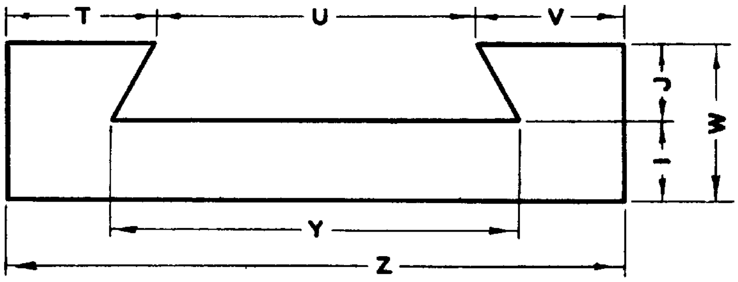
3. On the lathe center, measure the length K, L, and M, and check the sum of their lengths against the overall dimension Z.



4. Measure dimensions E, F, G, H, and the overall length Y of this V-block; and check.



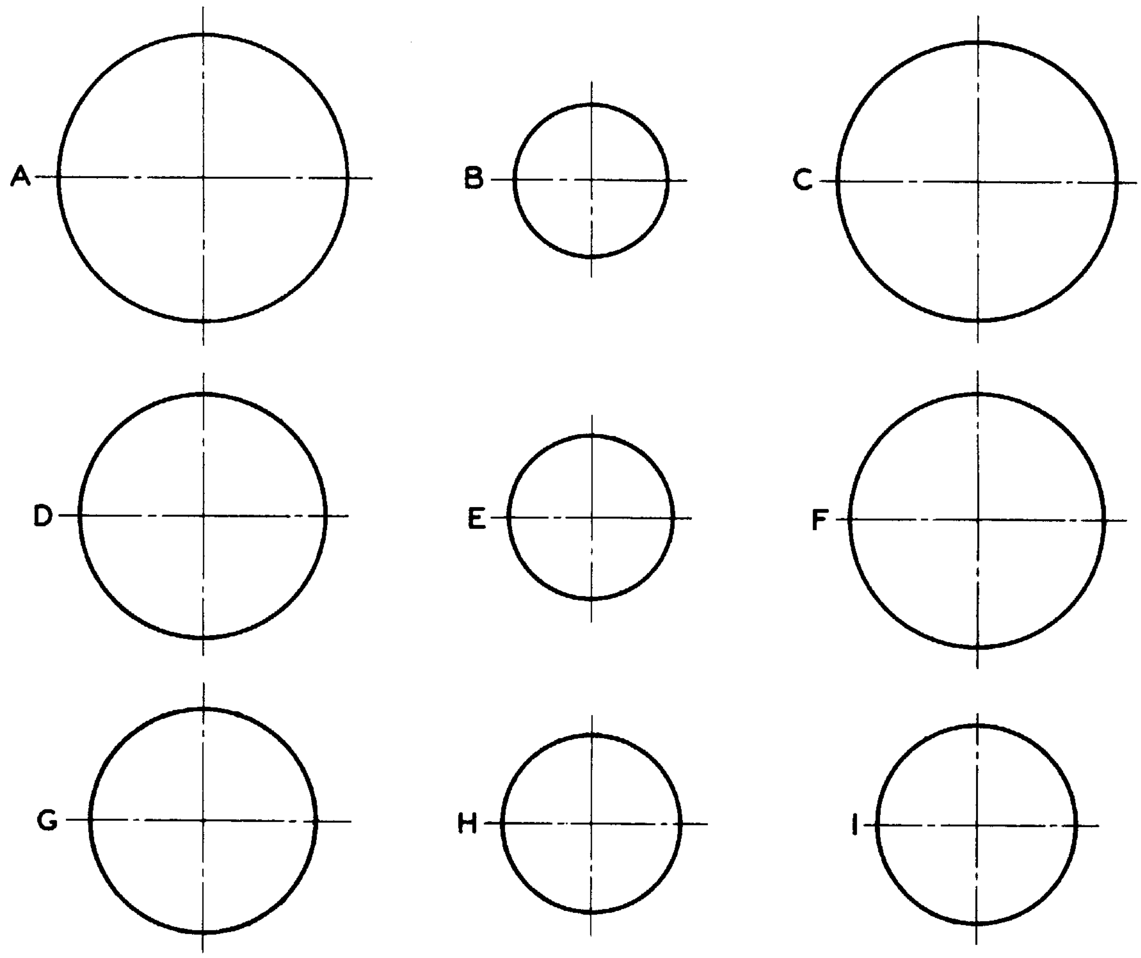
5. Measure dimensions T, U, and V, and check with the overall length Z of the lathe slide. Do the same for I and J and check with the overall length W.



LINEAR MEASURE

C. APPLICATION OF TRANSFERRED MEASUREMENT

1. The circles below represent the sizes of holes to be drilled. Measure the diameters with an inside caliper, transfer the measurement to a scale, and record the size drill to use.

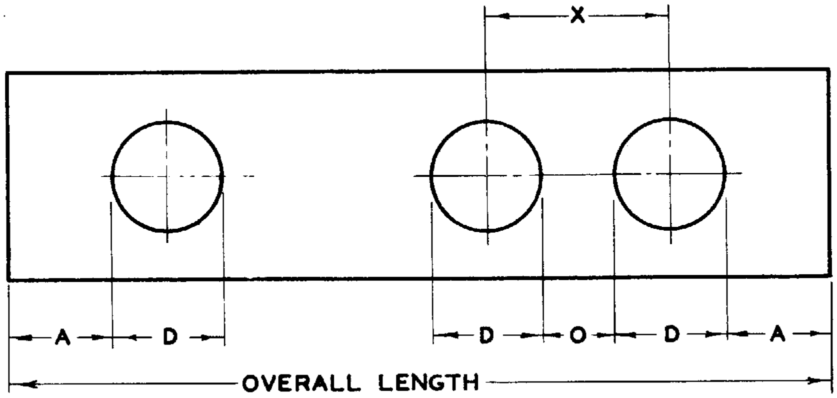


Diameter A ________ What size drill should be used? ________.
Diameter B ________ What size drill should be used? ________.
Diameter C ________ What size drill should be used? ________.
Diameter D ________ What size drill should be used? ________.
Diameter E ________ What size drill should be used? ________.
Diameter F ________ What size drill should be used? ________.
Diameter G ________ What size drill should be used? ________.
Diameter H ________ What size drill should be used? ________.
Diameter I ________ What size drill should be used? ________.

COMPUTED MEASURE

When a measurement is transferred from one measuring device to another, or an overall length is divided into a number of equal parts, the measurement is obtained indirectly.

1. The overall length of a piece of metal is 30". If 1/4" is allowed on each end, how many 1" holes can be bored leaving 1/2" between them? What is the distance from center to center of each hole?



2. On the bending jig illustrated above, find the missing dimensions and place these in the indicated place on the table.

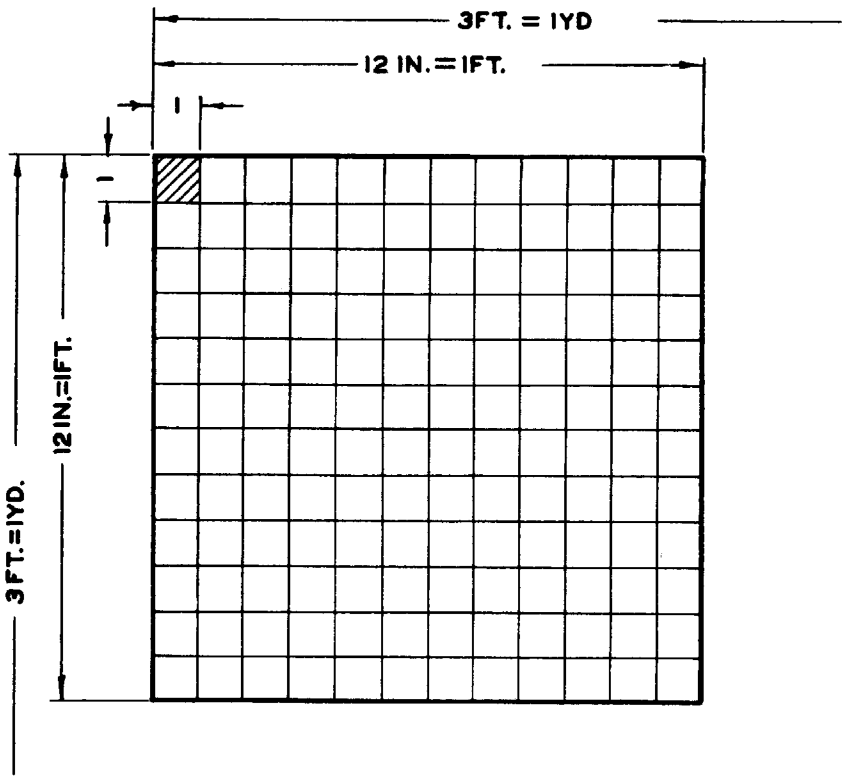
Overall length	(A) End spaces	No. of holes	(X) Center to center	(D) Diameter of circle	(O) Space between
1'4-7/8"	7/16		$1\frac{1}{4}$"	1"	$\frac{1}{4}$"
2' 0"		12	$1\frac{1}{4}$"		3/8
	7/8"	16		1/8"	$\frac{1}{2}$"
	1-1/16	17	2-9/16	2"	

MEASUREMENT

THE UNITS OF AREA

A. TABLE OF SQUARE MEASURE

unit	= 1 square inch
144 square in.	= 1 square foot
9 square ft.	= 1 square yard



B. SIMPLE SURFACE FORMULAS

The area of a rectangle is equal to length times width.

$$A = lw$$

The area of a square is equal to the square of one side.

$$A = s \times s \quad \text{or} \quad A = s^2$$

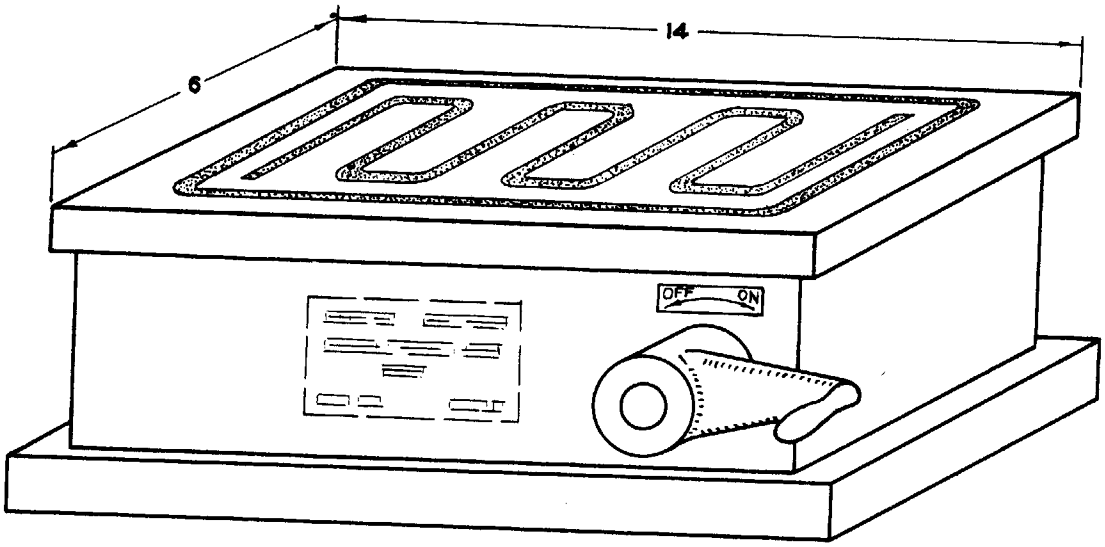
MEASUREMENT

APPLICATION OF SURFACE MEASURE

1. The top of a magnetic chuck for a surface grinder is 6" wide and 14" long.

   a. How many square inches are there on the surface of the chuck?

   b. How many pieces 2" x 2" can be placed over the entire area of the chuck face?

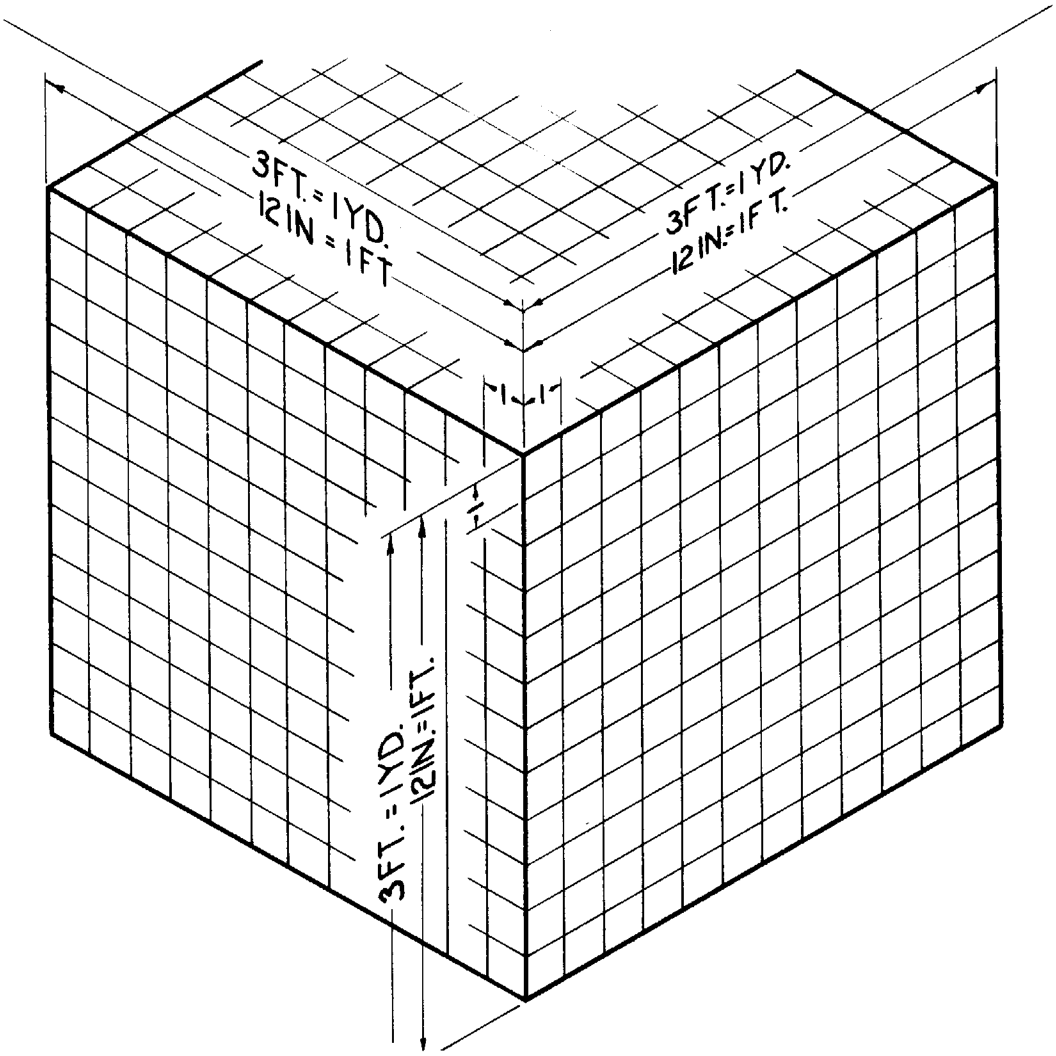


MEASUREMENT

THE UNITS OF VOLUME

A. TABLE OF CUBIC MEASURE

unit	=	1 cubic inch
1728 cubic inch	=	1 cubic foot
27 cubic feet	=	1 cubic yard



B. SIMPLE VOLUME FORMULAS

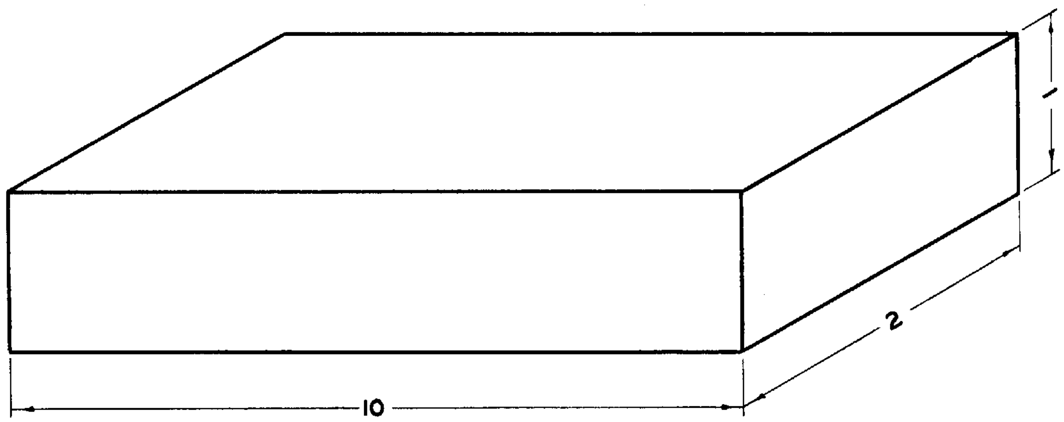
The volume of a rectangular solid equals the length times the width times the thickness. $V = lwh$.

The volume of a cylinder equals π times the square of the radius times the height. $\pi = 3.14$ $V = \pi r^2 h$

MEASUREMENT

APPLICATION OF VOLUME MEASURE

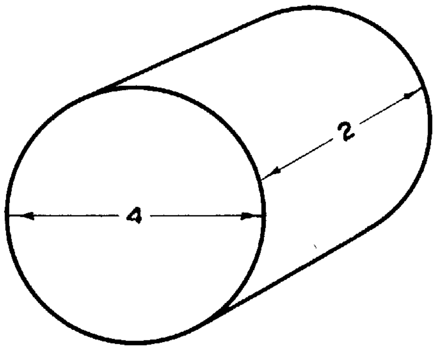
1. Twelve bars of 1" x 2" flat cold rolled steel are to be cut 10" long.



(a) How many cubic inches are there in each piece of stock?

(b) What is the weight of each piece when cold rolled steel weighs .28#/cu. in.

(c) What is the cost of the twelve bars of cold rolled steel at eight cents per pound.



2. Two bronze discs are to be machined from 4" diameter stock, 2" thick.

(a) How many cubic inches of metal are there in each disc?

(b) What is the weight of each disc if bronze weighs .28#/cu.in.?

(c) What is the cost of the two discs at forty cents per pound?

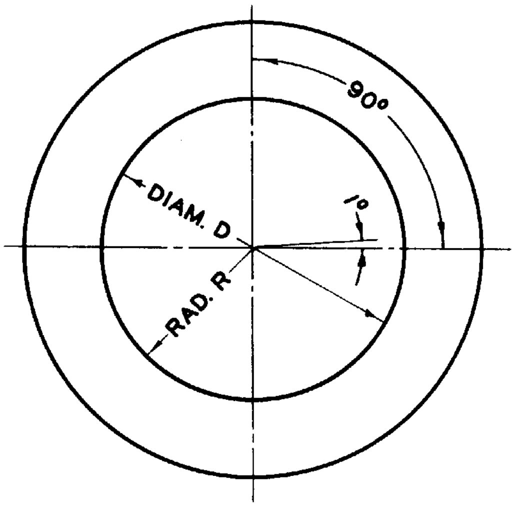
MEASUREMENT

THE UNITS OF ANGULAR MEASURE

A. ANGULAR MEASUREMENT

<u>Table of Angular Measure</u>

60 seconds	=	1 minute
60 minutes	=	1 degree
90 degrees	=	1 quadrant
360 degrees	=	1 circumference



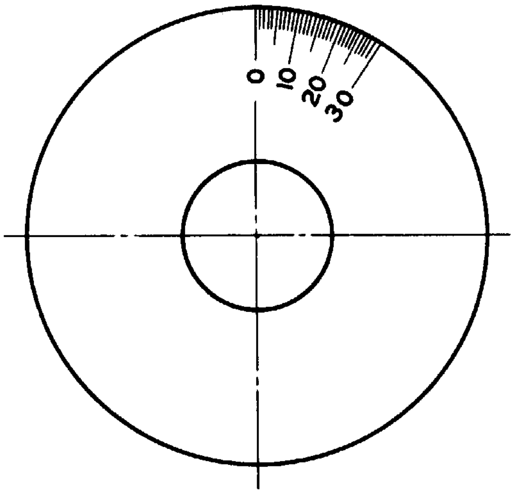
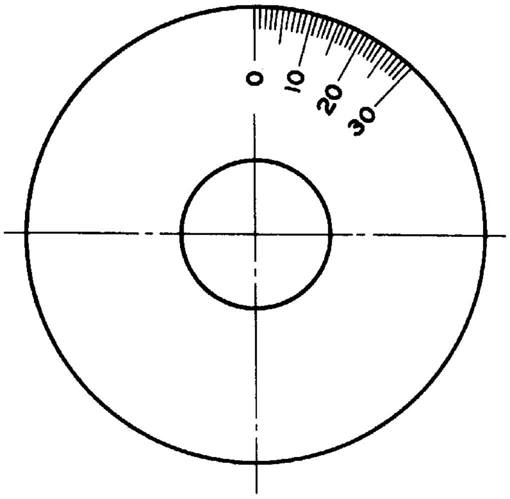


Illustration shows 1° between each space.

Angular Measure is obtained by measuring with a protractor.

B. LINEAR MEASURE ON A CIRCULAR FORM

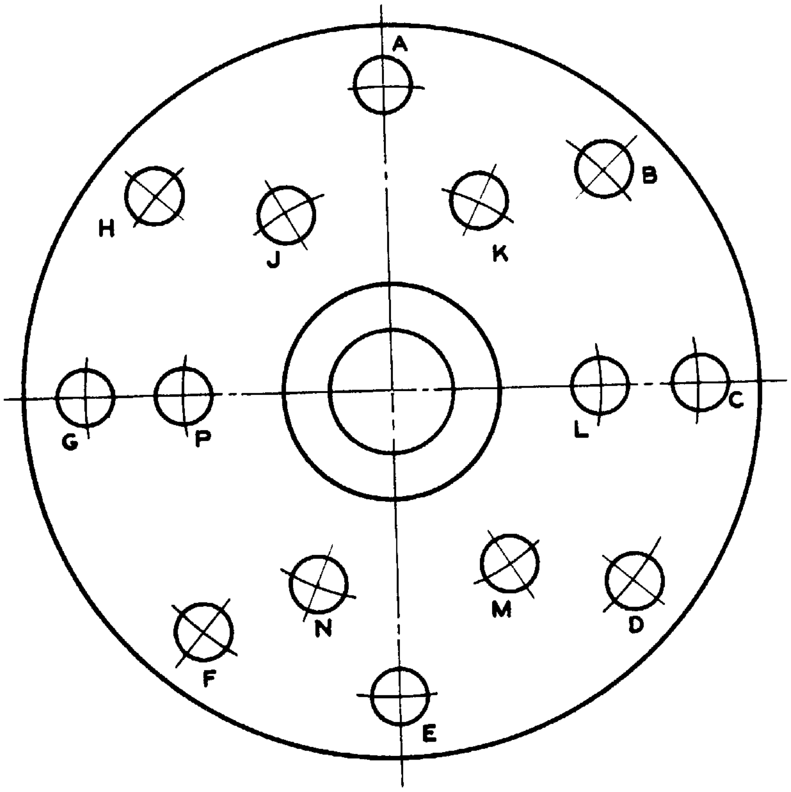
Illustration shows .001 movement between each space for .250 lead screw.



MEASUREMENT

APPLICATION OF ANGULAR MEASURE

Use a protractor to measure the angle to the nearest degree between the following holes on the face plate shown in the accompanying sketch.



1.	Hole	A	to	Hole	B	includes	an	angle	of	______	degrees	.
2.	"	B	"	"	L	"	"	"	"	______	"	.
3.	"	C	"	"	E	"	"	"	"	______	"	.
4.	"	L	"	"	M	"	"	"	"	______	"	.
5.	"	E	"	"	J	"	"	"	"	______	"	.
6.	"	F	"	"	H	"	"	"	"	______	"	.
7.	"	P	"	"	A	"	"	"	"	______	"	.
8.	"	B	"	"	P	"	"	"	"	______	"	.
9.	"	L	"	"	P	"	"	"	"	______	"	.
10.	"	G	"	"	L	"	"	"	"	______		

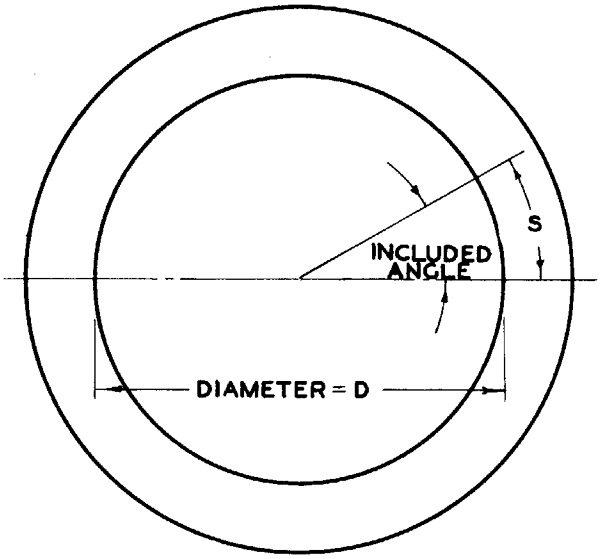
MEASUREMENT

MEASURE OF CIRCULAR LENGTH AND AREA

A. MEASURE OF CIRCULAR LENGTH

Circumference = π x Diameter

$$C = \pi D$$

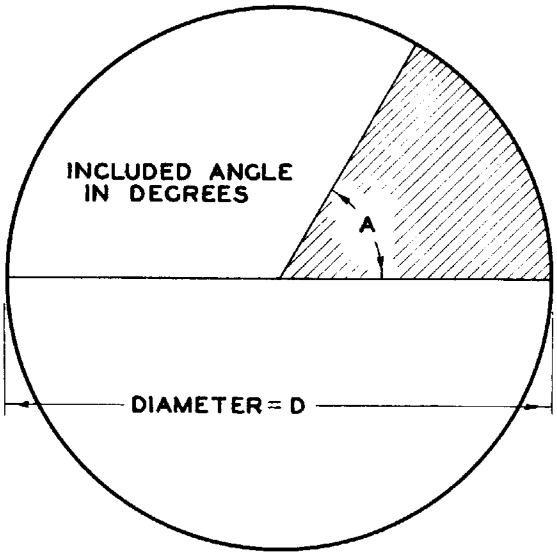


For a portion of the circumference,

$$S = \frac{\text{No. of degrees in the included angle}}{360^\circ} \times \pi D$$

B. MEASURE OF CIRCULAR AREA

$$\text{Area} = \frac{\pi D^2}{4}$$



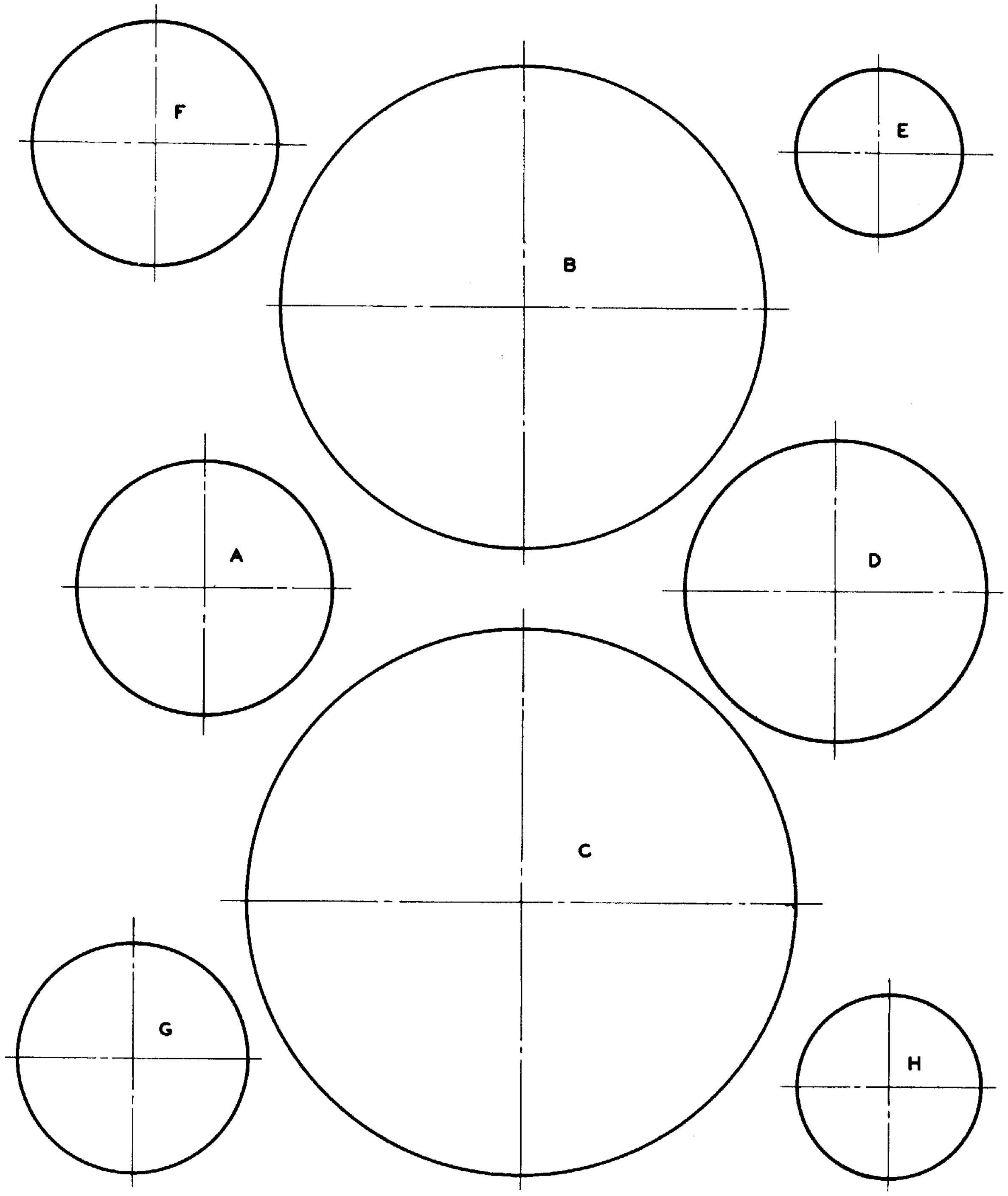
Portion of Area, as indicated =

$$\frac{\text{No. of degrees in the included angle}}{360^\circ} \times \frac{\pi D^2}{4}$$

MEASUREMENT

APPLICATION OF CIRCULAR MEASURE

1. Measure the diameter of each of the following circles and compute their circumferences.



MEASUREMENT

COMPARISON OF METRIC AND ENGLISH UNITS OF MEASURE

A. UNITS OF LENGTH

		Metric		English
One Millimeter	=	.001 meters	equals	.03937 inches
One Centimeter	=	.01 "	"	.3937 "
One Decimeter	=	.10 "	"	3.937 "
One Meter	=	1.0 "	"	39.37 "
One Kilometer	=	1,000 meters	=	.6214 miles

B. UNITS OF AREA

		Metric		English
One Sq. Millimeter	=	.000001 sq. meters	=	.00155 sq. in.
One Sq. Centimeter	=	.0001 sq. meters	=	.155 sq. in.
One Sq. Decimeter	=	.01 sq. meters	=	15.50 sq. in.
One Sq. Meter	=	1.0 unit	=	1550. sq. in.
One Hectare	=	10,000 sq. meters	=	2.471 acres

C. UNITS OF CUBIC MEASURE

One Milliliter = .001 liter = 1 cubic centimeter

Unit = one liter = 1,000 cubic centimeters = 1.057 qts.

D. UNITS OF WEIGHT

		Metric		English
Unit	=	1 gram	=	.03527 ounces
1,000 grams	=	1 kilogram	=	2.205 pounds

MEASUREMENT

PROBLEMS IN CONVERTING ENGLISH AND METRIC UNITS OF MEASURE

1. How many millimeters are there in 4 inches?

2. How many millimeters are there in $10\frac{1}{4}$ inches?

3. How many inches are there in 27 millimeters?

4. How many inches are there in 340 millimeters?

5. How many centimeters are there in 8 inches?

6. How many centimeters are there in 36 inches?

7. How many inches are there in 100 centimeters?

8. How many square centimeters are there in 5 square inches?

9. How many square inches are there in 80 square centimeters?

10. How many grams are there in 16 ounces?

11. How many ounces are there in 1000 grams?

12. How many pounds are there in 12 kilograms?

13. How many kilograms are there in 8 pounds?

MEASUREMENT

DEGREE OF ACCURACY

A. CONDITIONS WHICH AFFECT THE DEGREE OF ACCURACY

In a large number of machine shop operations, extreme accuracy is not required. As the production cost of a machine depends to a large degree on direct labor, it is important that the parts be made as economically as possible. If extreme accuracy is required by the designer when it is not needed, unnecessary costs are added.

To achieve extreme accuracy, rough machining, finish machining, grinding, and lapping are often required. For these operations, the degree of accuracy varies.

For rough machining, plus or minus 1/32" may be specified and this would be measured by a scale. For the second machining plus or minus 1/64" may be specified and measured by micrometers. For the grinding operation plus or minus .0002" may be given and again measured by a micrometer which should have .0001" graduations. For measuring the products during the lapping operation and also in its finished state, gage blocks and indicators would be used. (Comparison method). That this procedure is costly can be clearly seen. In determining the degree of accuracy for a part, great care must be exercised. If, for instance, a drill produces a slightly larger hole than is required for the corresponding tap, no harm would be done.

Should a drill cut larger by the amount allowed for reaming, no material would remain for this operation and spoilage may result. For milling machine and lathe operations the advance of the tool into the work or the work into the cutter is controlled by the graduated dial. A fair degree of accuracy may be expected of screws which transmit movement; but due to wear they should not be depended upon.

Lathes, milling machines, shapers, etc. are designed and built with such a degree of accuracy that tolerances of better than plus or minus .001" are obtainable if care and skill are employed. When measuring for extreme accuracy, care must be taken or the results will be misleading. If a micrometer is set too tightly, as much as .0005" can be forced. When reading a vernier scale, excessive pressure against the sliding jaw must be prevented as the deflection of the material and slight clearances in the bearing surfaces of the sliding jaw may cause wrong readings.

DEGREE OF ACCURACY

Often a magnifying glass is used for measuring to a graduated line as the width of the line itself is approximately .006. The temperature of the work to be measured should be about room temperature of 72 degrees, as higher temperatureswill expand, lower temperatures contract the work.

B. THE FACTORS WHICH DETERMINE THE DEGREE OF ACCURACY

1. Possible Limits.

   Measure can be determined under the best conditions to the accuracy of the wave-length of light. For most commercial uses, the limit of accuracy required will be to the fourth decimal place.

2. Specified.

   Specified tolerances are definitely a part of all engineering drawings. These are a function of many design and construction requirements.

   The American Standards Association has standardized tolerances and classes of fit for cylindrical fits, screw threads, and surface finish.

   Tolerances (specified deviations) originate in the design, and indicate the limits of accuracy desired.

3. Limitations of the measuring instrument.

   Possible exactness of measurements is limited to the tool used.

   a. The ordinary pocket scale has a limit of 1/64" and 1/100".

   b. The micrometer and caliper indicate measure to .001", with a vernier attachment, to .0001".

   c. Precision Gage blocks measure, (if ordinary) to .000008 of an inch, to .000002 of one inch (if of the finest grade). These blocks may be used in combination of ordinary and fine.

DEGREE OF ACCURACY

The figures (except those for precision gage blocks) represent the graduation on the scale on which the measure is indicated. The precision gage blocks are fixed and piled together in series to make the required dimension.

d. Tool-maker's microscope.

4. Errors in Measurement

a. **Measuring tool**

(1) Manufactured accuracy
(2) Wear
(3) Temperature (in 4th place work)

b. **Human Element**

(1) Eyesight (light available to read properly)
(ability to interpret 4th place correctly)
(2) Touch (ability to "feel" measure on measuring tools)

c. Possibility of securing mechanical duplication depends on:

(1) Variation in material
(2) Kind of machine, its rigidity, tightness of bearings, of bed, and fixture.
(3) Wear and support of tools

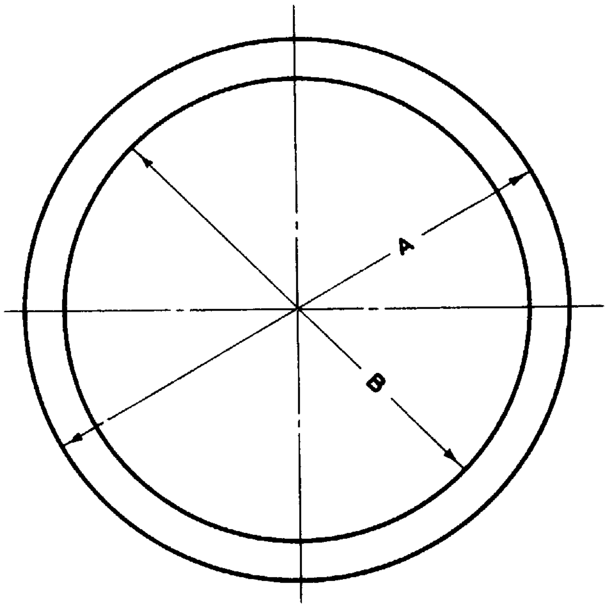
d. Development of judgment in working to practical limits of accuracy.

The character of the manufactured part and the nature of fit to mating members in an assembly determine the degree of accuracy required in production.

MEASUREMENT

DEGREE OF ACCURACY

A. PROBLEMS INVOLVING DEPTH OF CUT



On the piece to be turned, if the existing diameter A is measured and the finished diameter B is known, what is the depth of the cut?

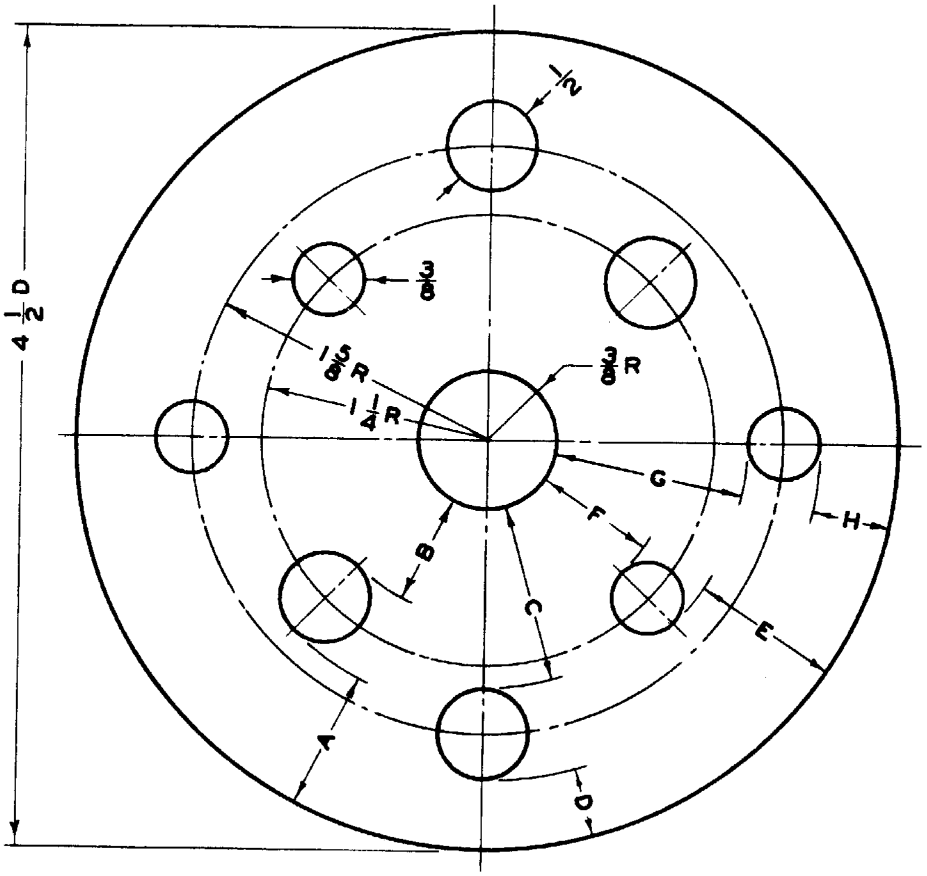
1. A is 1.875 B is to be 1.00" requiring ____" to be removed.
2. " " 1.350 " " " " 1.100 " ____" " " " .
3. " " 1.375 " " " " 1.300 " ____" " " " .
4. " " 2.125 " " " " 1.875 " ____" " " " .
5. " " 3.000 " " " " 1.600 " ____" " " " .
6. " " 2.831 " " " " 1.750 " ____" " " " .
7. " " 3.875 " " " " 3.500 " ____" " " " .
8. " " 1.380 " " " " 1.275 " ____" " " " .
9. " " 2.736 " " " " 1.254 " ____" " " " .
10. " " 1.937 " " " " 1.854 " ____" " " " .

DEGREE OF ACCURACY

B. PROBLEMS INVOLVING ALLOWANCES FOR REAMING

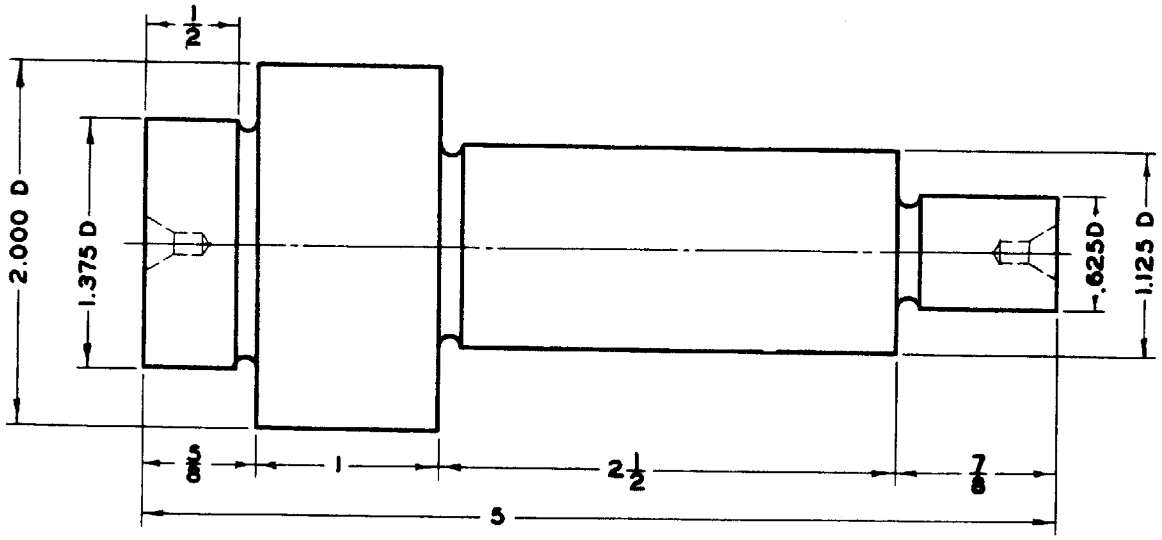
1. Find the distances A, B, C, D, E, F, G, and H, if on all 3/8" and 1/2" holes 1/64" is allowed for reaming.

2. What are the respective distances after reaming?



DEGREE OF ACCURACY

C. PROBLEMS INVOLVING ALLOWANCES FOR TURNING AND GRINDING



The above spindle must be rough turned, annealed, finish turned, hardened and tempered, and ground.

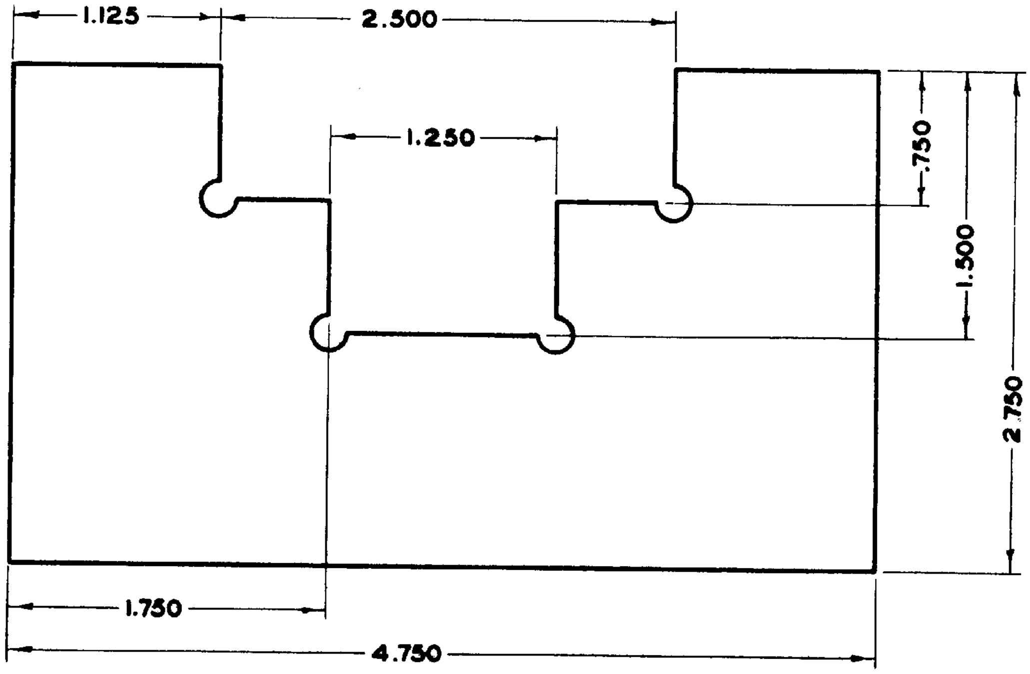
1. Rough turn the piece allowing 1/16" for finish machining on all diameters and 1/32" on all faces. Finish turn to allow .012 for grinding on all diameters and .008 on all faces.

   a. Find the corresponding dimensions for rough machining.

   b. Find the corresponding dimensions for finish machining.

DEGREE OF ACCURACY

D. PROBLEMS INVOLVING ALLOWANCES FOR MILLING AND GRINDING



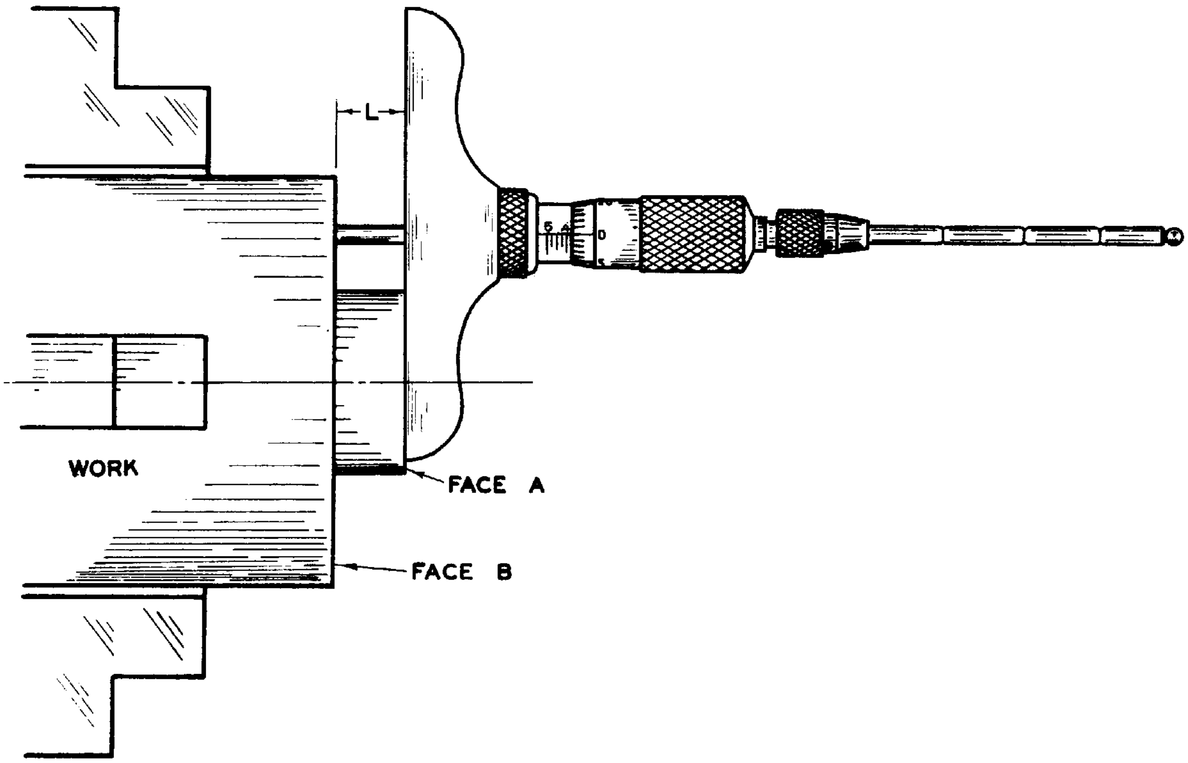
1. On the turbine gage above, the part must be rough machined, annealed, finish machined, hardened and tempered, and ground.

   a. Find the dimensions to which the piece must be roughly machined, allowing 1/32" for finish machining.

   b. Find the dimensions to which the piece must be finish machined before grinding, allowing .008" for grinding.

DEGREE OF ACCURACY

E. APPLICATION OF MEASUREMENT INVOLVING LIMITS

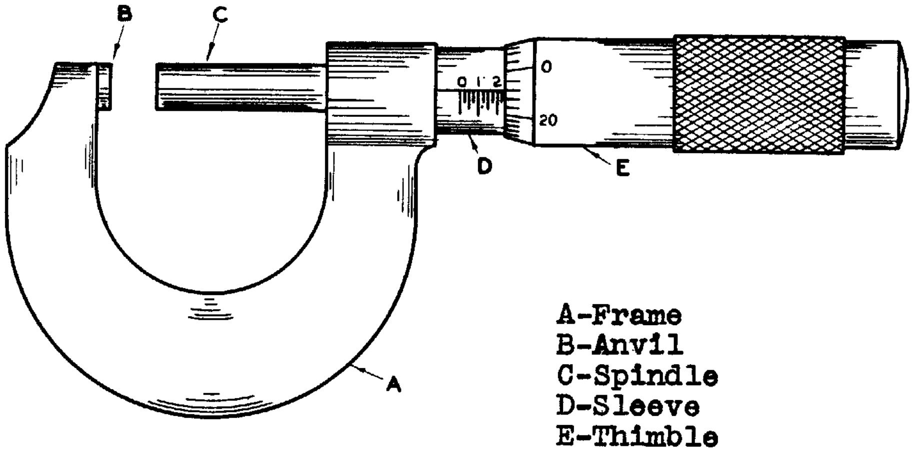


1. Dimension L must be .375 $^{+.001}_{-.001}$ How much material must be removed on faces A or B if the micrometer reads:

.372	______	.362	______
.374	______	.370	______
.380	______	.376	______
.386	______	.351	______
.398	______	.350	______

MEASUREMENT

READING A MICROMETER



A-Frame
B-Anvil
C-Spindle
D-Sleeve
E-Thimble

The spindle C is attached to the thimble E on the inside. The part of the spindle which is concealed within the sleeve and thimble is threaded to fit a nut in the frame A. The frame being held stationary, the thimble E is revolved by the thumb and finger, and the spindle C being attached to the thimble, revolves with it and moves thru the nut in the frame, approaching or receding from the anvil B.

The article to be measured is placed between the anvil B and the spindle C. The measurement of the opening between the anvil and the spindle is shown by the lines and figures on the sleeve D and the thimble E.

The pitch of the screw threads on the concealed part of the spindle is 40 to an inch. One complete revolution of the spindle therefore moves it longitudinally one fortieth (or twenty-five thousandths) of an inch. The sleeve D is marked with 40 lines to the inch, corresponding to the number of threads on the spindle. When the micrometer is closed, the beveled edge of the thimble coincides with the line 0 on the sleeve, and the 0 line on the thimble agrees with the horizontal line on the sleeve.

READING A MICROMETER

Open the micrometer by revolving the thimble one full revolution, or until the 0 line on the thimble again coincides with the horizontal line on the sleeve; the distance between the anvil B and the spindle C is then 1/40 (or .025) of an inch, and the beveled edge of the thimble will coincide with the second vertical line on the sleeve. Each vertical line on the sleeve indicates a distance of 1/40 of an inch. Every fourth line is made longer than the others, and is numbered 0, 1, 2, 3, etc. Each numbered line indicates a distance of four times 1/40 of an inch, or one tenth.

The beveled edge of the thimble is marked in twenty-five divisions, and every fifth line is numbered, from 0 to 25. Rotating the thimble from one of these marks to the next moves the spindle longitudinally 1/25 of forty thousandths, or one thousandths of an inch. Rotating it two divisions indicates two thousandths, etc. Twenty-five divisions will indicate a complete revolution, .025 or 1/40 of an inch.

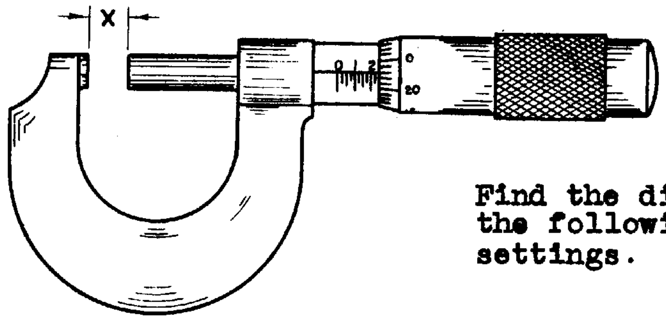
To read the micrometer, therefore, multiply the number of vertical divisions visible on the sleeve by 25, and add the number of divisions on the bevel sleeve. For example, as the tool is represented in the illustration, there are nine divisions visible on the sleeve. Multiply this number by 25, and add the number of divisions shown on the bevel of the thimble (23). The micrometer is open two hundred and forty-eight thousandths. (9 x 25 = 225; 225 + 23 = 248).

(Courtesy of L. S. Starrett Company)

MEASUREMENT

PROBLEMS IN READING A MICROMETER

A. DIRECT MEASURE



Find the distance "x" for the following micrometer settings.

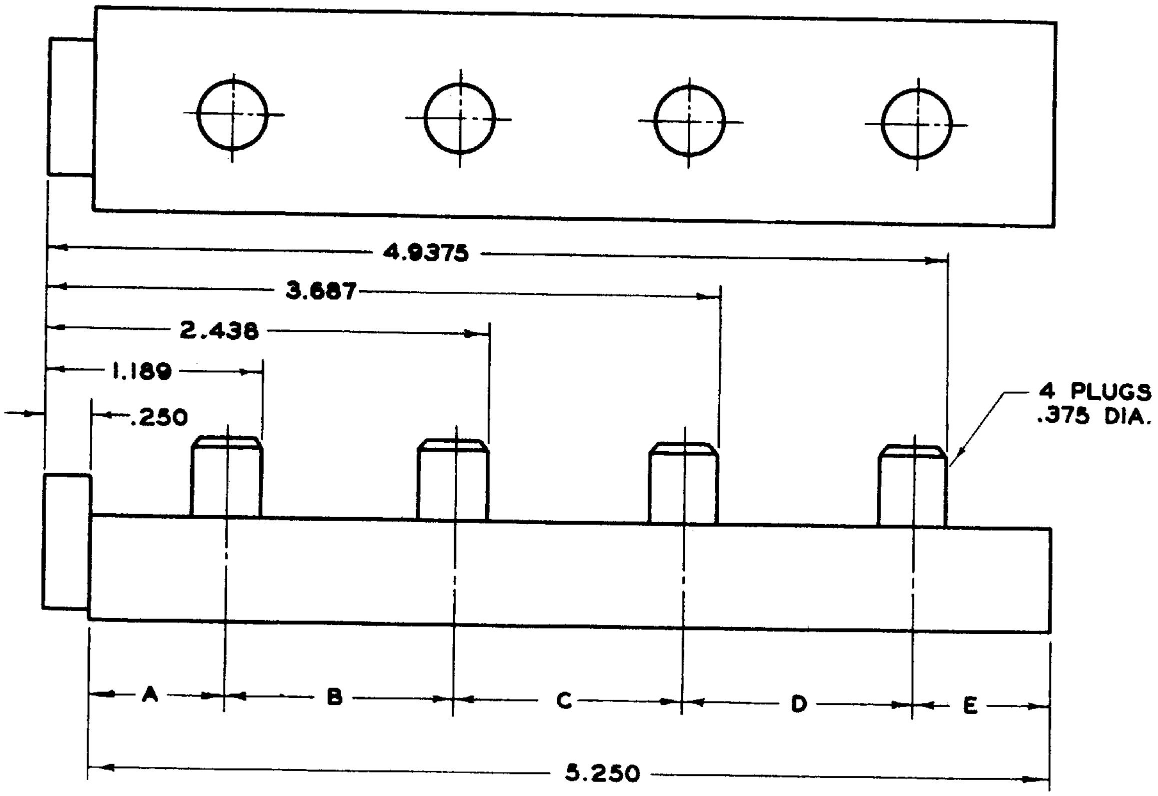
NOTE: Where possible, secure a micrometer, set at the indicated positions, and note the reading in each instance.

Reading on sleeve is between	Nearest line on thimble	Reading
.000 and .025	6	
.075 and .100	14	
.125 and .150	24	
.250 and .275	5	
.325 and .350	15	
.450 and .475	23	
.400 and .425	4	
.575 and .600	16	
.525 and .550	22	
.675 and .700	3	
.600 and .625	17	
.700 and .725	21	
.775 and .800	2	
.825 and .850	18	
.900 and .925	20	
.975 and 1.000	1	
.800 and .825	19	
.800 and .825	7	
.750 and .775	13	
.625 and .650	8	

PROBLEMS IN READING A MICROMETER

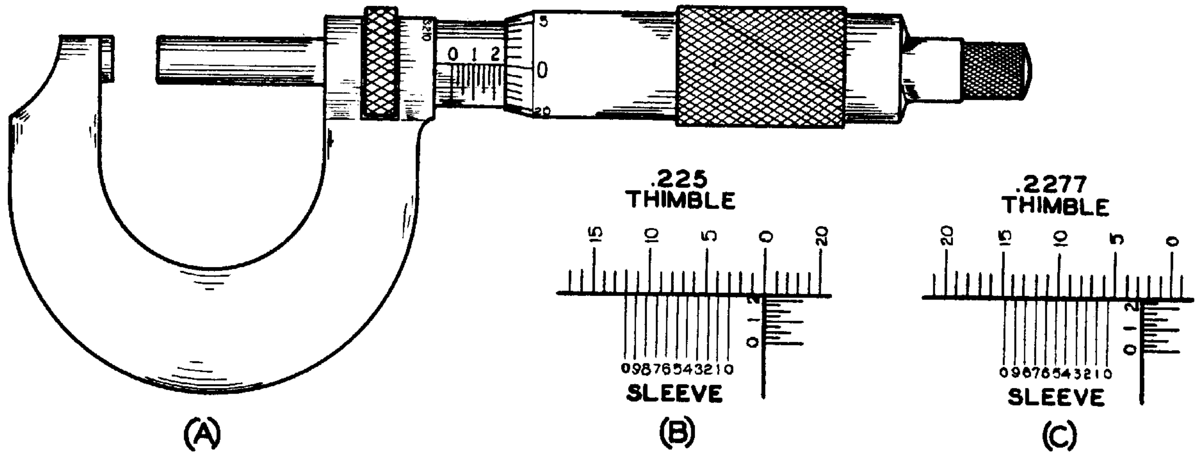
B. COMPUTED MEASURE

1. Find distances A, B, C, D and E.



MEASUREMENT

READING A MICROMETER GRADUATED IN TEN-THOUSANDTHS OF AN INCH



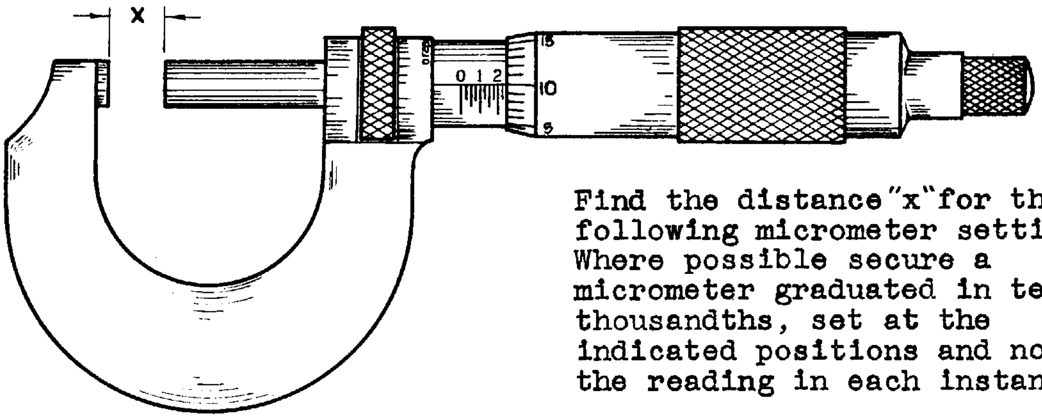
Readings in ten thousandths of an inch are obtained by the use of a vernier, so named from Pierre Vernier, who invented the device in 1631. As applied to a micrometer, this consists of ten divisions on the adjustable sleeve, which occupy the same space as nine divisions on the thimble. The difference between the width of one of the ten spaces on the sleeve and one of the nine spaces on the thimble is, therefore, one tenth of a space on the thimble. In the illustration B, the third line from 0 on the thimble coincides with the first line on the sleeve.

The next two lines on thimble and sleeve do not coincide by one tenth of a space on thimble; the next two marked 5 and 2, are two tenths apart, and so on. In opening the tool, by turning the thimble to the left, each space on the thimble represents an opening of one thousandth of an inch. If, therefore, the thimble be turned so that the lines marked 5 and 2 coincide, the caliper will be opened two tenths of one thousandth or two ten-thousandths. Turning the thimble further, until the line 10 coincides with the line 7 on the sleeve, as in the illustration C, the caliper has been opened seven ten-thousandths, and the reading of the tool is .2277.

To read a ten-thousandths micrometer, first note the thousandths as in the ordinary micrometer, then observe the line on the sleeve which coincides with a line on the thimble. If it is the second line, marked 1, add one ten-thousandth; if the third, marked 2, add two ten-thousandths, etc.

MEASUREMENT

PROBLEMS IN READING A MICROMETER GRADUATED IN TEN-THOUSANDTHS OF AN INCH



Find the distance "x" for the following micrometer settings. Where possible secure a micrometer graduated in ten-thousandths, set at the indicated positions and note the reading in each instance.

Reading on sleeve is between	Reading on thimble between	Vernier line	Reading
.000 and .025	7 and 8	2	
.075 and .100	15 and 16	3	
.125 and .150	23 and 24	5	
.250 and .275	6 and 7	7	
.325 and .350	16 and 17	9	
.450 and .475	24 and 25	2	
.400 and .425	5 and 6	4	
.575 and .600	17 and 18	6	
.525 and .550	23 and 24	8	
.675 and .700	4 and 5	1	
.600 and .625	18 and 19	5	
.700 and .725	22 and 23	9	
.775 and .800	3 and 4	2	
.825 and .850	19 and 20	6	
.900 and .925	21 and 22	3	
.975 and 1.000	2 and 3	7	
.800 and .825	20 and 21	1	
.800 and .825	8 and 9	9	

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