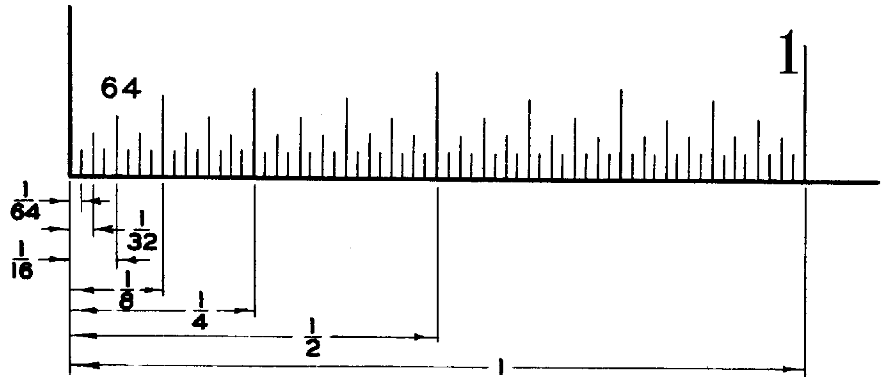
MEASUREMENT

THE UNITS OF LINEAR MEASURE

TABLE OF LINEAR MEASURE

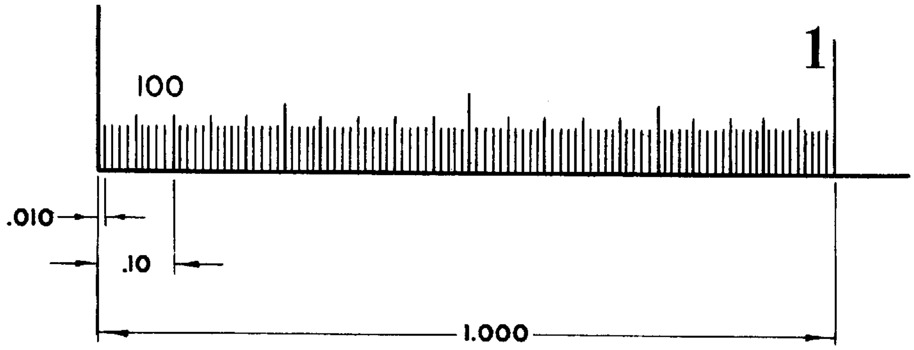
unit	=	1 inch
12 inches	=	1 foot
3 feet	=	1 yard

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



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

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

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.

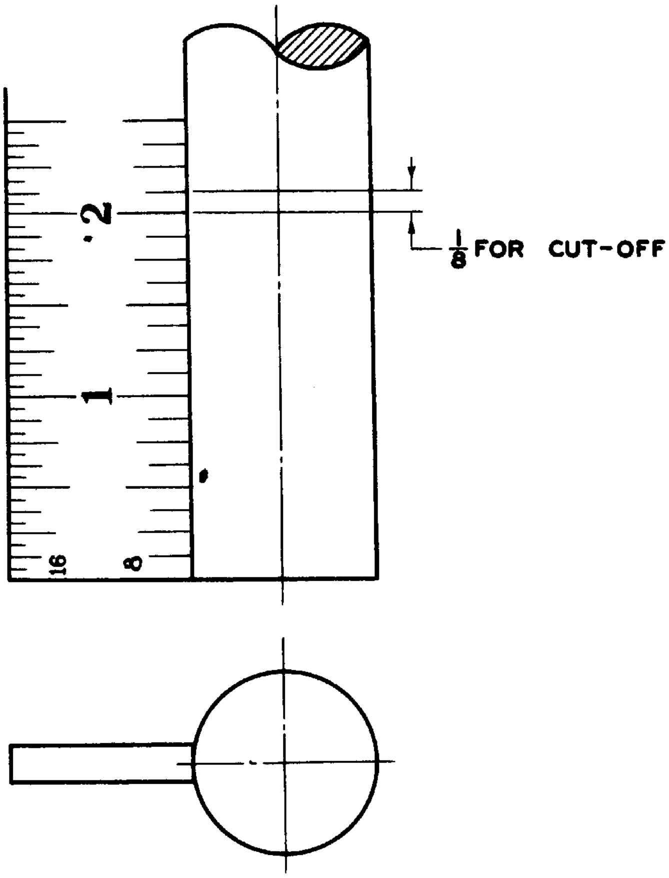
i.

j.

k.

B. PRACTICAL APPLICATION OF LINEAR MEASURE

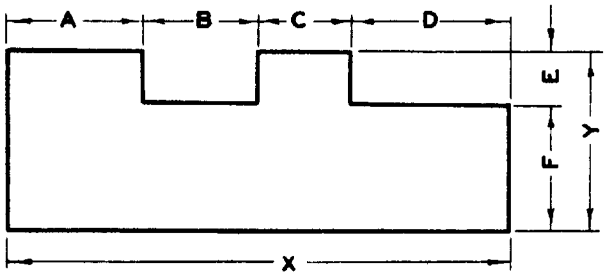
Allowances For Cutting Off Stock



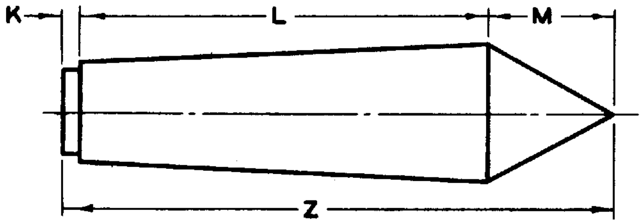
1. How much stock is required for 4 pieces of C. R. S. $2\frac{1}{4}$" long, if 1/8" must be allowed for each piece for cutting off?

LINEAR MEASURE

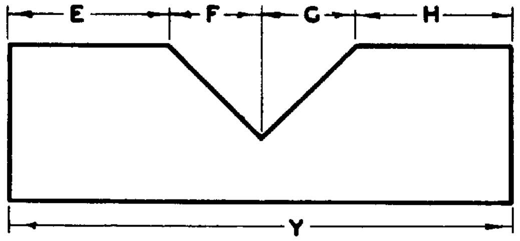
2. In this milled block, measure lengths A, B, C, and D and check the sum of these against the overall dimension X. Do the same for dimensions E, F, and Y.



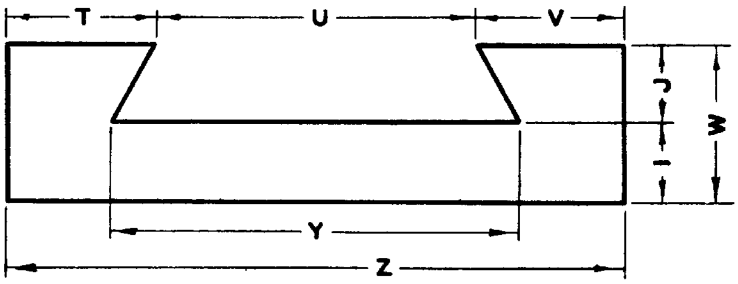
3. On the lathe center, measure the length K, L, and M, and check the sum of their lengths against the overall dimension Z.



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



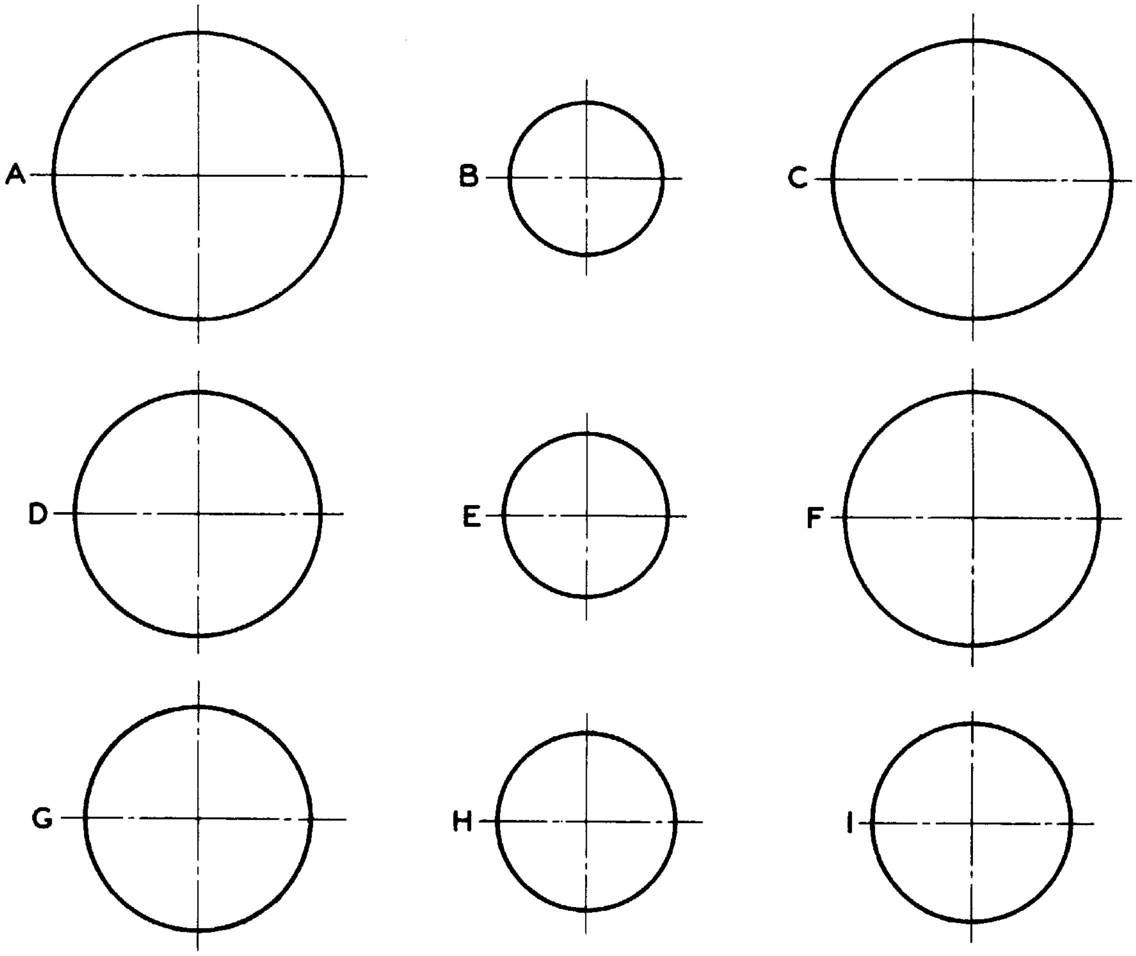
5. Measure dimensions T, U, and V, and check with the overall length Z of the lathe slide. Do the same for I and J and check with the overall length W.



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.

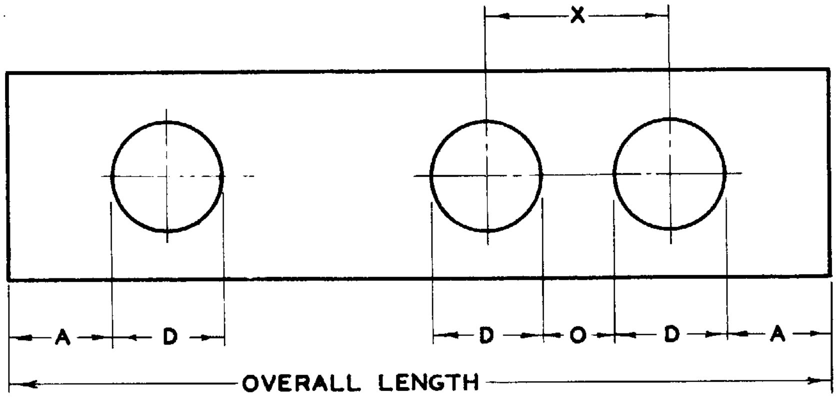


Diameter A ________ What size drill should be used? __________.
Diameter B ________ What size drill should be used? __________.
Diameter C ________ What size drill should be used? __________.
Diameter D ________ What size drill should be used? __________.
Diameter E ________ What size drill should be 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.

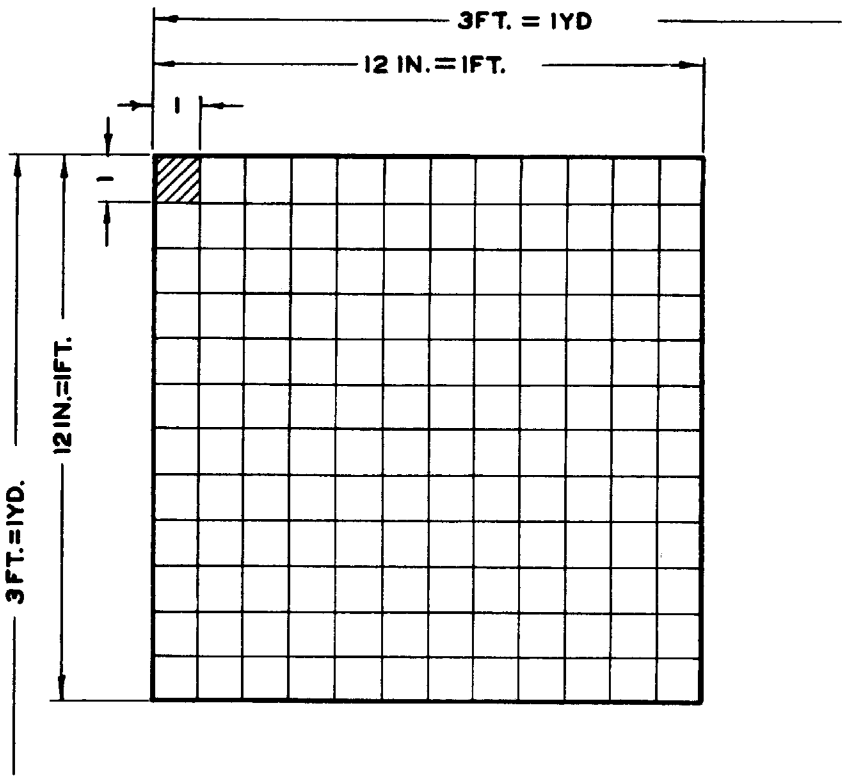
Overall length	(A) End spaces	No. of holes	(X) Center to center	(D) Diameter of circle	(O) Space between
1'4-7/8"	7/16		$1\frac{1}{4}$"	1"	$\frac{1}{4}$"
2' 0"		12	$1\frac{1}{4}$"		3/8
	7/8"	16		1/8"	$\frac{1}{2}$"
	1-1/16	17	2-9/16	2"	

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.

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

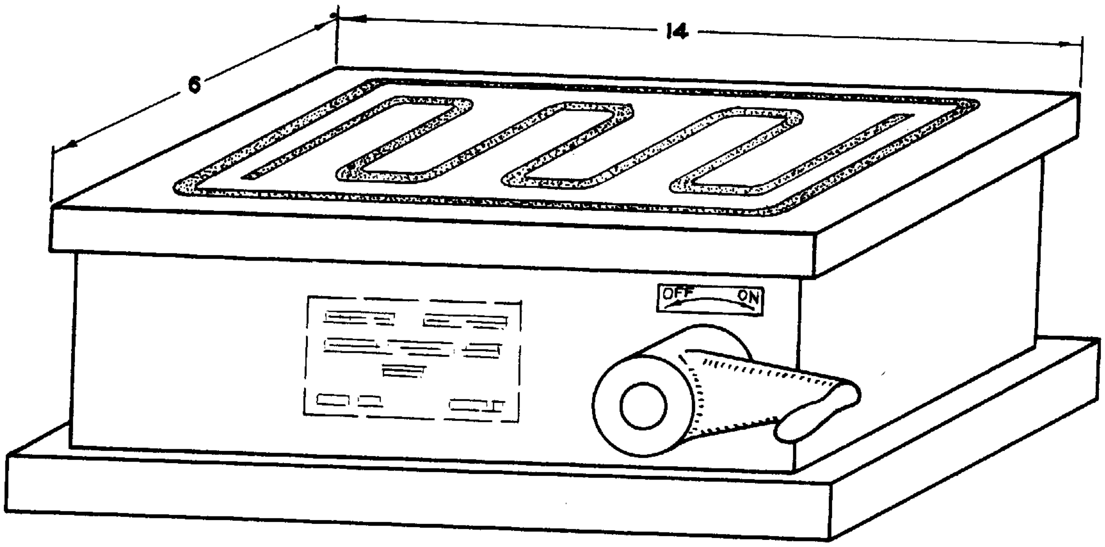
MEASUREMENT

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?

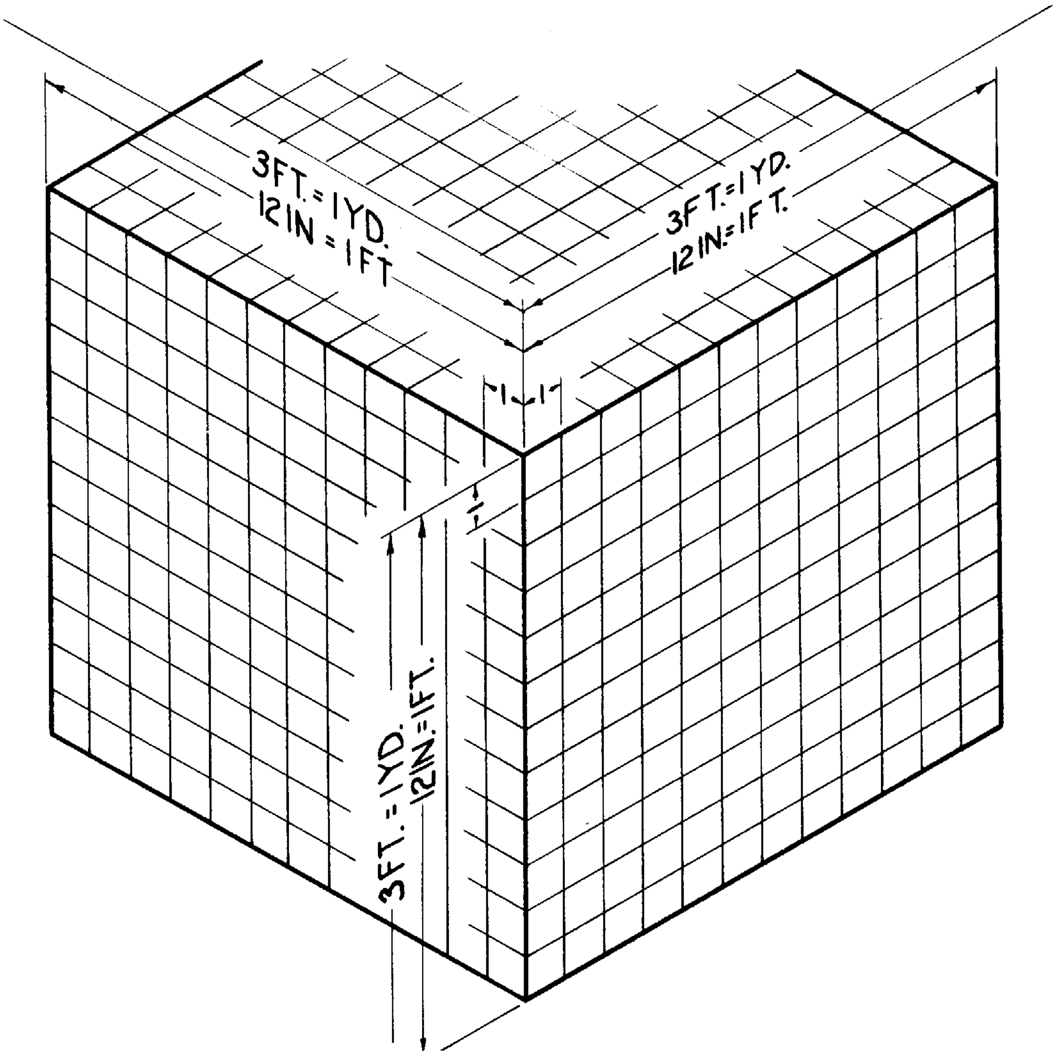


MEASUREMENT

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

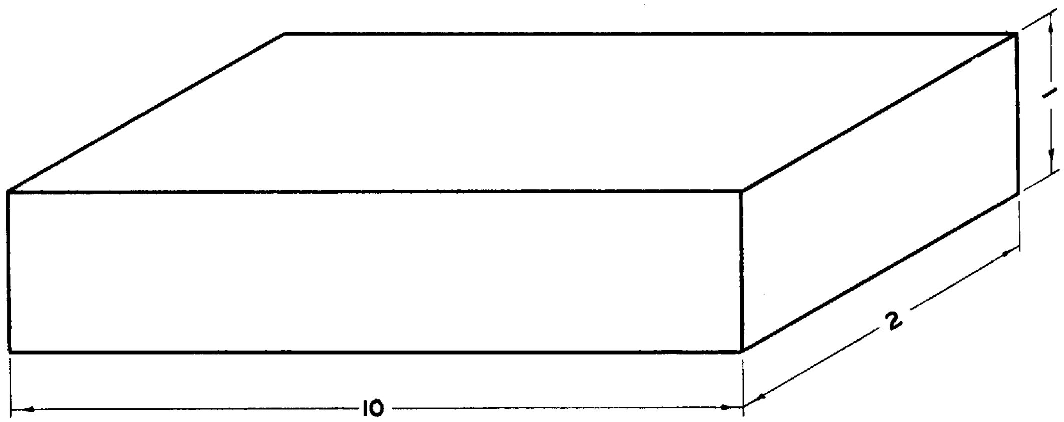
The volume of a rectangular solid equals the length times the width times the thickness. $V = lwh$.

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

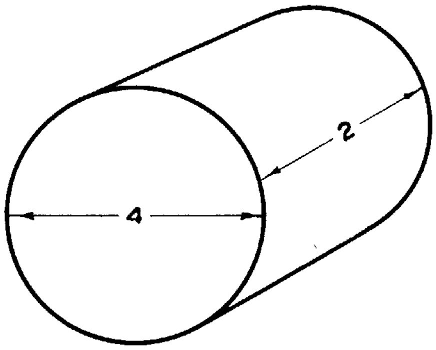
1. Twelve bars of 1" x 2" flat cold rolled steel are to be cut 10" long.



(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

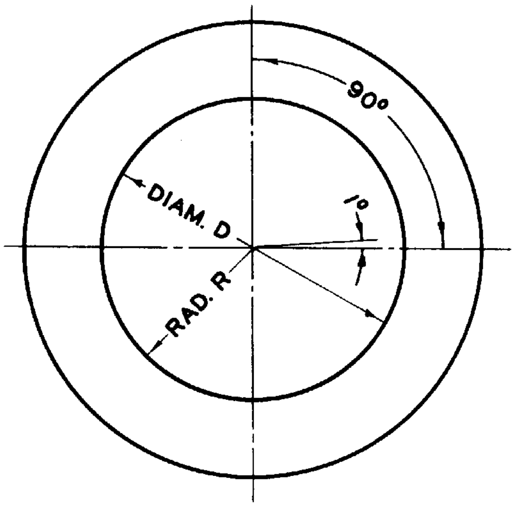


Table of Angular Measure

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

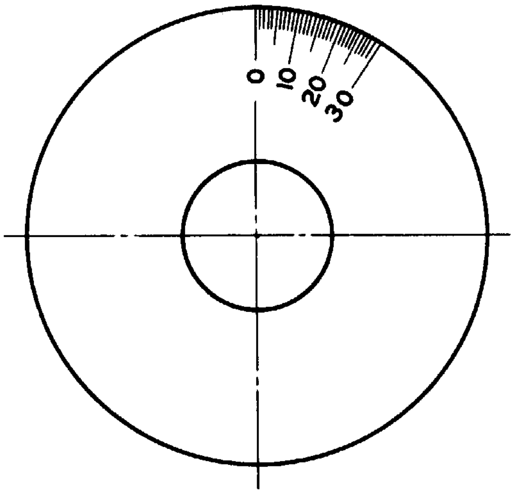
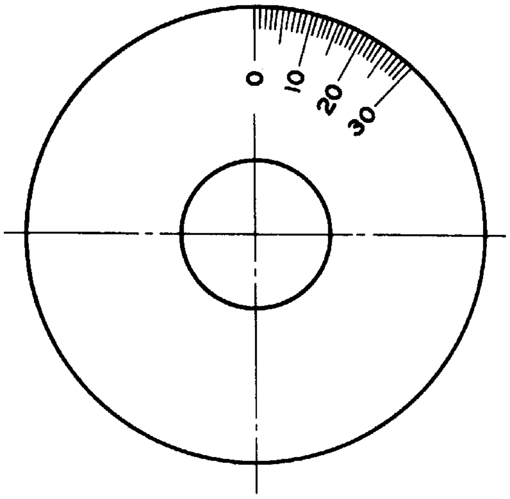


Illustration shows 1° between each space.

Angular Measure is obtained by measuring with a protractor.

B. LINEAR MEASURE ON A CIRCULAR FORM

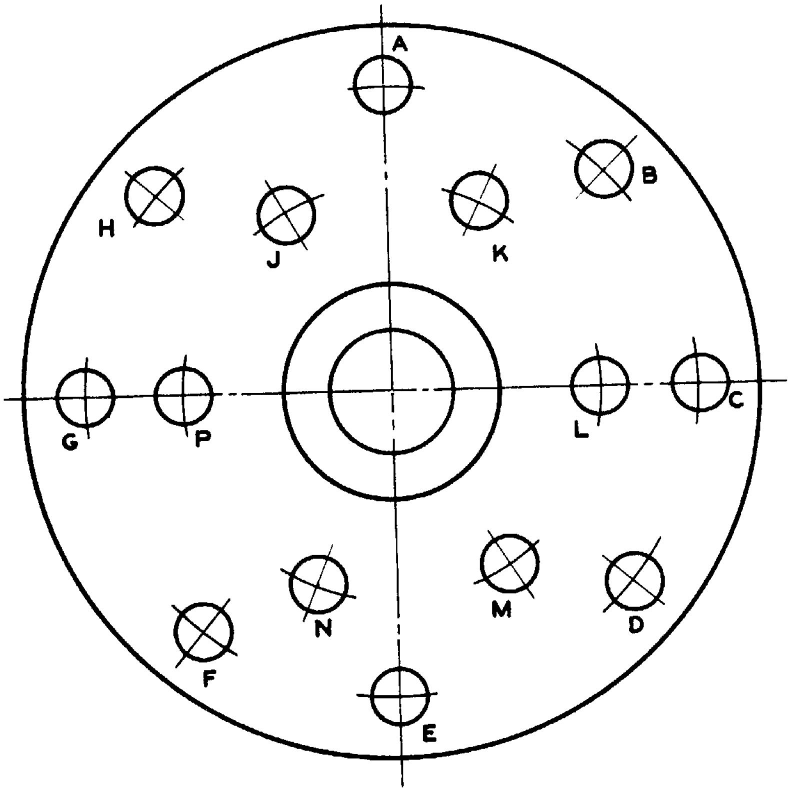
Illustration shows .001 movement between each space for .250 lead screw.



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	"	"	"	"	______	

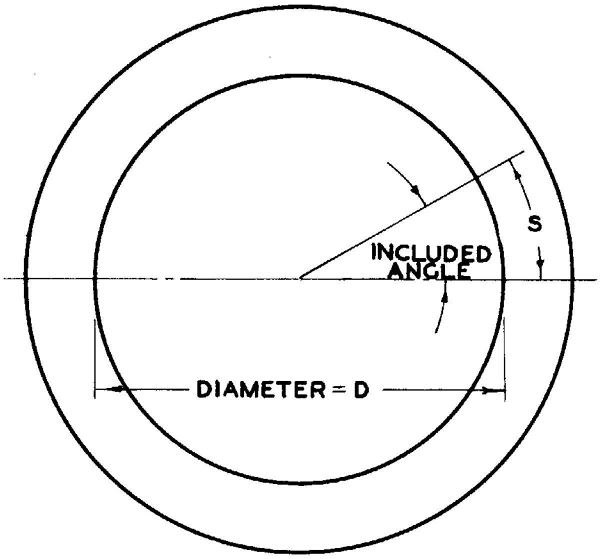
MEASUREMENT

MEASURE OF CIRCULAR LENGTH AND AREA

A. MEASURE OF CIRCULAR LENGTH

Circumference = π x Diameter

$$C = \pi D$$

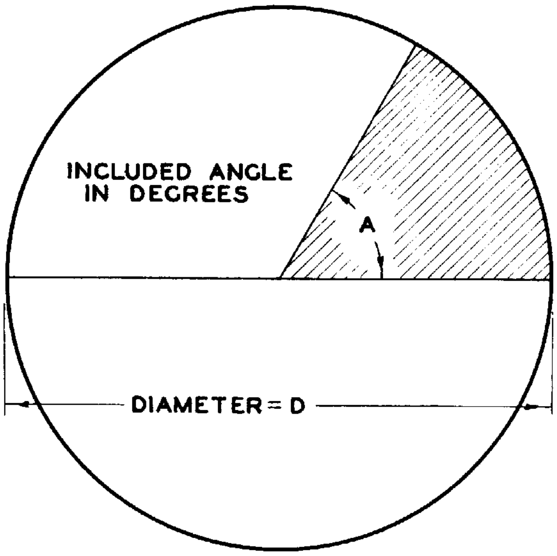


For a portion of the circumference,

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

B. MEASURE OF CIRCULAR AREA

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



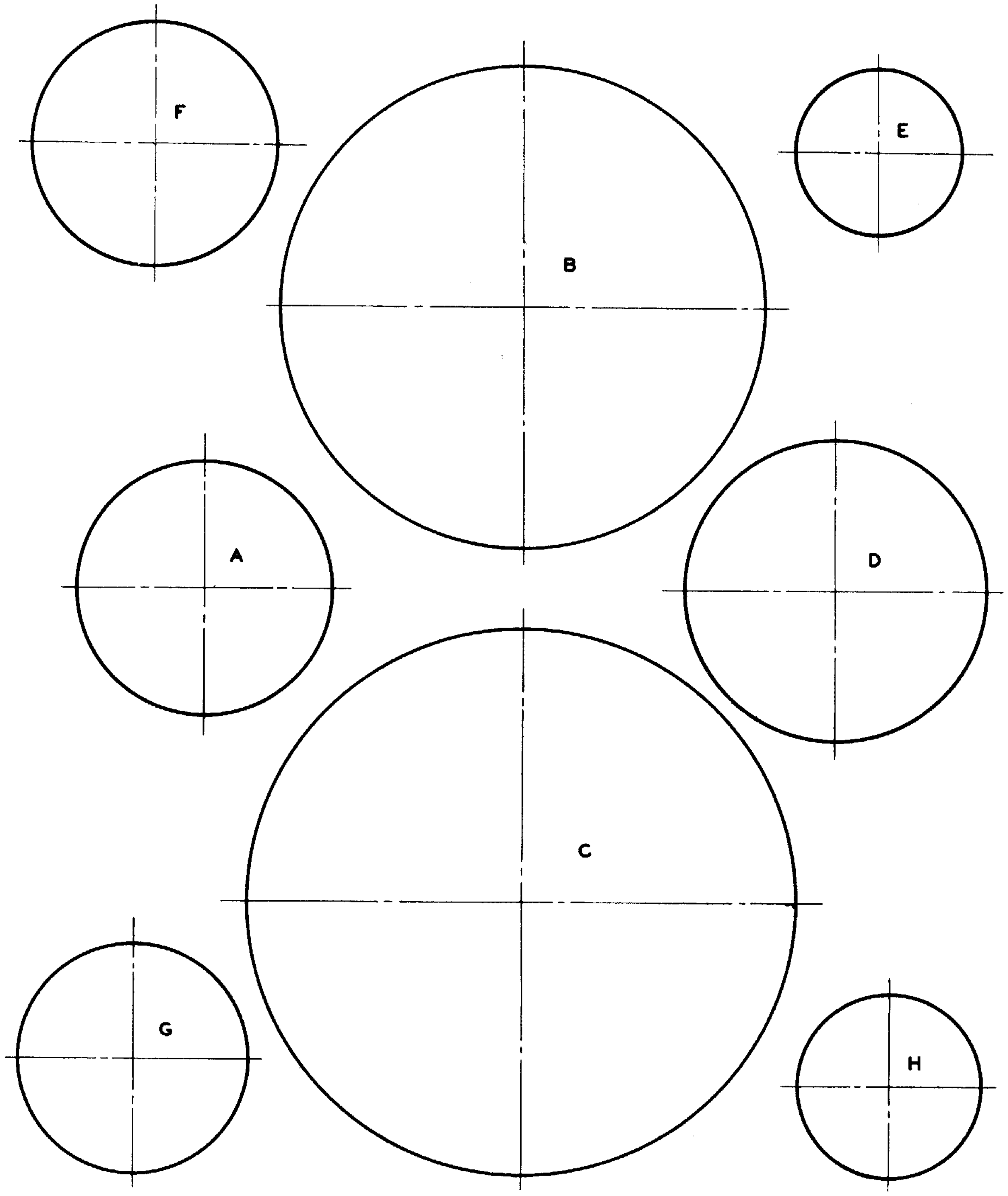
Portion of Area, as indicated =

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

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 temperatures will 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

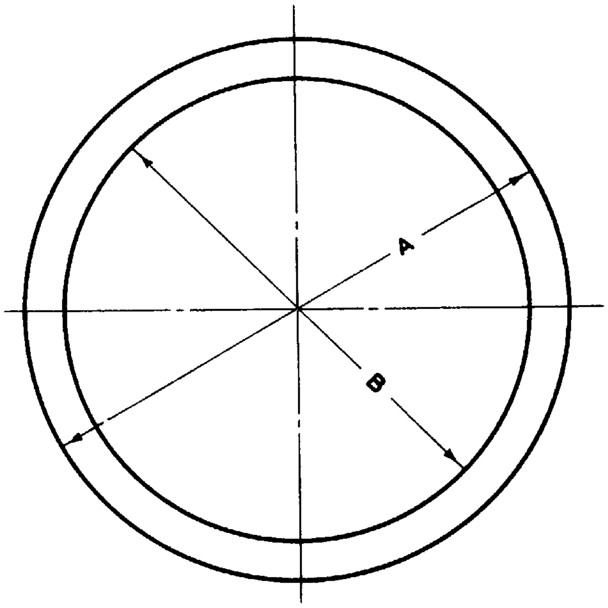
d. **Development of judgment in working to practical limits of accuracy.**

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?

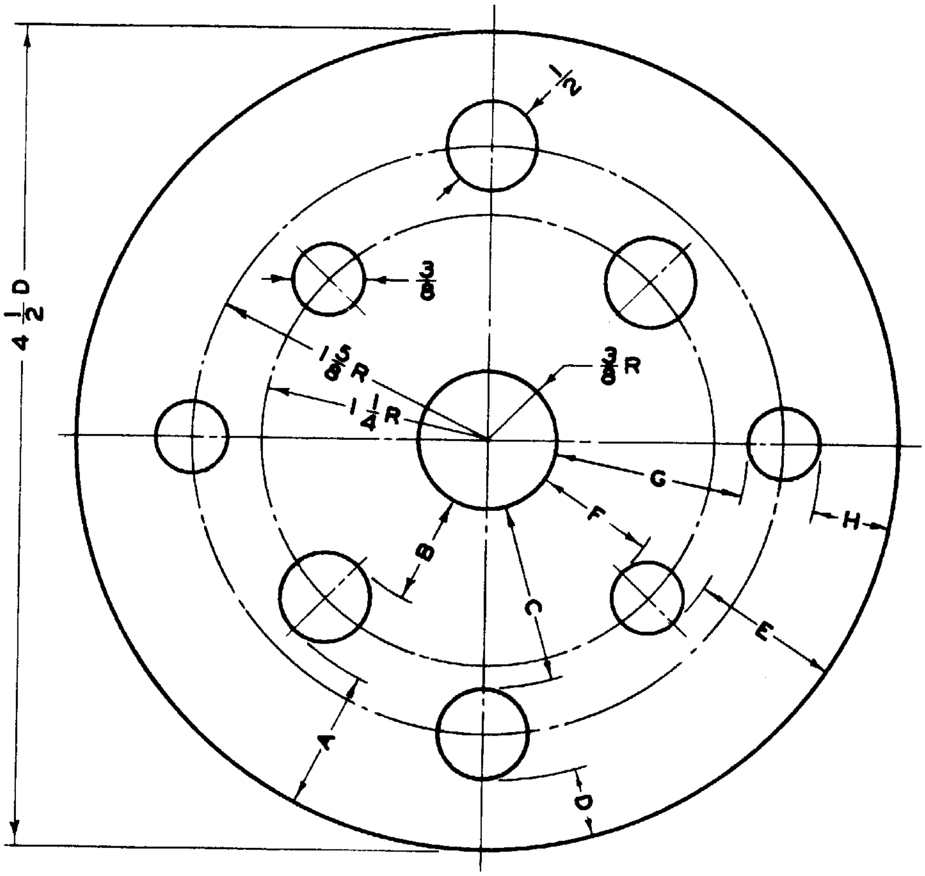
1.	A	is	1.875	B	is	to	be	1.00"	requiring	____"	to	be	removed.
2.	"	"	1.350	"	"	"	"	1.100	"	____"	"	"	" .
3.	"	"	1.375	"	"	"	"	1.300	"	____"	"	"	" .
4.	"	"	2.125	"	"	"	"	1.875	"	____"	"	"	" .
5.	"	"	3.000	"	"	"	"	1.600	"	____"	"	"	" .
6.	"	"	2.831	"	"	"	"	1.750	"	____"	"	"	" .
7.	"	"	3.875	"	"	"	"	3.500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

DEGREE OF ACCURACY

B. PROBLEMS INVOLVING ALLOWANCES FOR REAMING

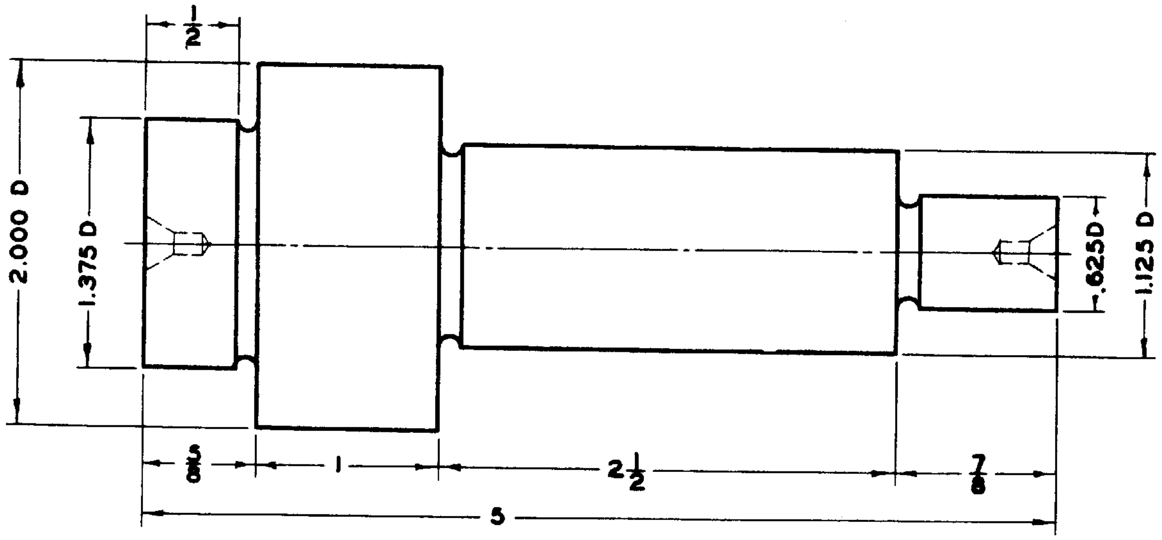
1. Find the distances A, B, C, D, E, F, G, and H, if on all 3/8" and 1/2" holes 1/64" is allowed for <u>reaming</u>.

2. What are the respective distances <u>after reaming</u>?



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.

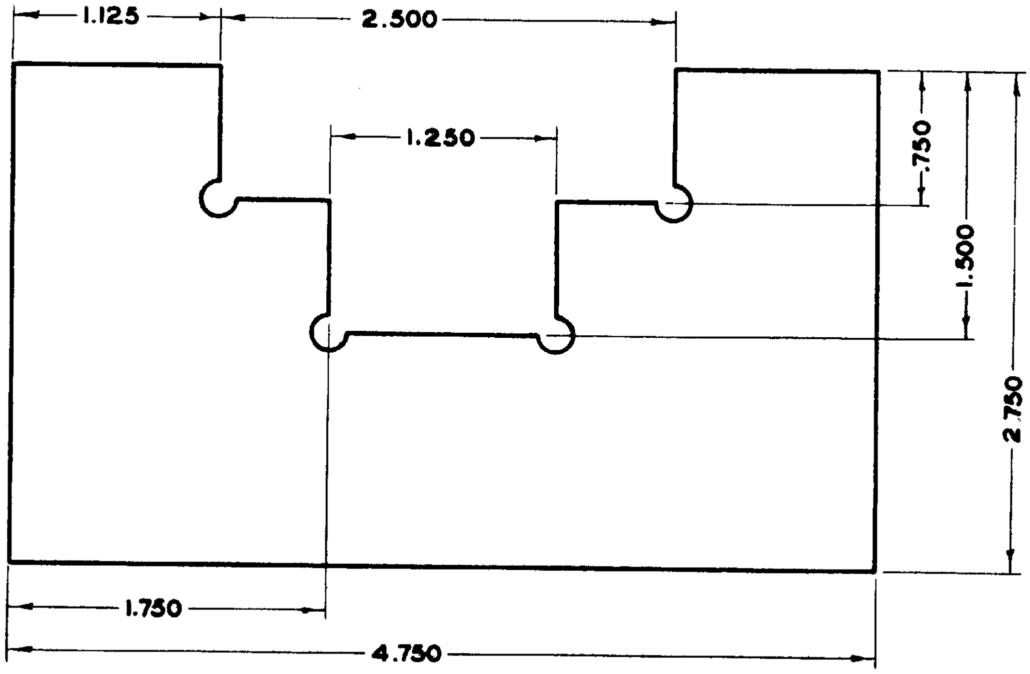
1. Rough turn the piece allowing 1/16" for finish machining on all diameters and 1/32" on all faces. Finish turn to allow .012 for grinding on all diameters and .008 on all faces.

   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



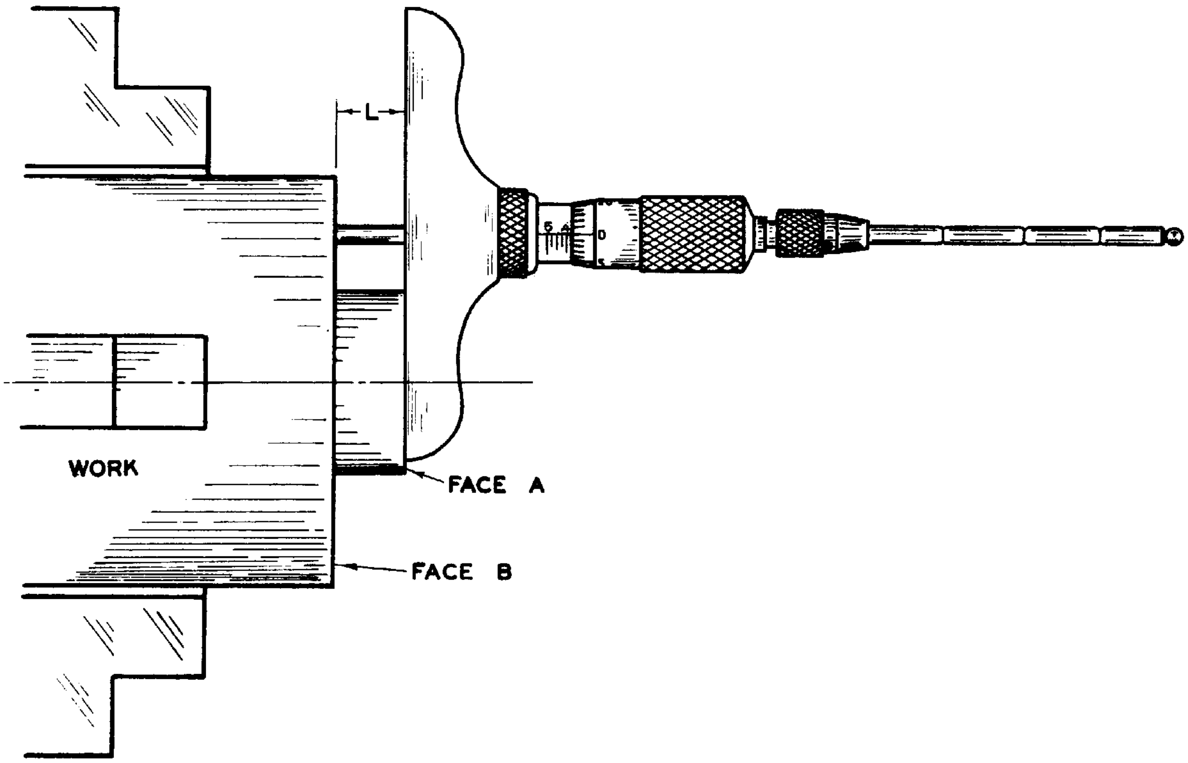
1. On the turbine gage above, the part must be rough machined, annealed, finish machined, hardened and tempered, and ground.

   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

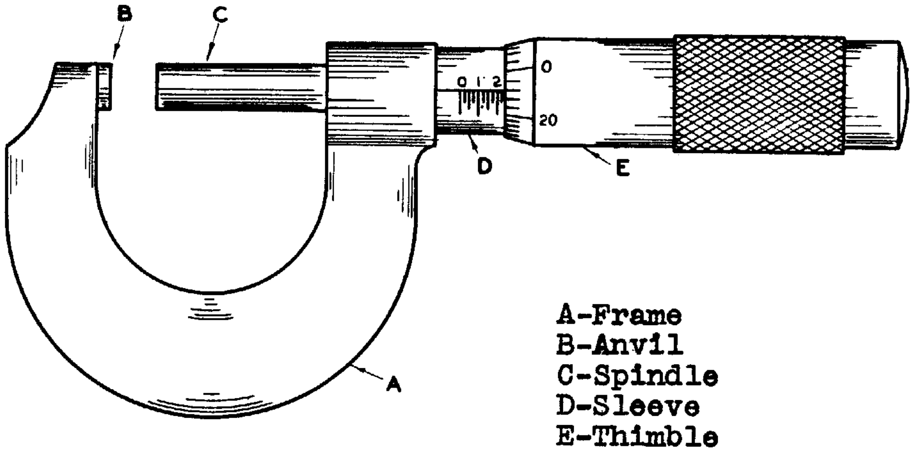


1. Dimension L must be $.375 \begin{smallmatrix} +.001 \\ -.001 \end{smallmatrix}$ How much material must be removed on faces A or B if the micrometer reads:

.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.

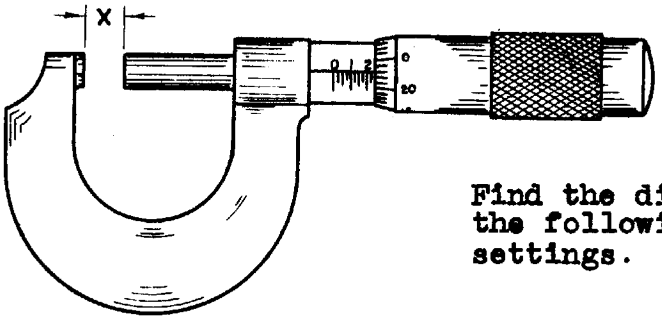
To read the micrometer, therefore, multiply the number of vertical divisions visible on the sleeve by 25, and add the number of divisions on the bevel sleeve. For example, as the tool is represented in the illustration, there are nine divisions visible on the sleeve. Multiply this number by 25, and add 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.

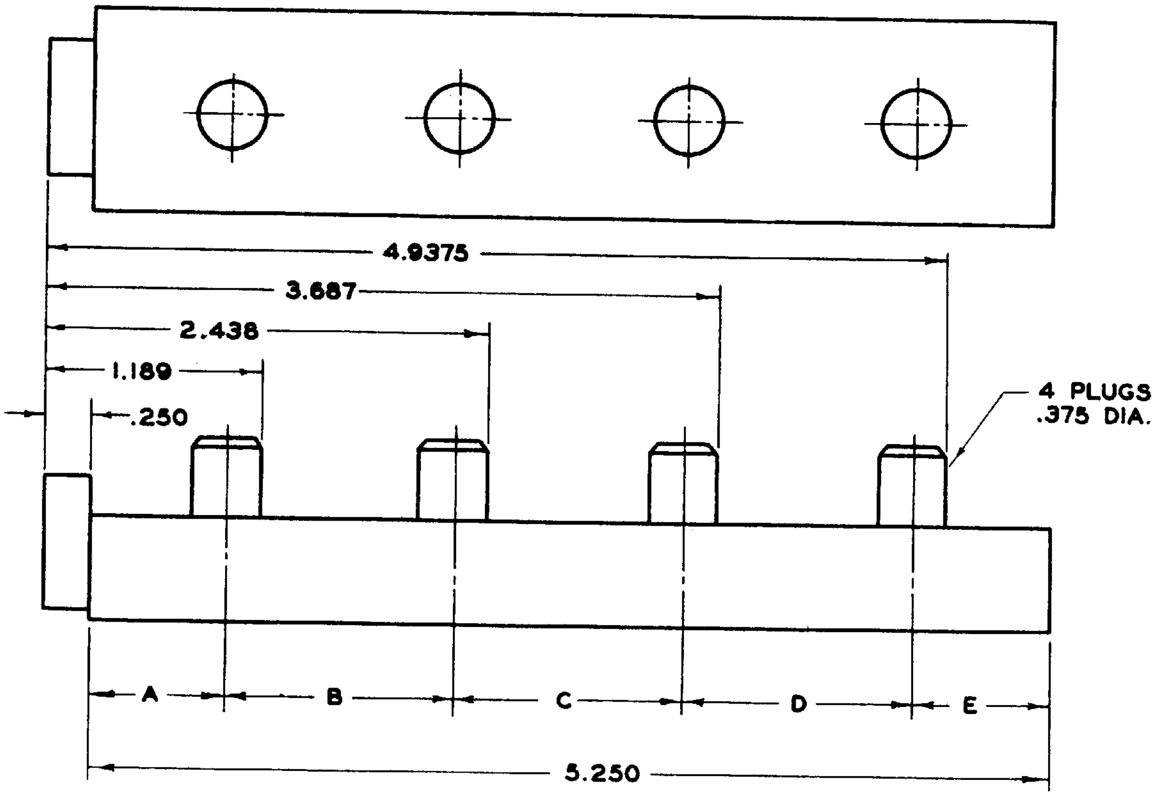
NOTE: Where possible, secure a micrometer, set at the indicated positions, and note the reading in each instance.

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

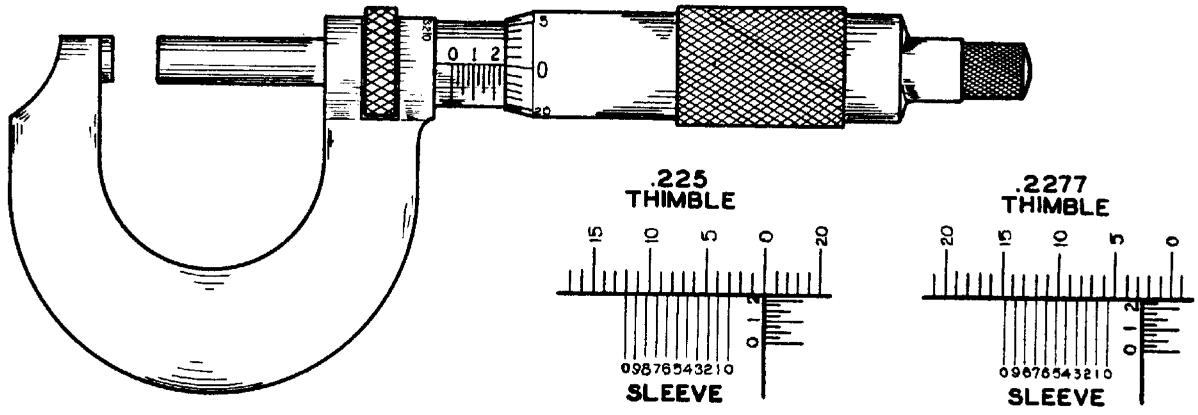
B. COMPUTED MEASURE

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



MEASUREMENT

READING A MICROMETER GRADUATED IN TEN-THOUSANDTHS OF AN INCH



(A) (B) (C)

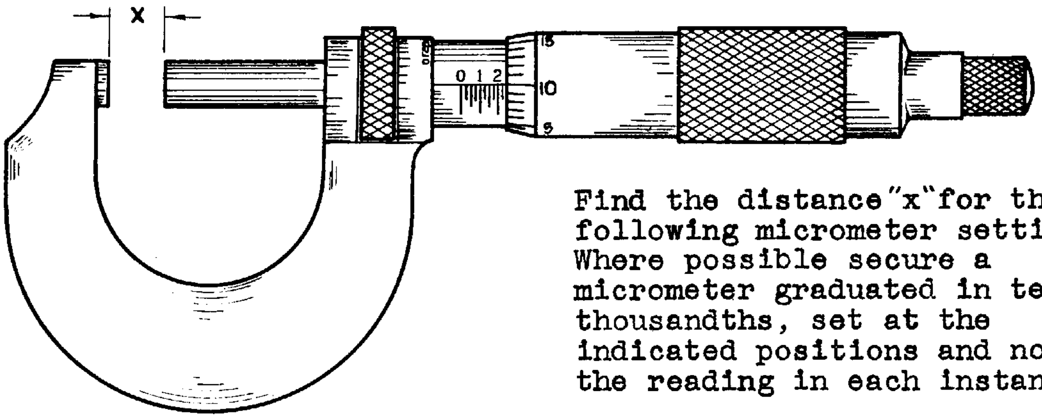
Readings in ten thousandths of an inch are obtained by the use of a vernier, so named from Pierre Vernier, who invented the device in 1631. As applied to a micrometer, this consists of ten divisions on the adjustable sleeve, which occupy the same space as nine divisions on the thimble. The difference 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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