BASIC
FITTING

FOR AIRCRAFTMEN, DEFENCE TRAINEES AND MACHINISTS

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PREFACE

At the present moment, when our very safety depends on the technical efficiency as well as the personal bravery of our fighting forces, it is not surprising to find a belated recognition of the value of technical training. Thousands of young men from all walks of life are endeavouring to fit themselves at short notice for the new duties they are being called upon by the nation to perform.

The object of this little book is to present concisely the elements of engineering fitting with particular reference to the requirements of aircraftmen and other defence trainees as well as machinists and motor mechanics.

Considerations of space have prevented elaboration of the subject, it being the desire of the publishers to provide a course of study for students of fitting at a reasonable price.

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November, 1940.

CHAPTER 1.

BENCH TOOLS

HAMMERS.

The hammer is perhaps the most commonly used tool.

There are a number of different kinds of hammers each with its own particular application. These are listed below.

(1) The Ball Pane Hammer.

This is also known as an engineer's hammer, and is the hammer most frequently used by them.

(2) The Straight Pane Hammer.

(3) The Cross Pane Hammer.

(4) The Wooden Mallet.

This is used where a steel hammer would damage the finish of the work.

(5) The Lead-headed Hammer.

This hammer is used where a heavy blow is desired without marking or damaging the work.

CHISELS.

Chisels are usually made of .7 to .9 per cent. carbon steel.

The various types of chisels in common use are shown in figure 1, and listed below.

(1) The Flat or Cold Chisel.

The flat or cold chisel is used for chipping a flat surface and for general use in the workshop. The cutting angle is not extremely critical, but should be in the

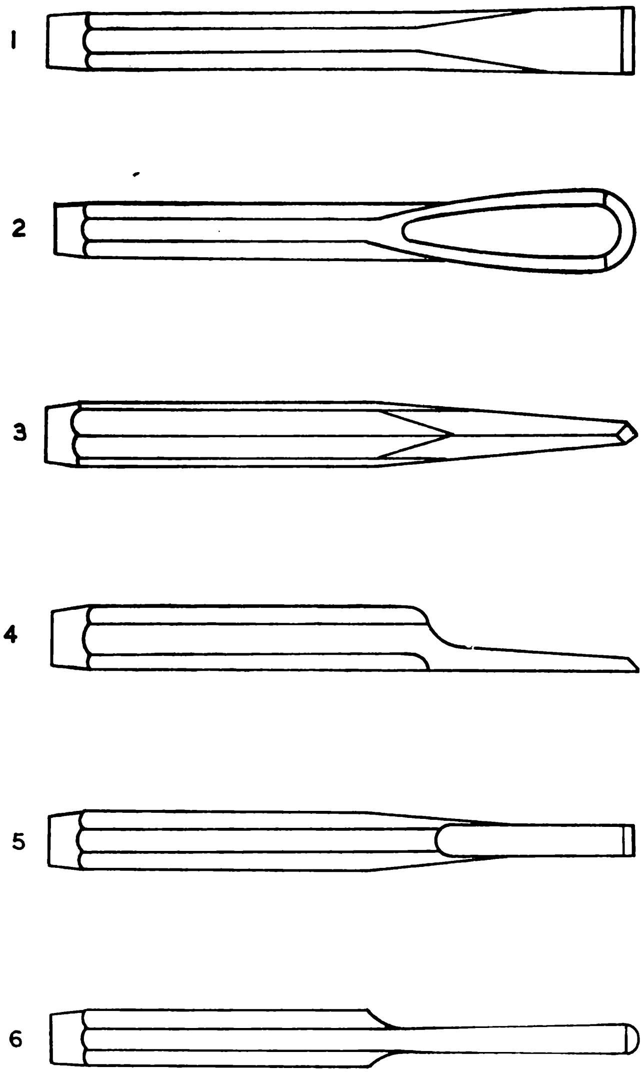


Figure 1.—Various Types of Chisels

region of 60-70 degrees for cast iron, 50-60 degrees for steel, while 40-50 degrees will be found most suitable for soft metals such as brass, copper, lead, etc.

(2) The Large Round Nose or Gouge Chisel.

This chisel is used for semicircular work such as fillets, etc.

(3) The Diamond Point Chisel.

The diamond point chisel is used for clearing out and cutting V-shaped grooves or corners.

(4) The Side Cutting Chisel.

This chisel, which is ground straight on the side next to the work, is useful for making a sharp corner at the bottom of a slot or keyway.

(5) The Cross Cut Chisel.

The cross cut chisel is used for cutting narrow slots, keyways, etc. The cutting edge is made wider than the back of the chisel to provide clearance so that as the keyway or slot becomes deeper the chisel will not become wedged in it.

(6) The Round Nose Chisel.

The round nose chisel is useful for drawing over holes to the desired position when commencing drilling, and also for cutting or enlarging holes in flat plates.

The Gutter Chisel.

This chisel finds its main use in cutting oilways in bearings.

CHIPPING.

The hammer should be held near the end of the handle and swung over the shoulder with a free forearm movement. Keep the chisel against the work, and at first keep your eye on the head of the chisel to prevent hitting your hand. Soon you will be able to watch the point which is the correct procedure. If the point of the chisel digs into or turns up out of the work lower or raise the head of the chisel accordingly.

THE USE OF LUBRICATION.

While cast iron and brass are best chipped dry, better results are obtained by using lubrication when wrought iron and mild steel are being worked.

FILES.

A file is a most valuable tool to the fitter. Files are classified by—

(1) Their cross-sectional shape.
(2) The character and fineness of the cut.
(3) Their length (not including the tang).

Figure 2 shows a number of different types of files.

Filing.

The file should be held with the thumb up and the palm of the hand grasping the end of the file.

The body should move in an even, regular manner when the file is pushed across the work. Relieve the pressure on the file on the backward stroke but do not lift it from the work. Do not allow oil or grease to clog the file, and clean it regularly with a wire brush file card. Chips can be prevented from clogging the teeth of the file by filling them with chalk.

HACKSAWS.

The hand hacksaw—the only one considered here—is held in much the same manner as a file. Like the file the cutting is done on the forward stroke, and the pressure is released on the return stroke. About one stroke per second should be maintained. For cutting mild steel and other soft metals a coarse blade should be used, as a fine blade quickly becomes clogged, causing it to jam and break. For general work on harder materials, such as tool steel, a blade of about eighteen teeth per inch is found advisable. For cutting angle iron and hard steels, brass and copper tubing, and iron piping, a fine pitch saw of about 32 teeth per inch is necessary.

Cutting Chart.

Length of Cut.	$\frac{1}{16}$ in. to $\frac{1}{4}$ in.	$\frac{5}{16}$ in. to $\frac{1}{2}$ in.	$\frac{9}{16}$ in. to $\frac{7}{8}$ in.	1 in. & over.
No. of teeth per in.	32	24	18	14

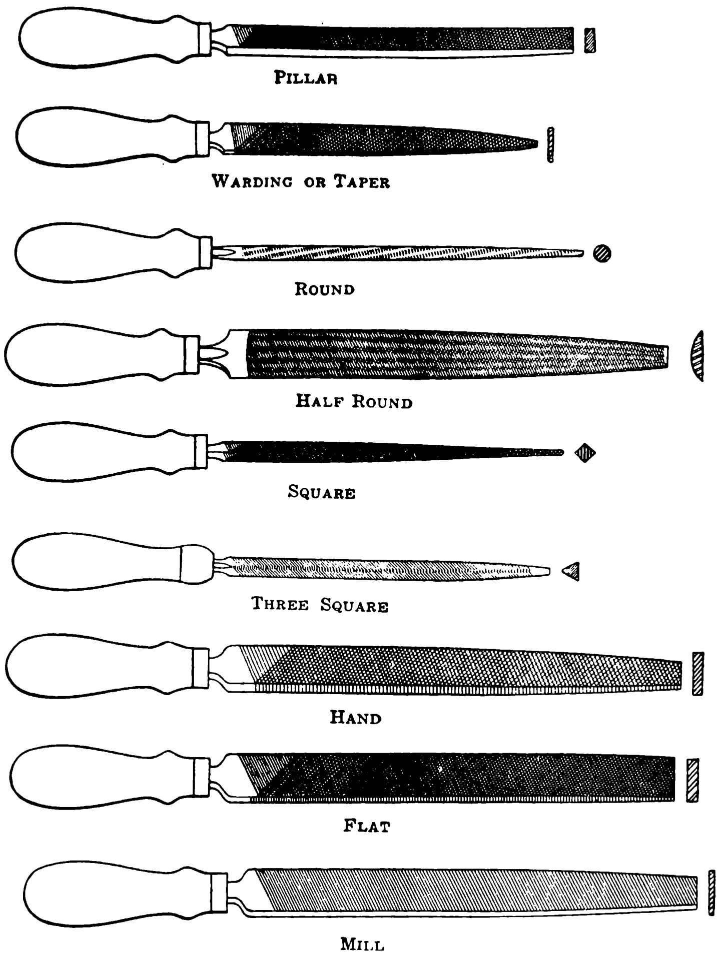


Figure 2.—Types of Files.

SCRAPERS AND SCRAPING.

Scraping is a hand operation employed to remove small amounts of metal from the high spots of surfaces in order to make them smooth and flat all over.

Types of Scrapers.

Figure 3 shows a number of scrapers which are commonly used.

A.—Flat Scrapers.

The flat scraper is most commonly used on flat work.

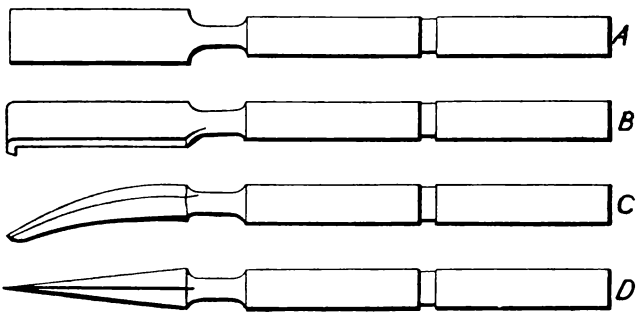


Figure 3.—Types of Scrapers.

B.—The Hook Scraper.

The hook scraper is also used for flat work, particularly where stippled effects are desired.

C.—The Half Round Scraper.

When it is desired to scrape bearings or other similar parts, the half round scraper is generally used.

D.—The Three Cornered Scraper.

This scraper finds its chief use in relieving the sharp edges of curved surfaces, holes, etc.

Sharpening the Scraper.

This is an operation that must be carefully performed if satisfactory results are to be obtained. The scraper should be first ground to shape and then smoothed off with an oilstone. The flat scraper must be ground flat, and the corners slightly relieved to prevent scoring. The scraper should be tested on a surface plate. Files that have been discarded can readily be made into scrapers.

Method of Scraping.

To obtain satisfactory results one must first know where the scraping is required. To find these high spots the surface is moved back and forth a few times over the face of a surface plate, which has previously been thoroughly cleaned and smeared with a thin coating of Prussian blue or Venetian red. The blue or red patches are the high spots that require scraping. This process is repeated until the surface is level all over, this being the case when rubbing on the surface plate produces a mark all over the surface being worked. The scraper should be firmly held at an angle of about 30 degrees. Scraping is a slow and tedious operation, but to attempt in any way to speed it up by taking longer, deeper or faster cuts will be disastrous. The stroke should be no longer than half an inch. The scraper must be kept very sharp by frequent use of the oilstone.

CHAPTER 2.

MEASURING INSTRUMENTS

THE RULE.

A machinist engaged on general work will find applications for a number of different types of rules. His general purpose rule should be of stainless steel graduated on one or both sides. It should be rigid and of a fixed length, although a flexible rule is a handy instrument. In addition, there are two other kinds of rules which find considerable use, the hook rule and the key seat rule or box square.

The Hook Rule.

The hook rule is useful for measuring concealed recesses, etc.

The Keyseat Rule or Box Square.

The keyseat rule, which is a bevelled edge rule, finds its greatest application in marking out keyways.

CALIPERS.

In making and transferring measurements in which extreme accuracy is not essential the caliper is commonly used. Calipers are of two main types, the spring

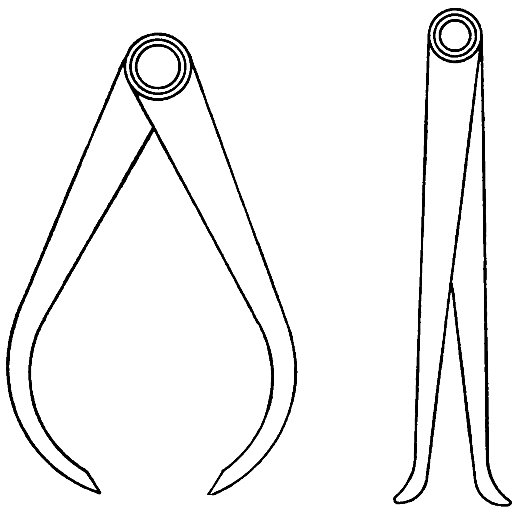


Figure 4.—External and Internal Calipers.

caliper, which is adjusted by means of a screw, and the firm joint calipers, which are set approximately and brought up to the required measurement by a gentle tapping process. These types are again divided into inside and outside calipers, depending on whether they are to measure internal or external work. Figure 4 shows an internal and an external caliper. Calipers are generally set by means of a steel rule. They should be held in such a manner that both points of the caliper legs are an equal distance from the edge of the rule.

PROTRACTORS.

All are familiar with the simple semicircular protractor which may have either a straight or a bevelled edge. In addition to the above type there is the combination set type of protractor and the universal bevel-edged protractor which may be with or without a vernier.

THE MICROMETER.

The micrometer is a precision instrument accurate to a thousandth part of an inch. Special micrometers

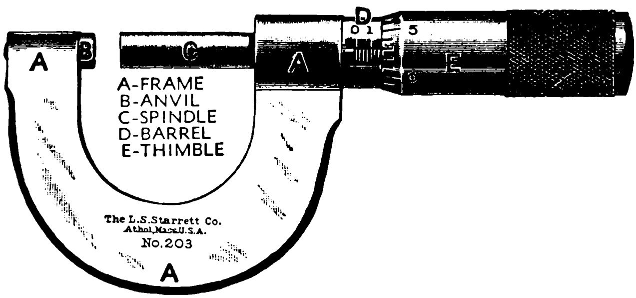


Figure 5.—The Micrometer.

are available which read to a ten-thousandth part of an inch. The "secret" of the micrometer is a very accurate screw moving in a fixed nut in such manner that a variable opening is obtained between the end of the screw or spindle and a fixed face or anvil. A micrometer is shown in Figure 5.

On English-reading micrometers the screw has a pitch of one-fortieth of an inch, which means that for each revolution the contact face on the end of the screw has moved either towards or away from the anvil one-fortieth of an inch, or .025 inches. Every four turns of the screw therefore means a movement of 4/40 or .1 inches. Every line on the barrel represents .025 in. and every fourth line .1 in., these latter being numbered 1, 2, 3, 4, 5, etc. The bevelled edge of the thimble is graduated into 25 equal parts, each representing one twenty-fifth of a complete revolution of the thimble, which is .025 in. (1/40). Thus each graduation of the thimble represents 1/25 of 1/40 or 1/1000 in. (.001). Every fifth graduation on the thimble is numbered from 5 to 25.

How to Read a Micrometer Graduated in Thousandths of an Inch.

Figure 6 represents the reading portion of a micrometer when set in two different positions. At A the highest visible figure on the barrel is 3 = .300 in. The number of lines visible between the number three and

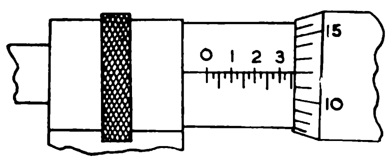


Figure 6A.—Reading Portion of Micrometer.

the edges of the thimble is 2 = 2/40 or .050 in. The line on the bevelled edge of the thimble closest to the long horizontal line on the barrel is 12 = (12/1000 in.) .012 in. Since the micrometer reading is the sum of the readings on the barrel and on the thimble, in this case it is:

.300 = 3/10
.050 = 2/40
.012 = 12/1000

.362 inches

At B the number of tenths showing is 4 (.400), the number of fortieths 1 (.025), and the number of thousandths 4 (.004 in.). The reading of the micrometer is therefore:

.400
.025
.004

.429 inches

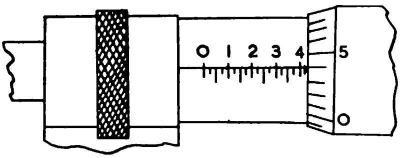


Figure 6B.—Reading Portion of Micrometer.

The Ten-thousandth Micrometer.

By the addition of a "vernier" on the barrel of the micrometer it is possible to read directly to a ten-

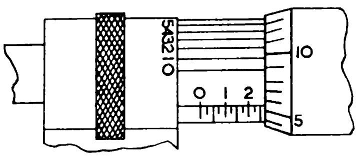


Figure 7.—The Ten-thousandths Micrometer.

thousandth part of an inch. This vernier, as Figure 7 shows, consists of a number of lines running parallel to the main .025 in. graduation line. Each one of these lines represents a ten-thousandth part of an inch. The reading of a "ten-thou." micrometer simply means the addition of the ten-thousandths to the thousandths found as previously explained.

The number of ten-thousandths to be added is found by noting which line on the vernier coincides with a line of the thimble. Should the zero line coincide then no ten-thousandths have to be added. Figure 7 shows the reading section of a "ten-thou." micrometer. This reading is (2/10)in. .2000in. plus (2/40)in. .050in. plus (5/1000)in. .005in. The line on the vernier marked 5 coincides with a line on the thimble meaning that (5/10000)in. .0005in. are to be added. The total of these figures (which is the micrometer reading) is:

.2000
.0500
.0050
.0005

.2555 inches

Lubrication for the Micrometer.

In the normal course of events a micrometer does not require to be lubricated frequently. When this is done, however, only the best quality of light grade oil should be used, and this in a small quantity.

Care of the Micrometer.

When handling a micrometer it should be remembered that it is a precision instrument and should be treated as such.

After long periods of continual use the measuring faces of a micrometer may become worn, which means that the reading will no longer be true. This failing, which is known as "zero error," must be allowed for if accurate results are to be obtained. This zero error can be found by screwing the micrometer closed and noting the number of thousandths showing on the thimble.

The Inside Micrometer.

The principle of this instrument is the same as the outside micrometer, and it is read in exactly the same manner. Internal micrometers to measure work below 2 in. diameter are rare because of the space taken up by the instrument itself. The internal micrometer is usually adjustable over a range of only ½ in., the rest being made up by means of extension rods.

Micrometer Depth Gauge.

The micrometer depth gauge is used when it is desired to accurately measure the depth of holes, grooves, cavities, etc. A range of from 0 to 3 in. is obtained by the use of additional rods in a similar manner to the extensions to an inside micrometer.

VERNIER CALIPER.

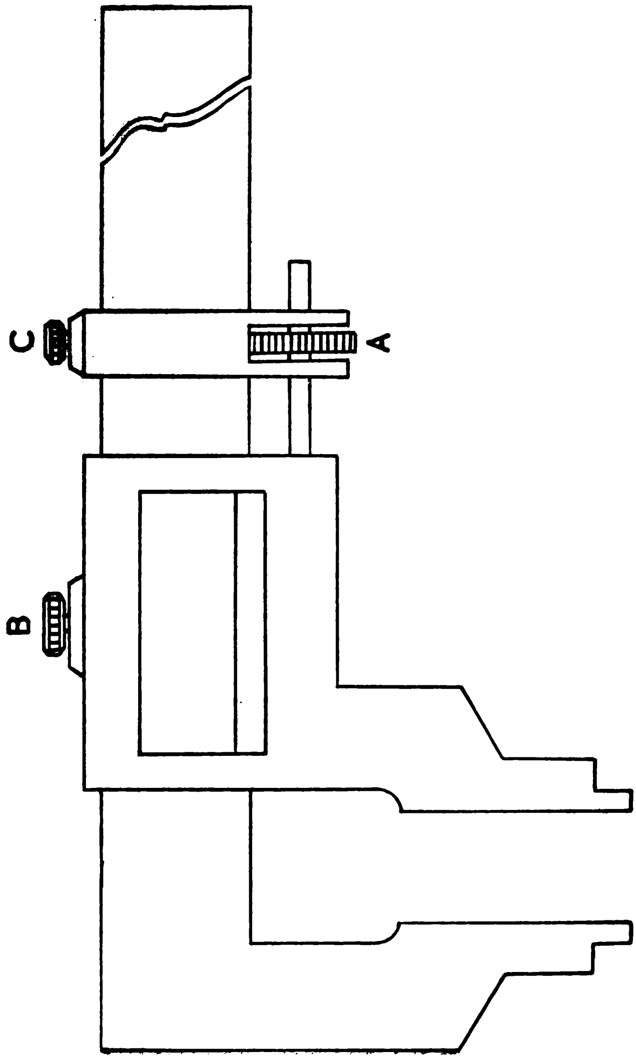
Vernier calipers are available which can read to thousandths of an inch. Others can only be read to a 1/128 part of an inch. These instruments are of three main types—outside, inside and a combination of both. Figure 8 shows an outside vernier caliper. The screws B and C are used to lock the jaws in a desired position when the one measurement is being continually used. A fine adjustment screw, which is very useful in setting the instrument, is provided at A.

How to Read the Vernier Calipers.

In the case where the vernier has 8 divisions and the scale 16 (divided into sixteenths), the smallest part of an inch which can be read is 1/128. Instruments which read in thousandths have the vernier divided into 25 parts, and the scale into 40.

Figure 9 shows the reading portion of a vernier which can be read to a thousandth of an inch.

At Figure 9 it can be seen that the main scale is divided into tenths and fortieths, while the vernier is graduated into 25 parts. The 0 on the vernier corresponds to the actual measurement. To take a reading the number of whole inches are noted (this makes the figure before the decimal point), then note the number of whole tenths (the small figure above and to the left of 0 on the vernier); this gives a decimal figure in first place, then note the number of whole fortieths after the tenth (this cannot be more than 3) and for one-fortieth add .025; for two-fortieths add .050; for three-fortieths add .075; then find a line of the vernier which exactly coincides with any line of the scale above it, and count the number of vernier divisions from 0 to this


C
A
B

line. The number so found gives additional thousandths of an inch.

The reading shown in Figure 9 is therefore 3.4 plus 2/40 = .050, plus 14 vernier divisions = .014, so the complete reading is 3.464 inches.

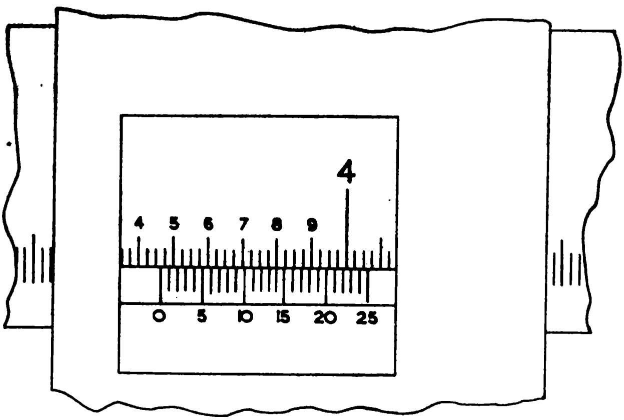


Figure 9.—Vernier Reading.

Inside Measuring Vernier Calipers.

In some vernier calipers one side of the scale is graduated to read measurements inside the jaws and the other scale measurements outside the jaws. Instruments which are graduated in both English and metric units cannot have this third scale, so both outside and inside measurements must be taken from the one scale. In this case allowance must be made for the thickness of the nibs.

Other Types of Vernier Gauges.

For accurate machine work the vernier calipers are supplemented with height gauges, depth gauges and gear tooth vernier calipers. The height gauge is particularly useful when used in conjunction with the surface plate, while the depth gauge is similar to the micrometer depth gauge explained elsewhere. Gear tooth vernier calipers are a combination of the outside vernier calipers and the depth gauge. This instrument is of great assistance to the machinist for measuring milling and gear cutters, gear teeth, etc.

DIAL TEST INDICATORS.

The dial test indicator finds extensive use in mass production, inspection of work for roundness, parallelism, concentricity, etc., and in conjunction with the surface plate. These instruments magnify small deviations of the order of 1/1000 in. to about 1/16 in. on a scale or dial. The face of the indicator bears a close resemblance to the face of an ordinary pocket watch. The divisions of deflection are usually in thousandths of an inch.

COMBINATION SQUARE AND PROTRACTOR.

This very useful instrument has many applications, one of the most important, however, being for the

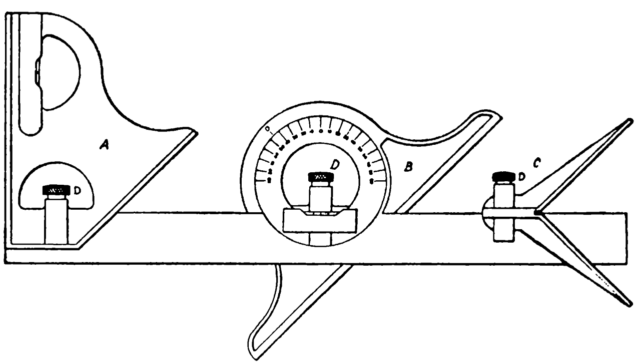


Figure 10.—The Combination Set.

marking out of work. As Figure 10 shows, it is a combination of a square head A, centre head C, and protractor B, mounted on a steel scale and held in position by nuts D.

All of these attachments may be used in combination or separately. The protractor has a spirit level fitted to it, thus making it possible to measure the angle of fixed slopes. The protractor scale may be graduated in degrees or a vernier attached, thereby making it possible to read in minutes (1/60 of a degree).

CHAPTER 3.

MARKING OUT

Marking out is the process of making lines on parts or surfaces to show the exact position and nature of the operations to be performed on those parts.

To assist in making the lines on the work show up more clearly the surface is often coated with chalk, whiting, or a solution of copper sulphate (bluestone and water) for machined surfaces.

If only one machining operation is to be performed, in most cases marking out is not necessary, but for two or more operations marking out is usually required.

MARKING OUT TOOLS.

The Marking Out Table.

The marking out table is a flat surface providing a base from which the other marking out tools can be used. These tables are usually made of cast iron machined flat on the top surface.

Scribers.

Scribers are used for making lines on work which has to be machined, etc. They are essentially a steel wire, hardened, tempered and ground to a sharp point.

Surface Gauge.

Figure 11 shows a common type of surface gauge. In such a gauge a fine screw motion is provided for obtaining the final adjustment of the scriber. The pillar or spindle carrying the scriber can be set to any position from vertical to horizontal. On the underside of the base is a V-shaped groove which enables the gauge to be used on circular work. A surface gauge may be

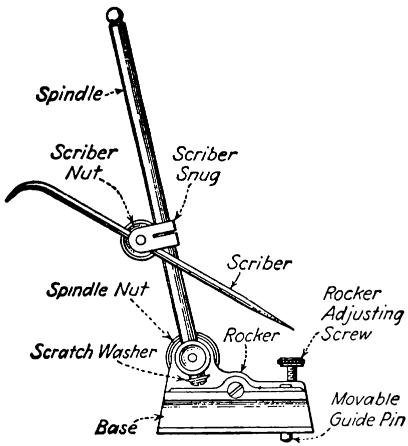


Figure 11.—Surface Gauge.

used for comparing the various heights on a piece of work or making a line around the work. The bent end of the scriber is used for ascertaining whether a surface is level by trying if the point of the scriber touches the work all over. It is extremely useful in this respect for setting up work in a lathe, planer or drilling machine.

Centre Punch.

The centre punch is used to make permanent marks, such as witness marks, on work that has been marked out, and also for spotting holes that have to be drilled.

Dividers.

Dividers are used for marking out curves and circles and also for dividing, spacing and transferring measurements.

Straight Edges.

Straight edges are used for scribing straight lines, testing for flatness, etc. For general purposes the edge of a steel rule will serve as a straight edge, although special knife-edge straight edges are obtainable.

Squares.

Squares are used for testing to ensure that one face is at right angles with another.

Testing a Square.

Take a piece of metal planed on one edge. Apply the square to the edge and scribe a line along the edge of the blade. Then reverse the square, and if the blade now coincides with the scribed line the square is true.

Protractors.

These instruments are dealt with in the section on measuring instruments.

Angle Plates.

Angle plates are used for clamping work to when marking off or machining.

Parallel Strips.

As their name implies, these are mild steel strips whose sides have been machined and ground parallel. They are used for packing up work for marking out or machining.

"V" Blocks.

"V" blocks are used for supporting round work for marking out or machining.

Clamps.

Clamps serve the purpose of fixing work to a marking out table or machine bed. There are a number of different types, among them being the plate clamp, the toolmaker's clamp, the C clamp, etc.

Plumb Bobs.

A plumb bob is simply a weight on the end of a string or line. Plumb bobs are used for obtaining a vertical line or a point vertically below another point. They find a useful application in lining up machinery or shafting.

Levels.

Levels are used for obtaining a horizontal surface. They consist essentially of a glass tube inserted in a cast iron base. This tube, in which a small amount of air is left, is filled with alcohol or ether. A line is marked on the glass to split the air bubble when the instrument is horizontal.

Tilting Plates.

A tilting plate is similar to an angle plate except that it can be set at any angle.

Trammels.

Trammels are a form of dividers used for large lengths.

Hermaphrodite Calipers or Jennies.

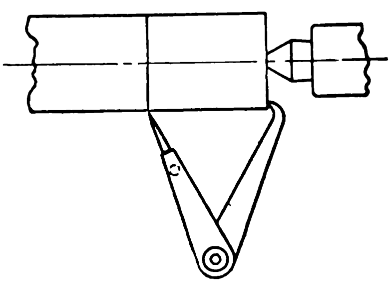


Figure 12.—Using Jennies to Scribe the Position of a Shoulder on a Piece of Round Work.

These instruments are used for scribing lines parallel to an edge, setting out distances from an edge or finding the centre of round work. Figure 12 shows a pair of jennies being used as a scriber.

CHAPTER 4.

ALLOWANCE, LIMIT, AND TOLERANCE.

Allowance.

Allowance is the difference in size necessary between the parts in question in order to obtain the class of fit desired. For example, it is necessary to make a two-inch diameter shaft approximately .0035 in. smaller than the hole into which it is to fit if a running fit is to be obtained. The allowance made is, therefore, .0035 in.

Limit.

It is impossible to make a part to an exact size, and it is seldom that this is required. There are certain bounds within which a part will function almost as efficiently whether it be the exact size specified or slightly larger or smaller.

For example, a 2 in. diameter shaft may perform its duty just as efficiently if it were either 1/32 below or above 2 in.

A greater deviation than this from 2 in. may result in faulty operation. Thus, when making or selecting the shaft, its size may range from 1-31/32 to 2-1/32 in. These last two figures are known as the limits placed upon the size of the shaft.

Tolerance.

Tolerance is defined as the amount of variation permitted on dimensions, and is the difference between the maximum and minimum limits. The tolerance may be all above or below the specified size, or it may be part of each. To assist in explaining this let us take some examples.

Suppose we have a three-inch shaft on which an upper limit of .002 (written +.002) and a lower limit of .003 (written —.003) is called for. The tolerance totals .005 in., but .003 in. is minus and .002 in. plus. The dimension is written $3.000 {}^{+.002}_{-.003}$ inches.

As a second example, let us take the case in which the shaft is one inch diameter and has a limit placed upon it of plus .004 and minus .000. The tolerance is therefore .004 ins., and the dimension is written

$$1.000 {}^{+.004}_{-.000} \text{ inches.}$$

CHAPTER 5.

CLASSES OF FITS.

Four classes of fits are encountered in normal practice—running fits, driving fits, forced fits, and shrink fits.

Running Fits.

Running fits are used wherever it is necessary for parts to rotate in relation to each other. The parts concerned must be perfect cylinders and of such a difference of diameter as to allow the shaft to run freely when oil has been admitted.

Machining.

It is essential for smooth running that the parts be smooth and round. The hole should be made first and the shaft made to fit.

Driving Fits.

Driving fits are used when it is desired that the parts be fixed to each other. The shaft is made slightly larger than the hole. The parts are driven together with a hammer or sledge. The surfaces should be smooth, true and well oiled.

Shrink Fits.

Shrink fits are used where the use of forced fits is limited by the pressures available for pressing as in the case of rail wheels. The boss surrounding the hole is heated, thus causing it to expand, when the cold shaft is put in and the boss cooled.

The allowances for shrink fits are a little greater than those made for forced fits. It is not necessary, however, that the mating surfaces be extremely smooth as in the case of forced fits.

Forced Fits.

This class of fit is used for assembling parts which must not move in relation to each other. With a forced fit the cylindrical part is forced into a slightly smaller diameter hole by means of a press, either mechanical or hydraulic. The parts should be thoroughly lubricated. For this purpose a mixture of whitelead and lard oil is recommended. When placing the parts under the press they should be kept square, and once moving they should not be stopped, otherwise seizing is likely. The allowances to be made for fits depend on the diameter and length of the hole and the conditions of the surfaces.

Pressure Required for Forced Fits.

The pressure required is governed by the allowance left for fitting and the area of the surfaces.

The approximate pressure in tons can be found by use of the following formula in conjunction with Table No. 1:

$$P = \frac{A \times a \times F}{2}$$

Where

A = area of surface in contact.
a = total allowance in inches.
P = ultimate pressure required in tons.
F = pressure factor based upon the assumption that the diameter of the hub is twice the diameter of the bore, and that the shaft is of machine steel, and the hub of cast iron. This pressure factor is given in Table No. 1.

TABLE NO. 1.

Diam., Ins.	Pressure Factor.	Diam., Ins.	Pressure Factor.
1	500	6¼	72
1¼	395	6½	69
1½	325	6¾	66
1¾	276	7	64
2	240	7¼	61
2¼	212	7½	59
2½	189	7¾	57
2¾	171	8	55
3	156	8½	52
3¼	143	9	48.7
3½	132	10	43.5
3¾	123	11	39.3
4	115	12	35.9
4¼	108	13	33
4½	101	14	30.5
4¾	96	15	28.3
5	91	15½	27.4
5¼	86	16	26.5
5½	82	16½	25.6
5¾	78	17	24.8
6	75	18	23.4

The Newall Standard Fits.

Table No. 2 shows the allowances for different classes of fits as recommended in the Newall system. This system is founded on the "hole basis," in which all holes are made by ordinary standard tools. The selection between classes A and B is a matter for the user's decision. Some prefer to use class A as working limits and class B as inspection limits.

Class F produce shafts that are either a force or shrink fit.

Class D shafts are a driving fit.

Class P shafts are a push fit.

Running fits are divided into three grades—X, Y and Z.

Class X is suitable for engine and other work where easy fits are required.

Class Y is used for high speeds and good average machine work.

Class Z is suitable for fine tool work.

TABLE NO. 2.

The Newall Allowances for Different Classes of Fits.

Class.	Nominal Diameters.	Up to ½in.	9/16-1in.	1 1/16-2in.	2 1/16-3in.	3 1/16-4in.	4 1/16-5in.
	Tolerances in Standard Holes.						
A	High Limit	+0.0002	+0.0005	+0.0007	+0.0010	+0.0010	+0.0010
	Low Limit	—0.0002	—0.0002	—0.0002	—0.0005	—0.0005	—0.0005
	Tolerance	0.0004	0.0007	0.0009	0.0015	0.0015	0.0015
B	High Limit	+0.0005	+0.0007	+0.0010	+0.0012	+0.0015	+0.0017
	Low Limit	—0.0005	—0.0005	—0.0005	—0.0007	—0.0007	—0.0007
	Tolerance	0.0010	0.0012	0.0015	0.0019	0.0022	0.0024
	Allowances for Forced Fits.						
F	High Limit	+0.0010	+0.0020	+0.0040	+0.0060	+0.0080	+0.0100
	Low Limit	+0.0005	+0.0015	+0.0030	+0.0045	+0.0060	+0.0080
	Tolerance	0.0005	0.0005	0.0010	0.0015	0.0020	0.0020
	Allowances for Driving Fits.						
D	High Limit	+0.0005	+0.0010	+0.0015	+0.0025	+0.0030	+0.0035
	Low Limit	+0.0002	+0.0007	+0.0010	+0.0015	+0.0020	+0.0025
	Tolerance	0.0003	0.0003	0.0005	0.0010	0.0010	0.0010
	Allowances for Push Fits.						
P	High Limit	—0.0002	—0.0002	—0.0002	—0.0005	—0.0005	—0.0005
	Low Limit	—0.0007	—0.0007	—0.0007	—0.0010	—0.0010	—0.0010
	Tolerance	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Allowances for Running Fits.						
X	High Limit	—0.0010	—0.0012	—0.0017	—0.0020	—0.0025	—0.0030
	Low Limit	—0.0020	—0.0027	—0.0035	—0.0042	—0.0050	—0.0057
	Tolerance	0.0010	0.0015	0.0018	0.0022	0.0025	0.0027
Y	High Limit	—0.0007	—0.0010	—0.0012	—0.0015	—0.0020	—0.0022
	Low Limit	—0.0012	—0.0020	—0.0025	—0.0030	—0.0035	—0.0040
	Tolerance	0.0005	0.0010	—0.0013	0.0015	0.0015	0.0018
Z	High Limit	—0.0005	—0.0007	—0.0007	—0.0010	—0.0010	—0.0012
	Low Limit	—0.0007	—0.0012	—0.0015	—0.0020	—0.0022	—0.0025
	Tolerance	0.0002	0.0005	0.0008	0.0010	0.0012	0.0013

TABLE No. 2 (Continued).
Formulas for Determining Allowances.

Class.	High Limit.	Low Limit.	Class.	High Limit.	Low Limit.
A	$+\sqrt{D}\times 0.0006$	$-\sqrt{D}\times 0.0003$	X	$-\sqrt{D}\times 0.00125$	$-\sqrt{D}\times 0.0025$
B	$+\sqrt{D}\times 0.0008$	$-\sqrt{D}\times 0.0004$	Y	$-\sqrt{D}\times 0.001$	$-\sqrt{D}\times 0.0018$
P	$+\sqrt{D}\times 0.0002$	$-\sqrt{D}\times 0.0006$	Z	$-\sqrt{D}\times 0.0005$	$-\sqrt{D}\times 0.001$

CHAPTER 6.

DRILLS AND DRILLING

The following types of drilling machines are met with in industry:

1. The sensitive drill.
2. The single spindle drill press.
3. The radial drill.
4. The three-spindle drill.
5. The multi-spindle drill.
6. The electric and pneumatic drill.
7. The ratchet drill.

1. The Sensitive Drill.

This machine is used for very light work where the feed is by hand and the drive by belts. It is perhaps the most commonly used type of drill.

2. The Single-spindle Drill Press.

The single-spindle drill press is used for work of a heavier nature than that performed in the sensitive drill. Figure 13 shows a common form of this drill. At the lower end of the vertical spindle is a tapered hole for receiving the drill shanks or a chuck when required.

The driving torque for this spindle is supplied at its upper end by means of bevel gears from the horizontal shaft which carries the cone pulleys, and which are connected to the main driving shaft through a system of belts. The table, which may be rotated, is moved up and down the column by means of a rack. The whole head of the machine may be moved up and down the column. This is known as a sliding head.

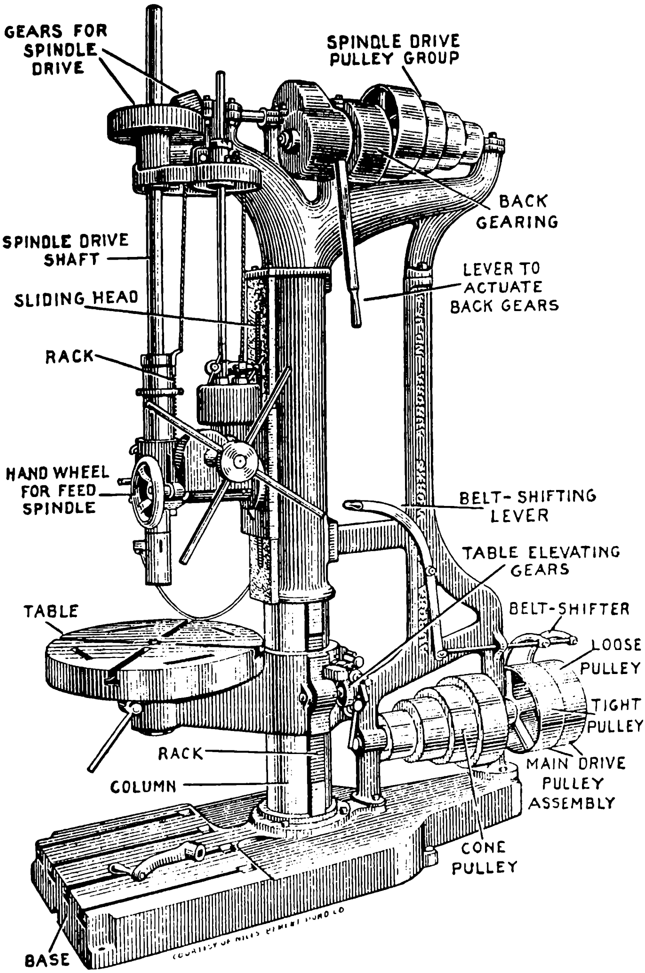


Figure 13.—Single Spindle Drill Press.

3. The Universal Radial Drill.

The universal radial drill is used for general jobbing work over a wider range than the drill press. Figure 14 shows a universal radial drill. It consists of a radial arm which can move through almost 360 degrees, and a drill spindle which can be moved along the arm. These two movements make it possible to leave heavy work fixed on the base and move the drill to the desired position. By means of gear boxes a number of different speeds can be quickly obtained.

4. The Three-spindle Drill.

This is a mass production machine having three spindles, each of which can hold a different size drill, reamer, etc.

5. The Multi-spindle Drill.

The multi-spindle drill is also a mass production machine finding considerable favour in the automobile industry. It has a number of spindles, each capable of holding a tool.

6. The Electric and Pneumatic Drills.

These are small portable drills used on work that cannot be placed under a drill press or moved to where one is available.

7. The Ratchet Drill.

This hand-operated drill is used for similar work to the electric and pneumatic drills. A ratchet brace is shown in Figure 15. The drill is held in the socket of the brace and is

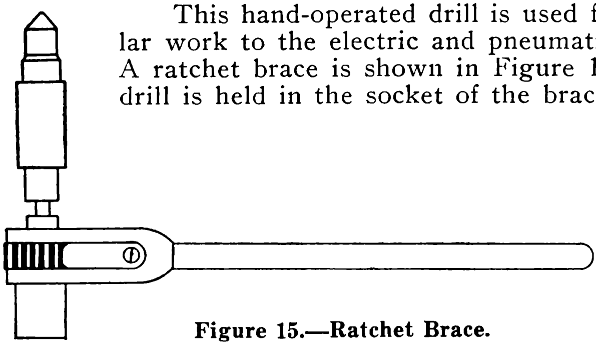


Figure 15.—Ratchet Brace.

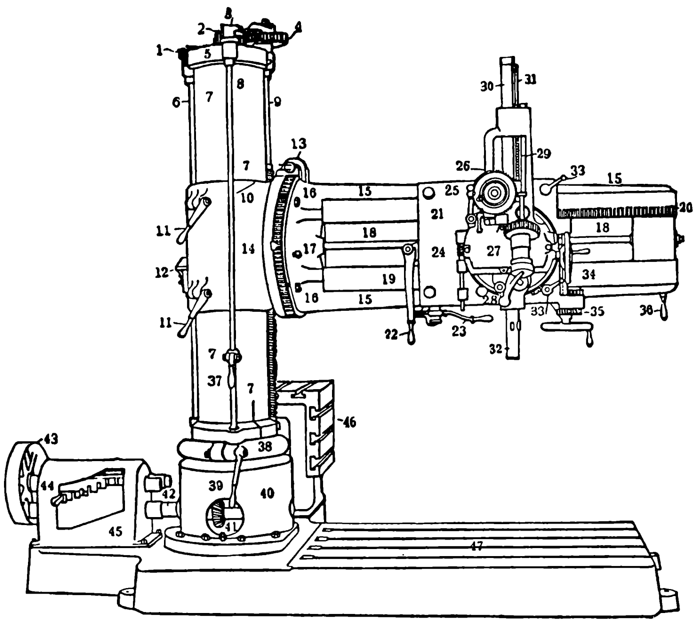


Figure 14.—The Universal Radial Drill.

1. Vertical driving shaft gear.
2. Centre driving shaft gear.
3. Elevating tumble plate segment.
4. Elevating screw gear.
5. Column cap.
6. Vertical driving shaft.
7. Column sleeve.
8. Elevating lever shaft.
9. Elevating screw.
10. Arm girdle.
11. Arm clamping lever.
12. Spindle driving mitre gear guard.
13. Arm rotating worm.
14. Arm indicating pointer.
15. Full universal arm.
16. Arm clamping nuts.
17. Arm locating pin.
18. Arm driving shaft.
19. Arm ways.
20. Spindle head traversing rack.
21. Saddle.
22. Spindle reversing lever.
23. Back gear lever.
24. Spindle head swivelling worm.
25. Spindle feed trip lever.
26. Depth gauge dial.
27. Universal spindle head.
28. Spindle quick return lever.
29. Spindle feed rack worm shaft.
30. Spindle.
31. Spindle feed rack.
32. Spindle sleeve.
33. Saddle clamping lever.
34. Spindle feed handwheel.
35. Spindle head traversing gear.
36. Arm swinging handle.
37. Arm elevating lever.
38. Clamping ring.
39. Clamping ring handle.
40. Column.
41. Main driving mitre gears.
42. Driving shaft coupling.
43. Driving pulley.
44. Speed change lever.
45. Speed change case.
46. Box table.
47. Base.

caused to revolve by moving the ratchet lever to and fro. Since each stroke of the lever only moves the drill a part of a revolution the operation of drilling a hole by this method is necessarily a slow one.

The ratchet is usually used in conjunction with a drilling post. This enables the drill to be fed downwards by means of a screw attachment. When using the ratchet drill, and indeed all portable drills, care must be taken that the drill is fed vertically and not allowed to veer over to some angle.

Drills.

There are three common types of drills—the flat drill, the straight flute drill, and the twist drill. This latter type may be further divided into straight and taper-shank drills.

Twist Drills.

The twist drill is the most common form of drill in use to-day. Figure 16 shows a twist drill and the names of the various sections. The flute or spirals assist in the cutting action, and also provide an outlet for the chips or cuttings. The lands bear against the sides of the hole and help to keep the drill square and straight.

The Flat Drill.

The flat drill was one of the earliest forms of drills, and is little used to-day because it is necessary to stop frequently to clean out the hole.

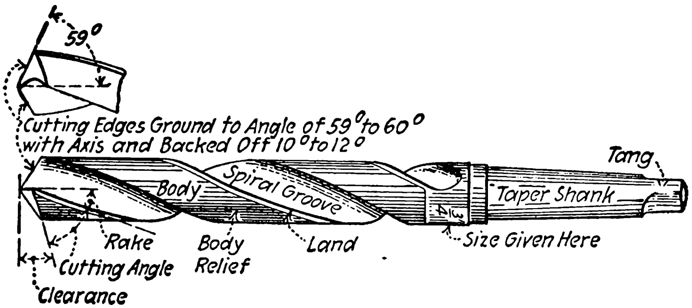


Figure 16.—Taper Shank Twist Drill.

The Straight Flute Drill.

The straight flute drill is sometimes used for the drilling of metals where "rake" is not required as in the case with brass.

Tapping Size Drill.

The size of drill to be used for a certain size tap is shown in the section on screw threads, so it will not be dealt with again here. There is, however, a simple rule by which you can get tapping size drills which will be found reasonably accurate.

The rule is to subtract the pitch of one thread from the tap size. For example, the size of drill for a $\frac{3}{8}$ in. tap (16T. P. I. or a pitch of 1/16) = $\frac{3}{8}$ —1/16 = 5/16 in. drill.

Sharpening Twist Drills.

To obtain good results, together with a minimum of drill breakages, drills have to receive special attention when sharpening. For drills larger than $\frac{3}{8}$ in. dia. it is recommended that they be ground in a machine. When sharpening carbon drills plenty of coolant should be used

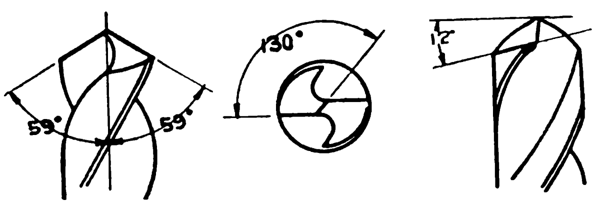


Figure 17.—Important Drill Point Angles.

to prevent overheating and drawing the temper of the drill. This is not, however, essential for high-speed steel drills. Figure 17 shows the three important angles to be watched when grinding a drill. Drill grinding gauges are available to assist in grinding drills to the correct size, etc.

The Cutting Angle.

The cutting angle should be 59 degrees, and both lips must have the same length.

Angle of Cutting Edge.

The angle of the cutting edge should be 130 degrees with the centre line across the point of the drill.

Clearance Angle.

The clearance angle which will be found best for general work is 12 degrees, which may be increased to 15 degrees for soft metals such as copper and brass.

Web Thinning.

When grinding a large drill or one which has worn down to a thicker portion of the web it is often found advisable to thin the web at the cutting end.

Lubricants or Cutting Compounds.

Table 3 lists various cutting compounds for drilling. These are recommended in the order named, and are for either carbon or high-speed drills.

TABLE NO. 3.

Material.	Lubricant or Cutting Compound.
Cast iron	Dry or with a jet of compressed air.
Hard Steel	Kerosene, turpentine, soluble oil.
Soft steel and wrought iron	Lard oil, soluble oil.
Malleable iron	Soda water.
Aluminium and other soft alloys	Soda water, kerosene, turpentine.
Brass	Paraffin oil, dry.

Speeds and Feeds for Drilling.

Table 4 will act as a guide for the selection of the correct speed at which drills should be run. It will be noted that high-speed steel drills can be run at twice the speed of carbon drills. The feeds, however, remain the same. The feeds given in Table No. 5 are common practice.

TABLE NO. 4.

Material.	Speed in feet per min. High-speed Steel Drills.	Carbon Drills.
Mild machinery steel	80-110	40-50
Tool steel	50-60	20-30
Steel forgings	50-60	20-30
Stainless steel	30-40	15-20
Alloy steel	50-70	20-35
Malleable iron	80-90	35-45
Hard chilled cast iron	70-100	30-50
Soft cast iron	100-150	50-70
Brass and bronze	200-300	100-150
Monel metal	40-50	20-30
Aluminium and its alloys	200-300	100-150
Magnesium and its alloys	250-350	100-200
Wood	300-400	100-200
Bakelite	100-150	50-75
Slate, marble and stone	15-25	5-10

TABLE NO. 5.

Size of Drill (Inches).	Feed (Inches per Revolution).
Under $\frac{1}{8}$ in.	.001 to .002
$\frac{1}{8}$ in. to $\frac{1}{4}$ in.	.002 to .004
$\frac{1}{4}$ in. to $\frac{1}{2}$ in.	.004 to .007
$\frac{1}{2}$ in. to 1 in.	.007 to .015
Over 1 in.	.015 to 0.25

Drill Shanks.

Drill shanks are of two types, straight and tapered. Straight-shank drills are held in a chuck, which fits into the machine spindle by means of a tapered shank, and is driven by a tang on the end of this shank. The tang fits into a slot in the machine spindle. Tapered shank drills fit directly into the machine spindle. The smaller diameter drills have to be fitted into a tapered shank which, in turn, fits into the machine spindle. Table 6 gives the morse taper sockets to be used for various sizes of drills.

TABLE NO. 6.

Socket No.	Size of Drill (Inches). From.	To.
1	$\frac{3}{16}$	$\frac{19}{32}$
2	$\frac{5}{8}$	$1\frac{9}{32}$
3	$1\frac{5}{16}$	$1\frac{9}{16}$
4	$1\frac{5}{8}$	2
5	$2\frac{1}{16}$	3

Drill Sizes.

Drill sizes are designated in English and metric units (64ths and mm.), wire number sizes, and letter sizes. The range covered by each system of sizing is shown in the accompanying Table No. 7. Twist drill sizes are given in Table No. 8.

TABLE NO. 7.

System.	Range Covered From.	To.
English	$\frac{1}{64}$ in.	3 in.
Metric	1 mm.	50 mm.
Wire number sizes	No. 80 (0.0135 ins.)	No. 1 (0.228 ins.)
Letter sizes	A (0.234 ins.)	Z (0.413 ins.)

Twist Drill Sizes.

TABLE NO. 8.

MORSE NUMBER DRILL SIZES.

No.	Inches.	No.	Inches.	No.	Inches.
1	0.228	21	0.159	41	0.096
2	0.221	22	0.157	42	0.093
3	0.213	23	0.154	43	0.089
4	0.209	24	0.152	44	0.086
5	0.205	25	0.149	45	0.082
6	0.204	26	0.147	46	0.081
7	0.201	27	0.144	47	0.078
8	0.199	28	0.140	48	0.076
9	0.196	29	0.136	49	0.073
10	0.193	30	0.128	50	0.070
11	0.191	31	0.120	51	0.067
12	0.189	32	0.116	52	0.063
13	0.185	33	0.113	53	0.059
14	0.182	34	0.111	54	0.055
15	0.180	35	0.110	55	0.052
16	0.177	36	0.106	56	0.046
17	0.173	37	0.104	57	0.043
18	0.169	38	0.101	58	0.042
19	0.166	39	0.099	59	0.041
20	0.161	40	0.098	60	0.040

LETTER DRILL SIZES.

Letter.	Inches.	Letter.	Inches.
A	0.234	N	0.302
B	0.238	O	0.316
C	0.242	P	0.323
D	0.246	Q	0.332
E	0.25	R	0.339
F	0.257	S	0.348
G	0.261	T	0.358
H	0.266	U	0.368
I	0.272	V	0.377
J	0.277	W	0.386
K	0.281	X	0.397
L	0.290	Y	0.404
M	0.295	Z	0.413

Calculating Speeds.

Table No. 9 will be of assistance in the calculation of speeds and r.p.m.

TABLE NO. 9.

To Find.	Having.	Rule.
Surface speed of drill in feet per min.	Dia. (ins.) of drill and r.p.m. of machine spindle	Dia. of drill × 3-1/7 × r.p.m. of machine spindle ÷ 12
R.P.M. of machine spindle	Dia. (ins.) and surface speed (feet per min.) of drill	$\frac{\text{Surface speed} \times 12}{\text{Dia. of drill} \times 3\text{-}1/7}$
Dia. of drill	Surface speed (feet per min.) and r.p.m. of machine spindle	$\frac{\text{Surface speed} \times 12}{\text{R.P.M.} \times 3\text{-}1/7}$

CHAPTER 7.

REAMERS.

Reamers are used for enlarging drilled holes to a definite diameter and finish, such as is necessary when fitting new bushings. The reamer consists of three parts —the body, the shank and the blades. The blades are hardened to such an extent that they are very brittle and are liable to chip unless handled with care. It is important that a reamer should never be turned backwards in a hole, otherwise the blades will become burred and cause a rough finish. Ordinarily 1/64 to 1/32 ins. of metal is left in the hole for the reaming operation, but if greater accuracy is required less material is left for removal by the reamer.

Allowance for Reaming.

Table 10 shows the allowances recommended for hand reaming.

TABLE NO. 10.

Dia. of Reamer (Ins.).	Amount of Material Left (Ins.).
Up to 3/8	.005
From 25/64 to 1 1/4	1/64
Over 1 1/4	1/32

Lubricant for Reaming.

Lubricant is advisable to carry away both the chips and the heat.

Lard oil is recommended for this purpose.

Hand Reamers.

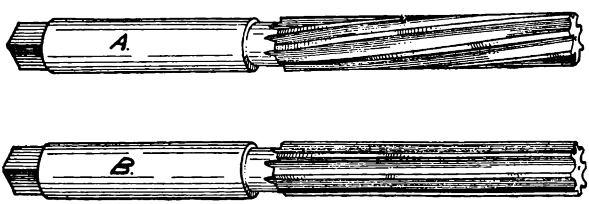


Figure 18.—Hand Reamers.
A.—With Spiral Flutes. B.—With Parallel Flutes.

When using a hand reamer it should be borne in mind that it is a hand tool, and as such must never be operated by power.

Figure 18 shows spiral and parallel fluted reamers for enlarging or finishing holes. It will be noticed that the end of the shank is machined square to take a wrench.

Expansion Hand Reamer.

The body of this reamer is slitted to permit a small expansion to be obtained.

Adjustable Reamer.

This is probably the most useful type of reamer, because it can be adjusted within a considerable range both over and under the nominal size. They are made either for hand use or for operation in a machine.

The Rose Reamer.

The rose reamer is often used before the common hand reamer. In the rose reamer the teeth are bevelled on the end, while the lands are almost as wide as the grooves. This reamer is usually made .003 in. to .005 in. undersize, so that an ordinary reamer can be put through after it.

Taper Reamers.

Reamers are obtainable for all standard tapers.

CHAPTER 8.

SCREW THREADS

Means of Producing External Threads by Hand.

Non-adjustable.

(a) Screw plates.
(b) Die nuts.
(c) Solid dies.

Adjustable.

(d) Adjustable dies.
(e) Stock with two or more sliding dies.
(f) Chasers.

Screw Plates.

These are plates carrying a number of different sizes of dies. They are only suitable for very small work.

Nut Die.

These dies resemble an ordinary nut, and are turned by means of a key or spanner. They are therefore suitable for use in confined spaces for such work as restoring damaged threads on bolts.

Solid Dies.

Solid dies are of two types, the actual solid die and the adjustable solid die. The failing of the solid die is that it has no adjustment for wear. They are used as a standard to check the setting of adjustable dies and also for general work.

Adjustable Dies.

The adjustable dies are similar to the solid dies except that they are split in halves to enable adjustment to be made for the size of thread or to compensate for wear. The setting is obtained by means of an adjustment of the stock.

Stock with Two or More Sliding Dies.

This arrangement is used mainly for small pipe thread work. The stock may hold from one to four dies.

Chasers.

The best form of large size dies have as their cutting tools four chasers. They are also used as screwing tools in the lathe.

Means of Producing Internal Threads by Hand.

Most internal threads are cut with taps operated either by hand, by a tapping machine, or by a tapping attachment in a drilling machine.

The Tapping Operation.

When tapping, the action should not be an attempt to wind the tap straight through the hole, but to give it an intermittent action advancing by about a quarter of a turn at a time. This applies especially to small taps, since it causes the chips to be broken up more finely, thus preventing binding, which usually results in a broken tap.

Forms of Taps.

Three taps make up a set as shown in Figure 19. These are known respectively as taper, second, and plug taps. The taper tap, which is tapered on the end, is used first to provide a start for the next or second tap. The last tap is the plug tap, the sides of which are parallel over its full length. For such metals as cast iron and brass the first or taper tap need not be used, the second tap providing sufficient start.

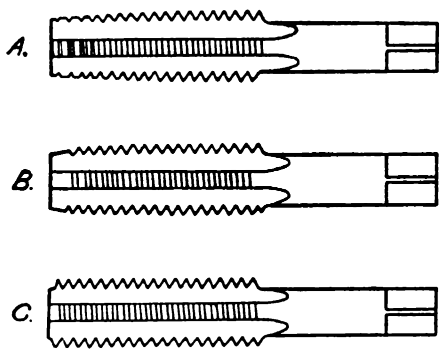


Figure 19.—A Set of Hand Taps.
A.—Taper. B.—Second. C.—Plug.

Removing Broken Taps.

Should you have the misfortune to break a tap (a not uncommon occurrence) you should be conversant with the manner in which it may be removed. Special tap extractors are made for removing broken taps, and, when available, should be used in preference to any other method. If an extractor is not available, the tap has to be drilled out. Since the tap is very brittle, it should be first softened by heating, if the nature of the work will permit such an operation.

Lubricants for Screwing and Tapping.

A liberal supply of lubricant should be used, as this both makes the operation easier and at the same time produces a higher grade thread. Lard oil or ordinary lubricating oil is used for this purpose. Metals such as cast iron and brass can be screwed or tapped dry.

Tapping Attachment for Use in Drill.

Figure 20 shows a spring-loaded tapping attachment for use in a drill. The clutch plates B and C, which are held together by spring A, transmit the drive to the tap. The nuts D are used to adjust the tension on the spring. When the tap reaches the bottom of the hole or becomes jammed the tap and lower clutch plate C remain stationary, while the upper section of the attachment

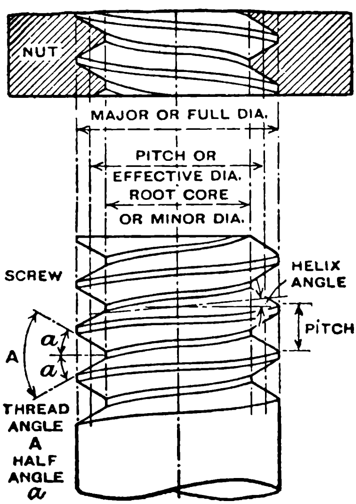


Figure 21.—The Elements of a Screw Thread.

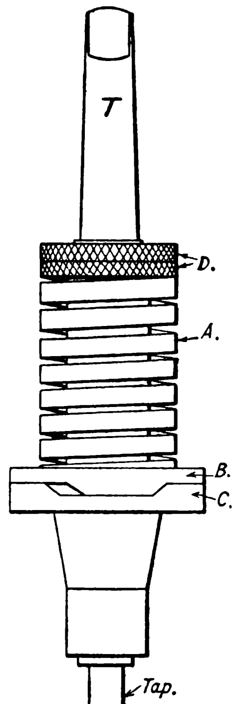


Figure 20.—Spring-loaded Tapping Attachment.

rotates the spring, being alternatively released and compressed as the clutch plates slip over each other. As soon as this occurs the machine should be reversed and the tap so withdrawn. The tapered shank T fits into the drilling machine spindle.

Right-hand Screw.

When it is being screwed into a nut a right-hand screw is turned in the direction of the hands of a clock.

Left-hand Screw.

A left-hand screw is turned in the opposite direction to a right-hand screw.

Single Thread.

The single thread is the one most commonly met with and consists of a single helical groove cut around a bolt.

Double Thread.

When two helical grooves are cut around a bolt the thread so produced is known as a double thread.

Triple Thread.

A triple thread is produced when three helical grooves are cut around a bolt.

The Screw Pitch Gauge.

This gauge consists of a number of blades into each of which is cut the same number of notches per inch as the thread it represents.

Figure 21 shows the elements of a screw thread and gives the names attached to the various sections of it.

Pitch.

Pitch is the distance from the centre of one screw thread to the centre of the next thread. This definition is true whether the screw has a single, double, triple or quadruple thread.

$$\text{Pitch} = \frac{1}{\text{No. of threads per inch.}}$$

Lead.

Lead is the distance a screw advances along its axis in one complete turn. The pitch and lead are identical on a single-pitch screw. On double and triple-thread screws the lead is respectively two and three times as great as the pitch.

British Standard Whitworth Screw Threads.

This thread was standardised by Sir Joseph Whitworth in 1841. It is the thread used most commonly in this country for bolts and nuts and for general engineering work.

Some particulars of this thread are given in Table No. 11.

The British Association Thread.

For screws below ¼ in. diameter the thread recommended by the British Standards Institution is the British Association (B.A.) thread. Table No. 12, giving the sizes of this thread, does not include the sizes ranging from No. 17 upwards. These sizes are not recommended by the Standards Institution, and are not in general use. The sizes recommended are numbers 0, 2, 4, 6, 8 and 10.

British Standard Fine Thread (B.S.F.).

The form of the B.S.F. thread is the same as the Whitworth except that there is a greater number of threads per inch. Table No. 13 gives some particulars of this thread.

American National Thread (Sellers).

In the American National thread, also known as Sellers' thread, the sides are inclined at 60 degrees, and the angle at the top and bottom are truncated to form a flat ⅛ of the pitch wide.

The Square Thread.

The sides of the square are made parallel, and the depth of the thread equal to half of the pitch.

The Acme Thread.

The Acme thread is sometimes used in preference to the square thread. The angle between the sides of the Acme thread is 29 degrees, and the depth of the thread equal to half of the pitch.

Buttress Threads.

Buttress threads are used where it is desired to resist heavy axial loads in one direction. One side of the thread is straight and the other sloping at an angle of 45 degrees.

TABLE NO. 11.

Dia., Ins.	Threads per Inch.	Pitch, Ins.	Tap Drill, Dia., Ins.
1/4	20	.05000	.196
5/16	18	.05556	1/4
3/8	16	.06250	5/16
7/16	14	.07413	23/64
1/2	12	.08333	13/32
9/16	12	.08333	15/32
5/8	11	.09091	17/32
11/16	11	.09091	37/64
3/4	10	.10000	41/64
13/16	10	.10000	45/64
7/8	9	.11111	3/4
15/16	9	.11111	13/16
1	8	.12500	55/64
1 1/8	7	.14286	31/32
1 1/4	7	.14286	1 3/32
1 3/8	6	.16667	1 3/16
1 1/2	6	.16667	1 5/16
1 5/8	5	.20000	1 13/32
1 3/4	5	.20000	1 33/64
1 7/8	4 1/2	.22222	1 5/8
2	4 1/2	.22222	1 3/4
2 1/8	4 1/2	.22222	1 7/8
2 1/4	4	.25000	1 31/32
2 3/8	4	.25000	2 3/32
2 1/2	4	.25000	2 7/32
2 5/8	4	.25000	2 23/64
2 3/4	3 1/2	.28571	2 7/16
2 7/8	3 1/2	.28571	2 9/16
3	3 1/2	.28571	2 11/16

British Association Screw Threads.

TABLE NO. 12.

British Association No.	Dia., Inches.	Threads per Inch.
0	.2362	25.4
1	.2087	28.2
2	.1850	31.4
3	.1614	34.8
4	.1417	38.5
5	.1260	43.0
6	.1102	47.9
7	.0984	52.9
8	.0866	59.1
9	.0748	65.1
10	.0669	72.6
11	.0591	81.9
12	.0511	90.9
13	.0472	102.0
14	.0394	109.9
15	.0354	120.5
16	.0311	133.3
17	.0276	149.0

British Standard Fine Threads.

TABLE NO. 13.

Diameter, Inches.	Threads per Inch.	Tap Drill Size.
7/32	28	No. 16
1/4	26	No. 5
9/32	26	B
5/16	22	G
3/8	20	O
7/16	18	3/8
1/2	16	27/64
9/16	16	1/2
5/8	14	35/64
11/16	14	39/64
3/4	12	21/32
13/16	12	23/32
7/8	11	25/32
1	10	57/64
1 1/8	9	1
1 1/4	9	1 1/8
1 3/8	8	1 15/64
1 1/2	8	1 23/64
1 5/8	8	1 31/64
1 3/4	7	1 19/32
2	7	1 27/32
2 1/4	6	2 1/16
2 1/2	6	2 5/16
2 3/4	6	2 9/16
3	5	2 3/4

CHAPTER 9.

GAUGES.

The Limit System of Manufacture.

As explained elsewhere, parts can usually be made within certain close sizes and be satisfactory. Maximum and minimum limits are specified, and all that is necessary is to keep the size within these limits. Gauges have been constructed to save an undue amount of measuring with instruments such as the micrometer.

In the limit snap gauge one end of the gauge is made the minimum size and the other end the maximum size which a part may be. The minimum size of the gauge should not pass (NO GO) the work whilst the maximum size end should pass (GO) over the work. When gauges can only measure one size it is necessary to use two, one "go" and the other "no go."

Wire and Sheet Metal Gauges.

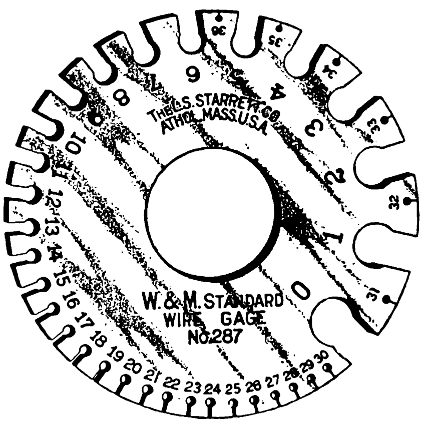
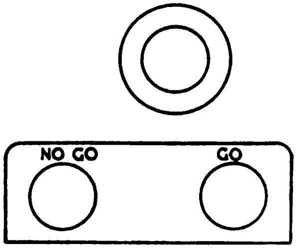


Figure 22.—Wire and Sheet Gauge.

Figure 22 shows the circular type of wire and sheet metal gauge. They are also available in various other shapes.

Ring Gauges.



Two types of ring gauges are shown in Figure 23.

Figure 23.—Ring Gauges.

Limit Snap Gauges.

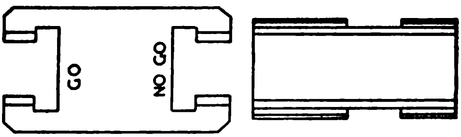


Figure 24.—Limit Snap Gauges.

Figure 24 shows an external and an internal snap gauge.

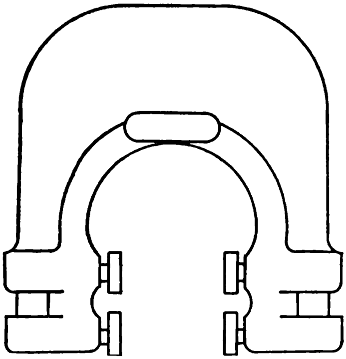


Figure 25.—Johansson Limit Gauge.

The Johansson limit gauge, Figure 25, has only one end in which there are two pairs of anvils, the outside pair being "go" and the inside pair "no go."

Plug Gauges.

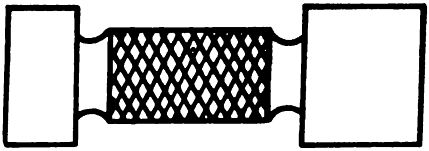


Figure 27.—Plug Limit Gauge.

Figure 27 shows a limit plug gauge, one end of which is made "go" and the other end "no go."

Caliper Limit Gauge.

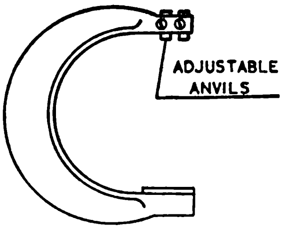


Figure 26.—Caliper Limit Gauge.

This gauge is illustrated in Figure 26. It can be seen that the anvils are adjustable, thus permitting the limits to be varied and also to make allowance for wear. As in the Johansson gauge, the outside anvils may be made "go" and the inside anvils "no go."

REVISIONAL ARITHMETIC

For the benefit of those who have largely forgotten their school arithmetic a few pages are allotted to the revision of fractions and decimals.

Any statement of quantity consists of two parts number and measure as 75 miles, where 75 is the number, and "mile" is the measure. A fractional quantity is only a little more complicated. As before, there is number and measure, but the number part is complicated by a lower figure which tells how many parts the measure has been divided into. For instance, three-fourths mile is written $\frac{3}{4}$ miles, and the lower figure shows that the mile is divided into four parts and the upper figure shows how many such parts are in the quantity.

The figure over the line is called the numerator, since it tells the number of parts. The figure under the line is called the denominator, since it tells the kind of part that the whole measure has been divided into.

To multiply common fractions as $\frac{1}{2} \times \frac{1}{4} = \frac{1}{8}$: Multiply all the numerators (top numbers); this gives the numerator in the answer. Then multiply all the denominators; this gives the denominator of the answer. Any whole number can be turned into a fraction by using the number as numerator and using 1 as denominator as $8 = \frac{8}{1}$. Such a fraction is called an improper fraction.

Any number partly whole and partly fractional, as $3\frac{2}{5}$ is converted into an improper fraction by multiplying the whole number by the denominator of the fractional part and then adding the numerator of the fractional part, as 3 x 5 = 15 add 2 = 17. The result is the new numerator which is placed over the old denominator so $3\frac{2}{5} = \frac{17}{5}$. Improper fractions are multiplied or divided, added or subtracted, in the same way as proper fractions. This leads to a simple commonsense check on procedure. When in doubt about a different set of fractions invent a similar sum using the simplest fractions and note how to do that. The most difficult fraction may be done in the same way.

Thus multiply $\frac{1728}{11} \times \frac{17}{9}$.

This is just similar to $\frac{1}{2} \times \frac{1}{4} = \frac{1}{8}$; here 1 x 1 = 1 gives the top figure of the answer and 2 x 4 = 8 gives the lower figure of the answer, so also 1728 x 17 = 29376 the top figure of the answer, and 11 x 9 = 99 the lower figure of the answer so $\frac{1728}{11} \times \frac{17}{9} = \frac{29376}{99}$.

To divide by a fraction simply turn the fraction by which you wish to divide upside down and multiply; thus divide $\frac{3}{4}$ by $\frac{1}{2}$; $\frac{1}{2}$ is the fraction by which you wish to divide, and it must be inverted and so becomes $\frac{2}{1}$.

Therefore, $\frac{3}{4} \div \frac{1}{2}$ is equal to $\frac{3}{4} \times \frac{2}{1} = \frac{6}{4} = 1\frac{1}{2}$.

Note that when a number is multiplied by a whole number the answer is greater than the original number. When a number is multiplied by a proper fraction the answer is less than the original number. When a number is divided by a whole number the answer is less than the original number, but when a number is divided by a fraction the answer is greater than the original number. Improper fractions have the same effect as whole numbers.

A fraction may be simplified by what is called cancellation. That is by dividing top and bottom (numerator and denominator) by the same figure. This does not alter the value of the fraction.

Thus $\frac{32}{16}$ divide top and bottom each by $2 = \frac{16}{8}$, divide each again by $4 = \frac{4}{2}$, divide each again by $2 = \frac{2}{1}$.

Reading these successively from left to right shows that the result of dividing top and bottom by the same figure leaves the value of the fraction unaltered. Reading the same group successively from the right backwards to the left shows that multiplying top and bottom by the same figure also does not affect the value of the fraction, and sometimes it is convenient to do this. Sums involving multiplication and division only are conveniently done in fractional form and every chance to cancel should be taken. Thus how many gallons are contained in a rectangular tank 12 ft. long by 8 ft. wide by 6 ft. deep?

The answer equals length by width by depth by $6\frac{1}{4}$ (gallons in cubic feet).

$$\frac{12}{1} \times \frac{\not{8}^{2}}{1} \times \frac{6}{1} \times \frac{25}{\not{4}} = \frac{3600}{1} = 3600 \text{ gallons.}$$

Numerator of answer = 12 x 2 x 6 x 25 = 3600.

Denominator of answer equals 1 x 1 x 1 x 1 = 1 (since 4 was cancelled).

Find the number of gallons in a circular tank 14 ft. in diameter and 4 ft. deep.

$$\frac{\not{14}}{\not{2}} \times \frac{7}{1} \times \frac{22}{\not{7}} \times \frac{\not{4}}{1} \times \frac{25}{\not{4}} = \frac{7 \times 22 \times 25}{1} = 3850 \text{ gallons.}$$

Sometimes fractions are used which have a fraction for either numerator or denominator, or for both. These are called compound fractions and are converted into common fractions by mutual multiplication of numerator and denominator. Thus $\dfrac{\frac{2}{3}}{\frac{3}{4}}$; first simplify the denominator by multiplying top and bottom by 4 thus: $\dfrac{\frac{2}{3} \times \frac{4}{1}}{\frac{3}{4} \times \frac{4}{1}} = \frac{8}{3}$, then simplify the numerator by multiplying both top and bottom by 3 thus: $\dfrac{\frac{8}{3} \times 3}{3 \times 3} = \frac{8}{9}$.

To add fractions a denominator must be found for the answer such that each denominator of the fractions to be added will divide into it without leaving a remainder. This is called the common denominator. Thus:

$$\frac{2}{5}+\frac{3}{7}.$$

A common denominator can always be found by multiplying the denominator of the fractions together; thus 7 x 5 = 35. The answer will thus be in some number of thirty-fifths. The two fifths will be equal to 7 times as many thirty-fifths. We say 5 into 35 goes 7, multiply by 2 = 14; similarly the three sevenths will be equal to five times as many thirty-fifths. We say 7 into 35 goes 5 x 3 = 15, so: $\frac{2}{5}+\frac{3}{7}=\frac{14+15}{35}=\frac{29}{35}$.

Subtraction is just similar except that the parts of the new or answer numerator are subtracted. Thus:

$$\frac{7}{8}-\frac{3}{5}=\frac{35-24}{40}=\frac{11}{40}. \textbf{ Ans.}$$

Decimals are a special kind of fractions devised by continuing the figure system further to the right to form a fractional series, and in which the place value of each figure in succession is one-tenth that preceding it.

A dot signifies that figures to the right of it are decimals and not ordinary numbers, thus .4 is 4 in the first decimal place and equals 4/10; .45 equals 45/100, etc.

To convert a decimal into its equivalent fraction use the figures of the decimal (without the decimal point) as numerator, and for denominator place a 0 for each figure in the decimal and a 1 to the left of the noughts. Thus: $.273645=\frac{273645}{1000000}$.

To convert a fraction into a decimal divide the denominator into the numerator.

In order to do this noughts must be added as required to the numerator. Thus: $\frac{1}{4} = 4\ \overline{)\ 100}$

$.25$ Answer

Or 4 into 1 will not go; add a nought and place decimal point in answer. 4 into 10 goes 2 and 2 over; add 0; 4 into 20 goes 5.

In doing this it will be found that frequently the process is such that it could be carried on indefinitely. Thus $1/3 = 3\ \overline{)\ 1000000...\text{etc.}}$

$.333333...\text{etc.}$

Such are called recurring decimals.

In order to save writing, a recurring decimal is denoted by a dot above it, thus .333, etc., to an infinite number of places is written as $.\dot{3}$.

To convert a recurring decimal into a fraction: If all the figures recur as $.\dot{3}$ or $.\dot{3}\dot{7}$. Place the decimal figures as numerator (without decimal or recurring points), and below each figure place a 9 to form the denominator, thus $.\dot{3} = \frac{3}{9}$ $.\dot{3}\dot{7} = \frac{37}{99}$

When several figures recur a recurring point is written only over the first and last of the group, thus $.67\dot{4}2\dot{8}$ means that the figures 428 are all repeaters.

To convert a decimal when some figures do not recur and the remainder recur: From the whole of the decimal subtract the figures that do NOT recur. The remainder is the numerator.

For denominator put a 9 for each figure that recurs and a 0 for each figure that does not recur. Thus:

$$.67\dot{4}2\dot{8} = \frac{67428-67}{99900} = \frac{67361}{99900}.$$

An advantage of the decimal system is that in order to multiply or divide by any multiple of ten it is only necessary to move the decimal point, thus 748.256 is multiplied by 100 by moving the decimal point two figures to the right, becoming 74825.6. Whereas it would be divided by 100 by moving the point two figures to the left, becoming 7.48256.

In the product of any number of decimals there must be as many figures after the decimal point as there are altogether in all the numbers, thus 3.03 x 4.035 x .127.

In these numbers there are eight figures after the decimal point altogether. Multiply successively and the product = 1.55270835 (eight decimal places).

Again, 21.05 x 3.04. Multiply as ordinary figures; the product is 63.9920, there being four decimal places.

When dividing by a decimal make the divisor a whole number by moving the decimal point to the end (i.e., by removing it), and move the decimal point in the dividend the same number of places in the same direction.

Thus: 45.671 ÷ 3.02 equals 4567.1 ÷ 302, and .004375 ÷ 2.671 equals 4.375 ÷ 2671.

A machinist should keep in mind the value of his decimals. If the given dimension is in inches then the first place of decimals are tenths of an inch, the second hundredths of an inch, and for general machining any decimals beyond the third place (thousandths) can be neglected. For finer work the fourth place of decimals must be taken into consideration, for they are ten-thousandths of an inch. Decimals beyond the fourth place can generally be neglected by machinists. The machinist can generally for this reason treat recurring decimals as ordinary decimals by simply taking them to the number of places required for accuracy and neglecting the rest.

It is interesting to note that a limit can be placed on the value of a decimal series. The greatest set of decimals that can be written is $.\dot{9}$, and it may be noticed that this being $\frac{9}{9}$ is just equal to 1 unit. That is to say, all of the succeeding decimals to infinity just make one in the next place to the left. This rule is general. For instance, what limit could be placed on the value of a long string of rejected decimals, say, beyond the third place in inches? The greatest string of decimals that could be rejected would be if they were all nines. That is to say, if the first rejected figure (fourth place) was a recurring 9. This would be equal to an addition of 1 in the next place to the left, that is, an addition of one-thousandth of an inch. Any other set of rejected figures must be less than this.

TABLE NO. 14.

Fraction.	Decimal Equivalent.	Fraction.	Decimal Equivalent.
1/64	.0156	1/32	.0312
3/64	.0468	1/16	.0625
1/16	.0625	5/64	.0781
3/32	.0937	7/64	.1093
1/8	.1250	9/64	.1406
5/32	.1562	11/64	.1718
3/16	.1875	13/64	.2031
7/32	.2187	15/64	.2343
1/4	.2500	17/64	.2656
9/32	.2812	19/64	.2968
5/16	.3125	21/64	.3281
11/32	.3437	23/64	.3593
3/8	.3750	25/64	.3906
13/32	.4062	27/64	.4218
7/16	.4375	29/64	.4531
15/32	.4687	31/64	.4843
1/2	.5000	33/64	.5156
17/32	.5312	35/64	.5468
9/16	.5625	37/64	.5781
19/32	.5937	39/64	.6093
5/8	.6250	41/64	.6406
21/32	.6562	43/64	.6718
11/16	.6875	45/64	.7031
23/32	.7187	47/64	.7343
3/4	.7500	49/64	.7656
25/32	.7812	51/64	.7968
13/16	.8125	53/64	.8281
27/32	.8437	55/64	.8593
7/8	.8750	57/64	.8906
29/32	.9062	59/64	.9218
15/16	.9375	61/64	.9531
31/32	.9687	63/64	.9843
1	1.000	——	——

TABLE No. 15.

MILLIMETRE EQUIVALENTS OF FRACTIONAL PARTS OF AN INCH.

Inches.	Mm.	Inches.	Mm.	Inches.	Mm.
1/64	.397	21/64	8.334	45/64	17.859
1/32	.794	11/32	8.731	23/32	18.256
3/64	1.191	23/64	9.128	47/64	18.653
1/16	1.587	3/8	9.525	3/4	19.050
5/64	1.984	25/64	9.922	49/64	19.447
3/32	2.381	13/32	10.319	25/32	19.844
7/64	2.778	27/64	10.716	51/64	20.240
1/8	3.175	7/16	11.113	13/16	20.637
9/64	3.572	29/64	11.509	53/64	21.034
5/32	3.969	15/32	11.906	27/32	21.431
11/64	4.366	31/64	12.303	55/64	21.828
3/16	4.762	1/2	12.700	7/8	22.225
13/64	5.159	33/64	13.097	57/64	22.622
7/32	5.556	17/32	13.494	29/32	23.019
15/64	5.953	35/64	13.890	59/64	23.415
1/4	6.350	9/16	14.287	15/16	23.812
17/64	6.747	37/64	14.684	61/64	24.209
9/32	7.144	19/32	15.081	31/32	24.606
19/64	7.541	39/64	15.478	63/64	25.003
5/16	7.937	5/8	15.875	1	25.400
		41/64	16.272		
		21/32	16.669		
		43/64	17.065		
		11/16	17.462		

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